2. Steady State Analysis Of AC Circuits.

Star to Delta & Delta to Star Conversion:-

$\lambda - \Delta$ & $\Delta - \lambda$ Transformation.

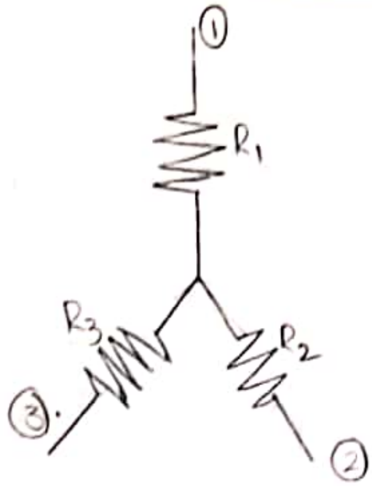
Star Connections:-

If three resistances are connected in such a manner that one end of each is connected together to form a junction point called as starpoint. Then the resistances are said to be connected in star.

Delta Connections:-

If 3 resistances are connected in such a manner that one end of the first is connected to the second, the second end of the first is connected to the other and so on, to form a loop. Then the resistances are said to be connected in Delta.

→ It is possible to replace Delta connected resistance by the equivalent star connection such that if the resistances b/w any 2 terminals must be the same in both type of connections.



R_{12} : Resistance b/w node ① and ②.

R_{23}: Resistance b/w nodes ② and ③.

R_{31}: Resistance b/w nodes ③ and ①

R_1 = Resistance b/w ① an common in star.

R_2 = Resistance b/w ② an common in star

R_3 = Resistance b/w ③ and common in star.

→ $R_{①②}\, \lambda = R_{12}\, \Delta$

$$R_1 + R_2 = R_{12} \parallel (R_{23} + R_{31})$$

$$R_1 + R_2 = \frac{R_{12}(R_{23} + R_{31})}{R_{12} + R_{23} + R_{31}}$$

$$R_1 + R_2 = \frac{R_{12} R_{23} + R_{12} R_{31}}{R_{12} + R_{23} + R_{31}} \longrightarrow ①.$$

→ $R_{②③}\, \lambda = R_{23}\, \Delta$

$$R_2 + R_3 = R_{23} \parallel (R_{12} + R_{31})$$

$$R_2 + R_3 = \frac{R_{23} R_{12} + R_{23} R_{31}}{R_{12} + R_{23} + R_{31}} \longrightarrow ②$$

$$R_{(31)}\,\lambda = R_{(31)}\,\Delta$$

$$R_3 + R_1 = \frac{R_{31}R_{12} + R_{31}R_{23}}{R_{12} + R_{21} + R_{23}} \longrightarrow (3).$$

(1) + (2) + (3)

$$R_1 + R_2 + R_2 + R_3 + R_3 + R_1 = \frac{R_{12}R_{23} + R_{12}R_{31}}{R_{12} + R_{23} + R_{31}} + \frac{R_{23}R_{12} + R_{23}R_{31}}{R_{12} + R_{23} + R_{31}}$$

$$+ \frac{R_{31}R_{12} + R_{31}R_{23}}{R_{12} + R_{23} + R_{31}}$$

$$\cancel{2}(R_1 + R_2 + R_3) = \frac{\cancel{2}\left(R_{12}R_{23} + R_{23}R_{31} + R_{31}R_{12}\right)}{R_{12} + R_{23} + R_{31}}$$

$$R_1 + R_2 + R_3 = \frac{R_{12}R_{23} + R_{23}R_{31} + R_{31}R_{12}}{R_{12} + R_{23} + R_{31}} \longrightarrow (4).$$

(4) − (1)

$$R_1 + R_2 + R_3 - (R_1 + R_2) = \frac{R_{12}R_{23} + R_{23}R_{31} + R_{31}R_{12}}{R_{12} + R_{23} + R_{31}} - \frac{R_{12}R_{23} + R_{12}R_{31}}{R_{12} + R_{23} + R_{31}}$$

$$R_3 = \frac{R_{23}R_{31}}{R_{12} + R_{23} + R_{31}} \longrightarrow (5)$$

④ - ② $\Rightarrow$

$$R_1+R_2+R_3-(R_2+R_3) = \frac{R_{12}R_{23}+R_{23}R_{31}+R_{31}R_{12}}{R_{12}+R_{23}+R_{31}} - \frac{R_{23}R_{12}+R_{23}R_{31}}{R_{12}+R_{23}+R_{31}}$$

$$R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} \rightarrow ⑥.$$

④ - ③ $\Rightarrow$

$$R_1+R_2+R_3-(R_3+R_1) = \frac{R_{12}R_{23}+R_{23}R_{31}+R_{31}R_{12}}{R_{12}+R_{23}+R_{31}} - \frac{R_{31}R_{12}+R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}$$

$$R_2 = \frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}} \rightarrow ⑦.$$

⑤ $\Rightarrow$ $R_3 = \frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}}$

⑦ $\Rightarrow$ $R_2 = \frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}$

⑥ $\Rightarrow$ $R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}.$

⑤×⑥ $\longrightarrow$ ⑧ $R_1R_3 = \frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \times \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}$

$$= \frac{(R_{23}R_{31})(R_{12}R_{31})}{(R_{12}+R_{23}+R_{31})^2}$$

$$R_1 R_3 = \frac{R_{12}\, R_{23}\, R_{31}^2}{(R_{12}+R_{23}+R_{31})^2} \longrightarrow (8).$$

$$(6) \times (7) \Rightarrow R_1 R_2 = \frac{R_{12}\, R_{31}}{R_{12}+R_{23}+R_{31}} \times \frac{R_{12}\, R_{23}}{R_{12}+R_{23}+R_{31}}.$$

$$R_1 R_2 = \frac{R_{12}^2\, R_{23}\, R_{31}}{(R_{12}+R_{23}+R_{31})^2} \longrightarrow (9).$$

$$(7) \times (5) \Rightarrow R_2 R_3 = \frac{R_{12}\, R_{23}}{(R_{12}+R_{23}+R_{31})} \times \frac{R_{23}\, R_{31}}{(R_{12}+R_{23}+R_{31})}$$

$$= \frac{R_{12}\, R_{23}^2\, R_{31}}{(R_{12}+R_{23}+R_{31})^2} \longrightarrow (10)$$

$(8) + (9) + (10)$

$$R_1 R_3 + R_1 R_2 + R_2 R_3 = \frac{R_{12}\, R_{23}\, R_{31}^2}{(R_{12}+R_{23}+R_{31})^2} + \frac{R_{12}^2\, R_{23} + R_{31}}{(R_{12}+R_{23}+R_{31})^2}$$

$$+ \frac{R_{12}\, R_{23}^2\, R_{31}}{(R_{12}+R_{23}+R_{31})^2} \longrightarrow (11)$$

$$= \frac{R_{12}\, R_{23}\, R_{31}}{R_{12}+R_{23}+R_{31}}$$

$$\frac{(11)}{(5)} = \frac{R_1R_3 + R_1R_2 + R_2R_3}{R_3} = \frac{\frac{R_{12}\cancel{R_{23}}\cancel{R_{31}}}{R_{12}+R_{23}+R_{31}}}{\frac{\cancel{R_{23}}\cancel{R_{31}}}{R_{12}+\cancel{R_{23}+R_{31}}}}$$

$$R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3} \longrightarrow (12)$$

$$\frac{(11)}{(6)} = \frac{R_1R_3 + R_1R_2 + R_2R_3}{R_1} = \frac{\frac{\cancel{R_{12}}R_{23}\cancel{R_{31}}}{R_{12}+R_{23}+R_{31}}}{\frac{\cancel{R_{12}}\cancel{R_{31}}}{R_{12}+\cancel{R_{23}+R_{31}}}}$$

$$R_{23} = R_3 + R_2 + \frac{R_2R_3}{R_1} \longrightarrow (13)$$

$$\frac{(11)}{(7)} = \frac{R_1R_3 + R_1R_2 + R_2R_3}{R_2} = \frac{\frac{\cancel{R_{12}}\cancel{R_{23}}R_{31}}{R_{12}+R_{23}+R_{31}}}{\frac{\cancel{R_{12}}\cancel{R_{23}}}{R_{12}+\cancel{R_{23}+R_{31}}}}$$

$$R_{31} = R_1 + R_3 + \frac{R_1R_3}{R_2} \longrightarrow (14)$$

~~star to~~

Delta to star

$$R_1 = \frac{R_{12}\,R_{31}}{R_{12}+R_{23}+R_{31}}$$

$$R_2 = \frac{R_{23}\,R_{12}}{R_{12}+R_{23}+R_{31}}$$

$$R_3 = \frac{R_{23}\,R_{31}}{R_{12}+R_{23}+R_{31}}$$

star to Delta.

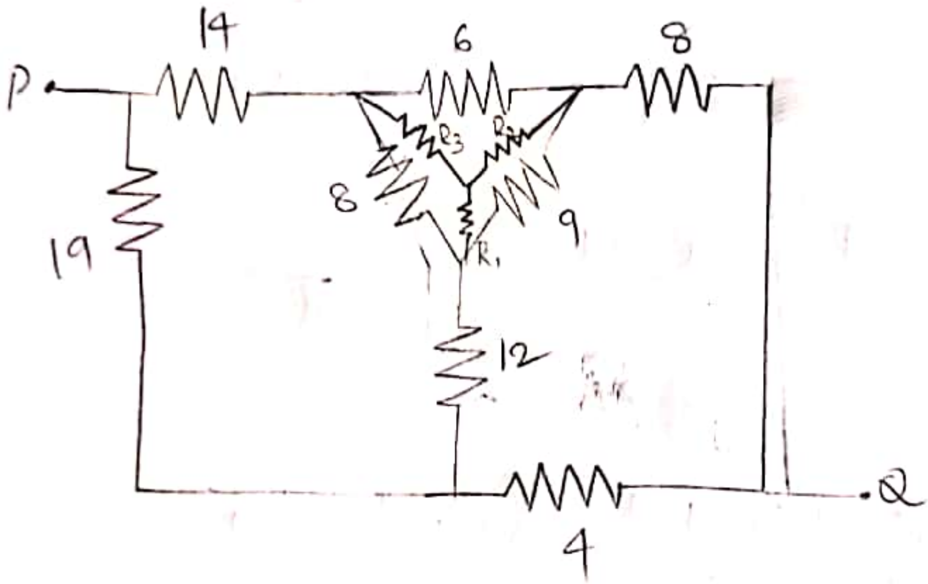
$$R_{12} = R_1+R_2+\frac{R_1 R_2}{R_3} \rightarrow (12)$$

$$R_{23} = R_2+R_3+\frac{R_2 R_3}{R_1} \rightarrow (13)$$

$$R_{31} = R_3+R_1+\frac{R_3 R_1}{R_2} \rightarrow (14).$$

Q:

Ans:-



let $R_{12} = 9$

$R_{23} = 6$

$R_{31} = 8$

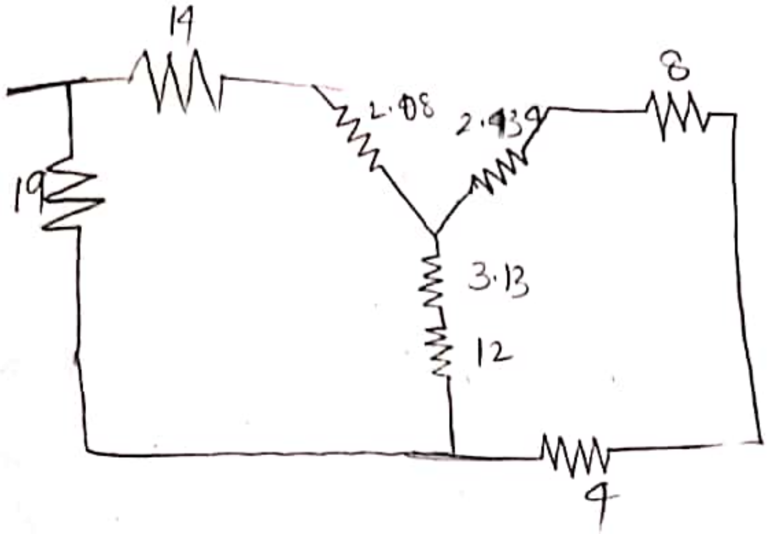
$$R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}}$$

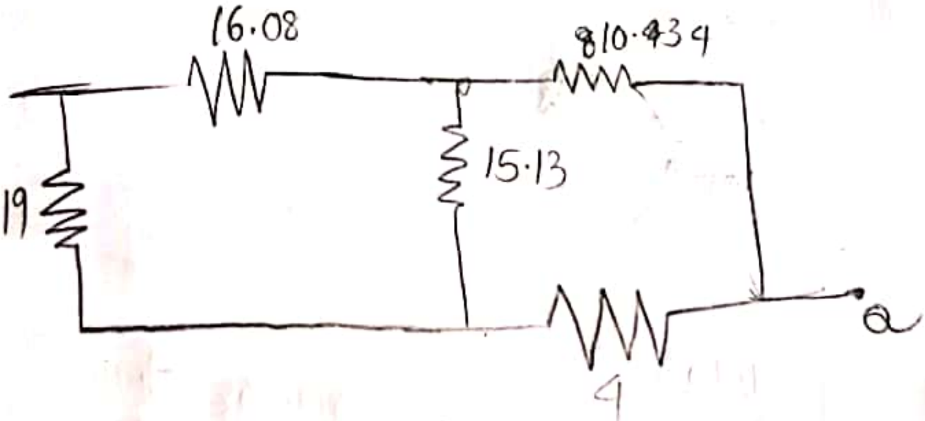
$$= \frac{9\times 8}{9+6+8} = \frac{72}{23} = 3.13$$

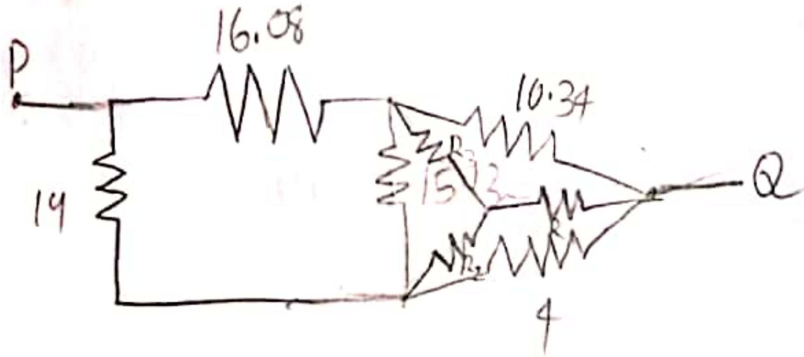
$$R_2 = \frac{R_{12} \cdot R_{23}}{R_{12}+R_{23}+R_{31}} = \frac{9 \times 6}{9+6+8} = \frac{54}{23}$$

$$= 2.4378.$$

$$R_3 = \frac{R_{23} R_{31}}{R_{12}+R_{23}+R_{31}} = \frac{6 \times 8}{23} = \frac{48}{23} = 2.08.$$







$$R_1 = \frac{10.34 \times 4}{10.34 + 4 + 15.13} = \frac{41.36}{29.47}$$

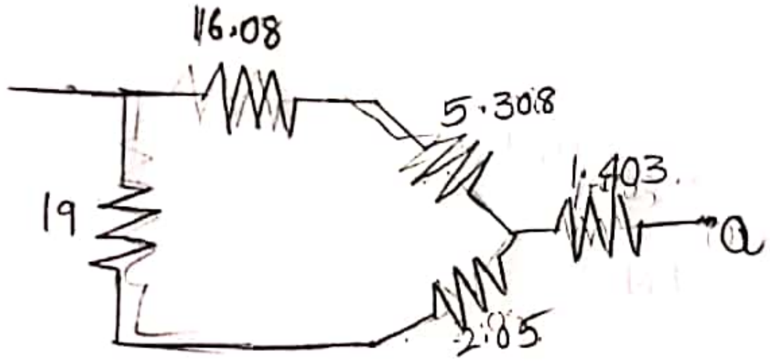
$$= 1.403$$

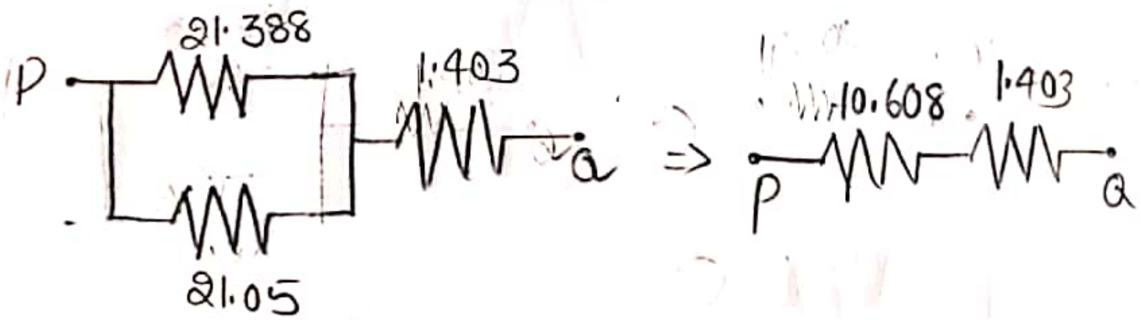
$$R_2 = \frac{4 \times 15.13}{29.47} = \frac{60.52}{29.47}$$

$$= 2.05.$$

$$R_3 = \frac{15.13 \times 10.34}{29.47} = \frac{156.44}{29.47}$$

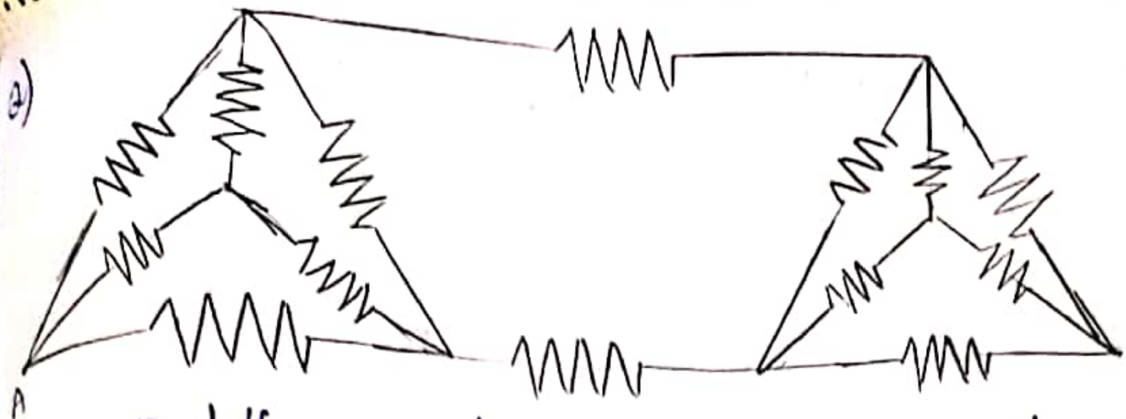
$$= 5.308.$$





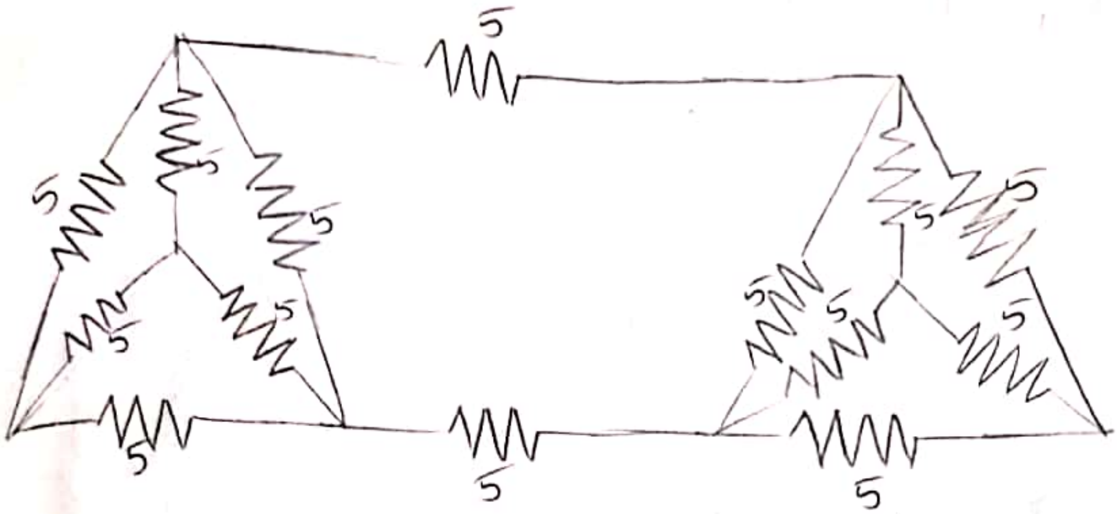
$\Rightarrow 12.011$

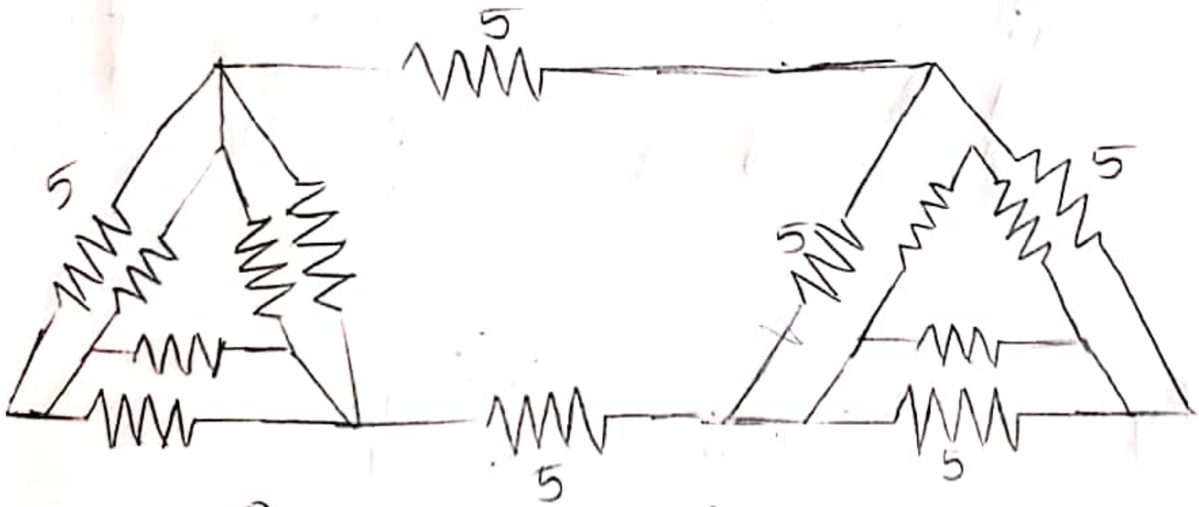
2)

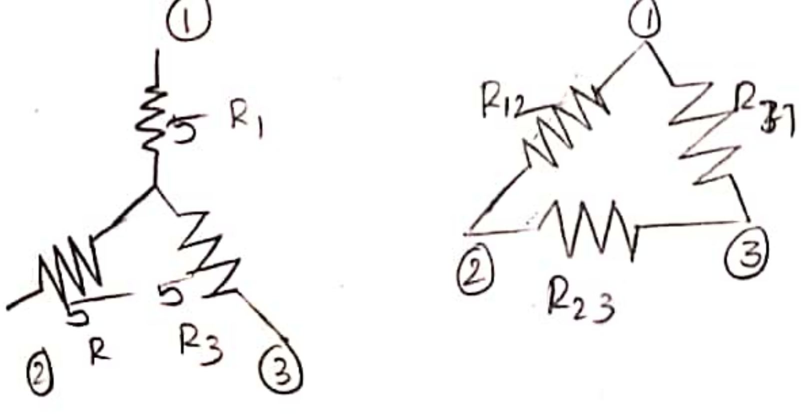


Find the equivalent restistance b/w the terminals A and B. If all the resistances are 5 Ω.

Ans:-







$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$= 5 + 5 + \frac{5 \times \cancel{5}}{\cancel{5}}$$

$$R_{12} = 5 + 5 + 5$$

$$R_{12} = 15$$

$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

$$= 5 + 5 + \frac{5 \times \cancel{5}}{\cancel{5}}$$

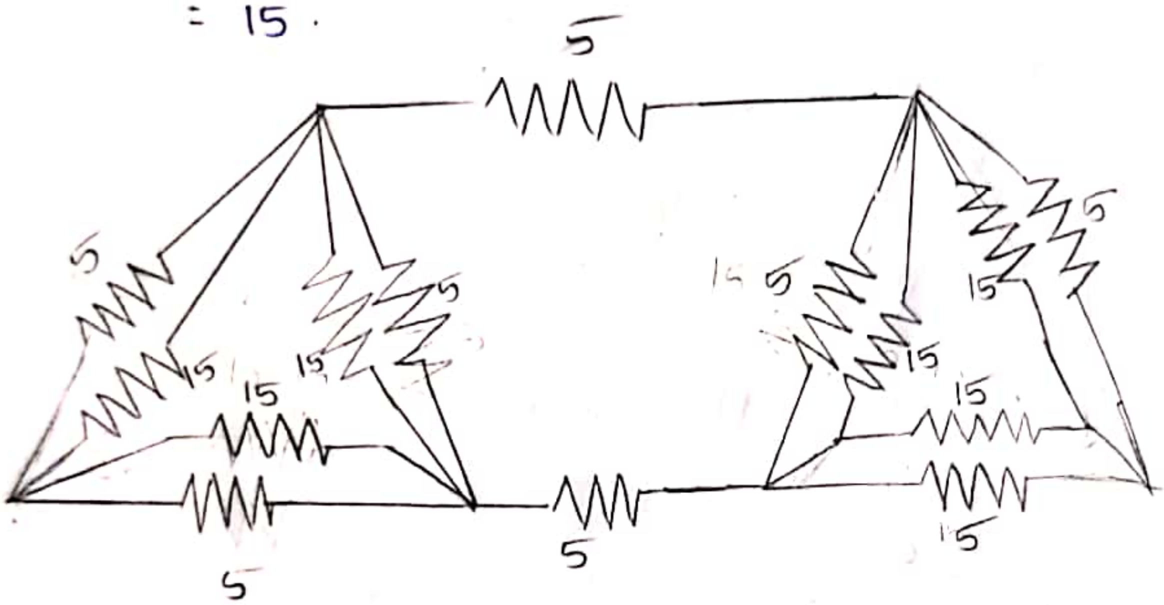
$$= 5 + 5 + 5$$

$$= 15.$$

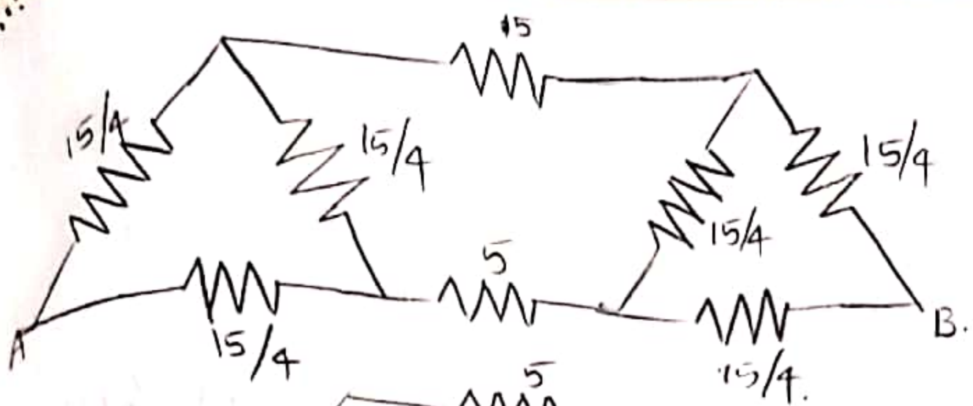
$$R_{31} = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

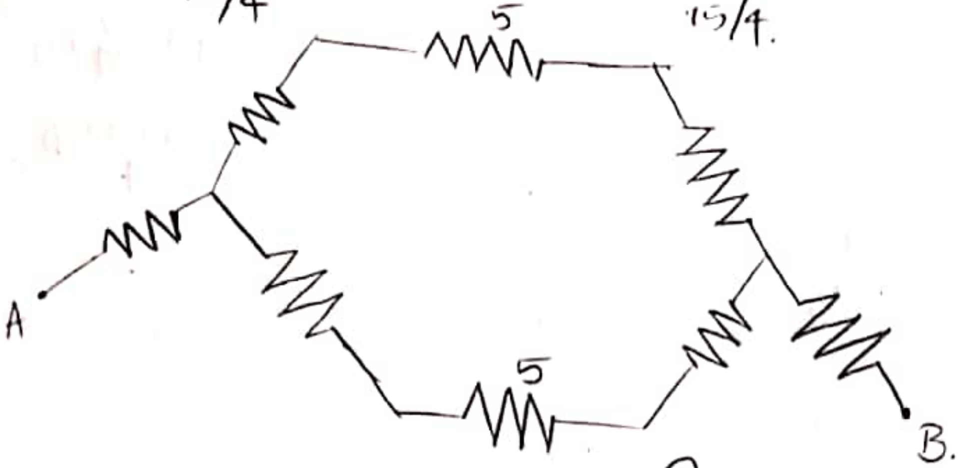
$$= 5 + 5 + \frac{5 \times \cancel{5}}{\cancel{5}}$$

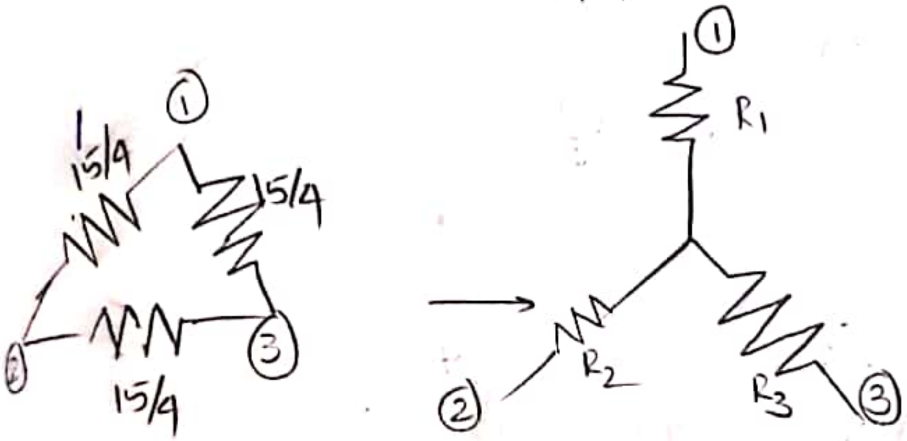
$$= 15.$$



$$R_{eq} \text{ of } 5 \,\&\, 15 = \frac{5 \times 15}{5 + 15} = \frac{\cancel{5} \times 15}{\cancel{20}\,4} = \frac{15}{4}$$

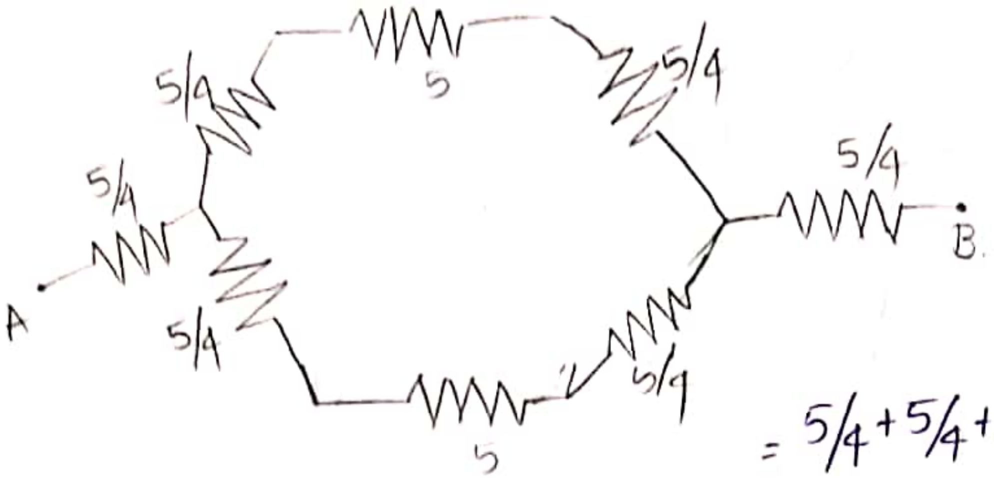






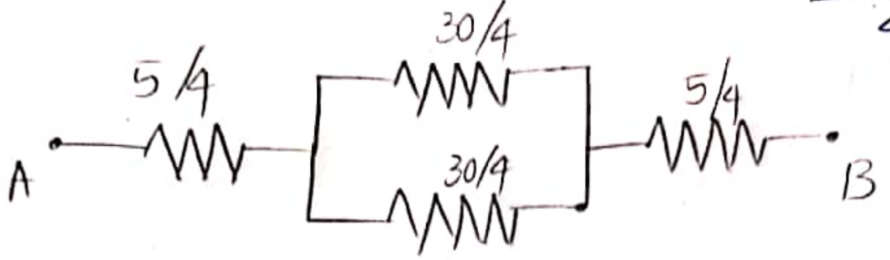
$$R_1 = \frac{R_{12}\,R_{31}}{R_{12}+R_{23}+R_{31}} = \frac{\frac{15}{4}\times\frac{\cancel{15}}{\cancel{4}}}{3\left(\frac{\cancel{15}}{\cancel{4}}\right)} = \frac{\cancel{15}^{\,5}}{\cancel{12}_{\,4}}$$

$$R_1 = R_2 = R_3.$$

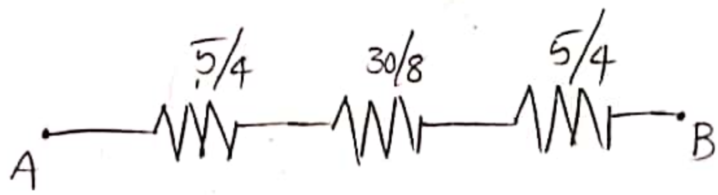


$$= 5/4 + 5/4 + 5$$

$$= \frac{5+5+20}{4} = \frac{30}{4}$$



$$\frac{\frac{30}{4} \times \frac{30}{\cancel{4}}}{2 \times \frac{\cancel{30}}{\cancel{4}}} = \frac{30}{8}.$$



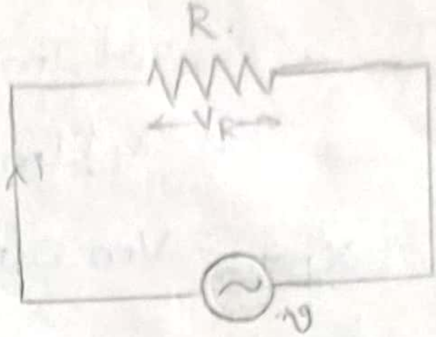
$$\frac{5}{4} + \frac{30}{8} + \frac{5}{4} = \frac{10+10+30}{8} = \frac{50}{8}$$

$$= 6.25\,\Omega.$$

$$8\overline{)50}(6.25$$
$$48$$
$$20$$
$$16$$
$$40$$

Response to Sinusoidal Excitation:

1) Pure Resistor:



$v = V_m \sin \omega t$

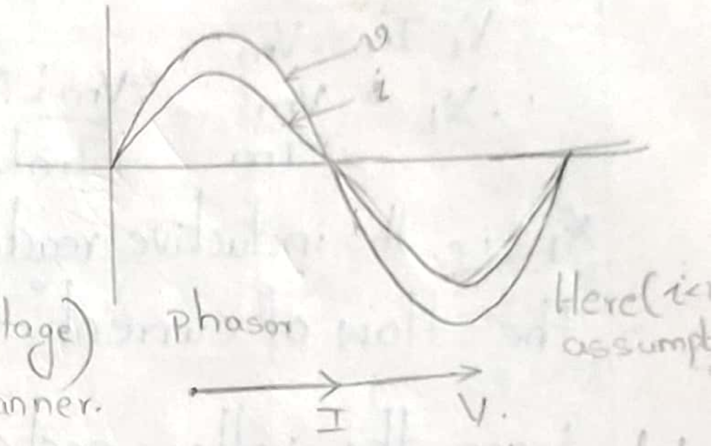
$i = I_m \sin \omega t$

$v = IR$

$= I_m \sin \omega t \cdot R$

$= I_m R \sin \omega t$

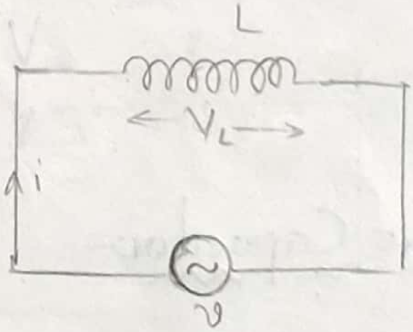
$\boxed{v = V_m \sin \omega t}$



(In a sinousodal signal the voltage & current are in inphase manner.)

The phase angle between voltage and current is zero ∴ Voltage and current starts at same time and reach the zero point at the same time.

2) Pure Inductor:-



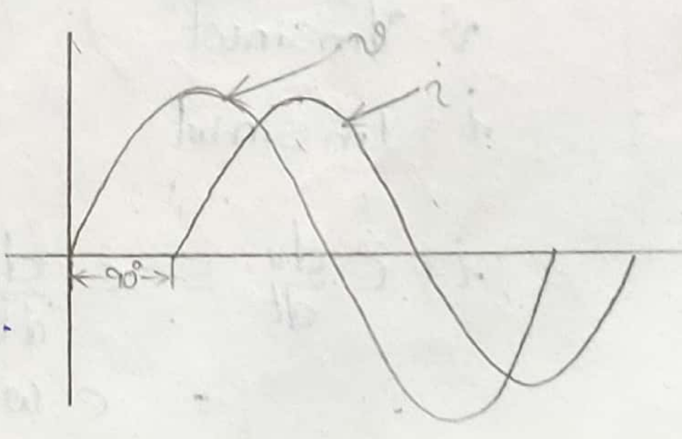
$v = V_m \sin \omega t$

$i = I_m \sin \omega t$

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

$$= L \frac{d}{dt}(I_m \sin \omega t)$$

$$= L I_m \omega \cos \omega t$$

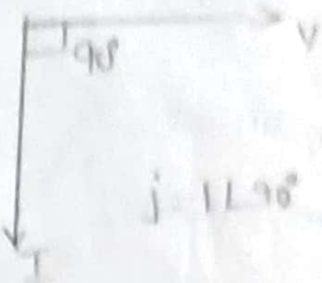


$= L I_m \omega \cos\omega t$

Voltage leads current by 90°.

$= \omega L I_m \sin(90 + \omega t)$

$= X_L I_m \sin(\omega t + 90°)$



$\cancel{X_L I_m} = V_m \sin(\omega t + 90°)$

$X_L I_m = V_m$

$X_L = \dfrac{V_m}{I_m} = \dfrac{V_m \angle 90°}{I_m \angle 0°} = jX_L = j \cdot 1 \angle 90° = j\angle 90°$

X_L is the inductive reactance and it is opposition to the flow of current

From the voltage and current equations in a pure inductor the current in an Inductor lags exactly by 90° w.r.t voltage.

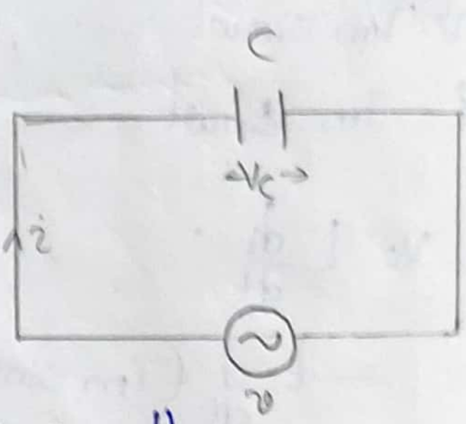
$\omega L = X_L$

$X_L = 2\pi f L$

$V = IR$

$V = I X_L$

3) Pure Capacitor:-



$v = V_m \sin\omega t$

$i = I_m \sin\omega t$

$i = C\dfrac{dv}{dt} = C\dfrac{d}{dt}(V_m \sin\omega t)$

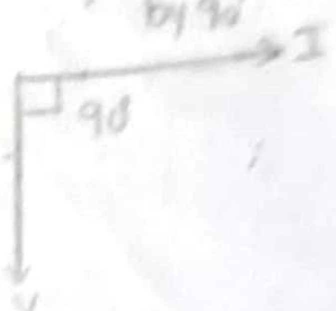
$= C\omega V_m \cos\omega t.$

$$i = \frac{V_m}{1/\omega C} \sin(\omega t + 90^\circ)$$

$$i = I_m \sin(\omega t + 90^\circ)$$

$$I_m = \frac{V_m}{R} = \frac{V_m}{\left(\frac{1}{\omega C}\right)} = \frac{V_m}{\frac{1}{(2\pi f C)}} = \frac{V_m}{X_c}$$

voltage lags current by 90°



$$I_m = \frac{V_m}{X_C} \Rightarrow X_C = \frac{V_m}{I_m}$$

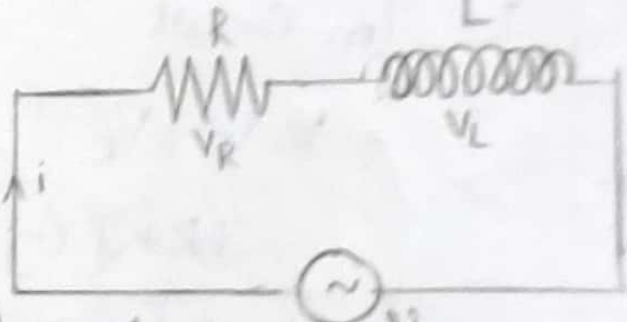
$$= \frac{V_m \angle 0^\circ}{I_m \angle 90^\circ} = X_C \angle -90^\circ = -jX_C$$

$$-j = 1 \angle -90^\circ.$$

$\Rightarrow X_C$ is capacitive reactance

In a pure capacitor the current leads the voltage by exactly 90°

Sinusoidal Response Of RL Circuit:



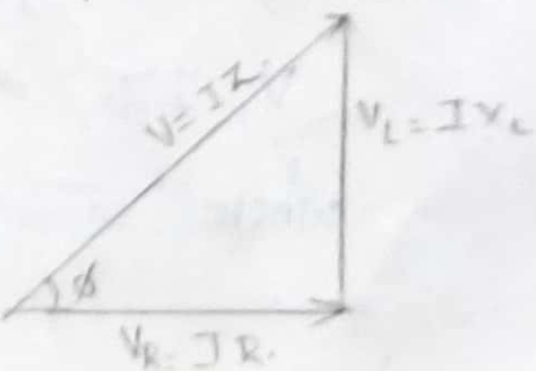
$v = V_m \sin \omega t$

$i = I_m \sin \omega t$

$V = V_R + V_L$ — It is an dc it is a phasor summation

$= IR + I(jX_L)$

$= I(R + jX_L)$



$Z = R + jX_L = $ Impedence

$V = IZ.$

$Z = R + jX_L \rightarrow$ Rectangular form

$r\angle\phi$ — polar form

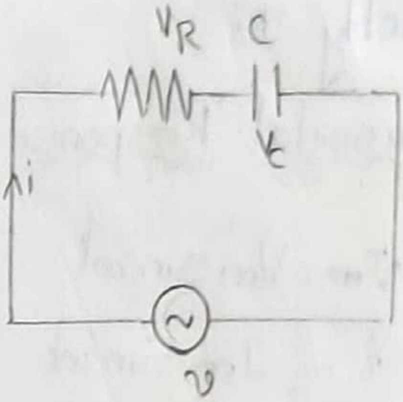
$r = \sqrt{R^2 + X_L^2}$

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

$$\cos\phi = \frac{IR}{IZ} = \frac{R}{Z}$$

$$\boxed{\therefore \cos\phi = \frac{R}{Z}}$$

Respone Of Sinusoidal Excitation of Resistor – Capacitor



$v = V_m \sin\omega t$

$i = I_m \sin\omega t$

$V = V_R + V_C$

$= IR + I(-jX_C)$

$V = I(R - jX_C)$

$V = IZ$

where $Z = R - jX_C$

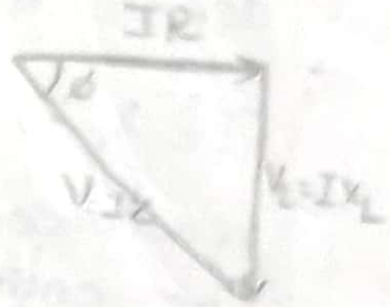
$=$ Impedence.

Rectangular Form.

$r\angle\phi$ — polar form.

$$r = \sqrt{R^2 + X_C^2}$$

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



$V = IZ$

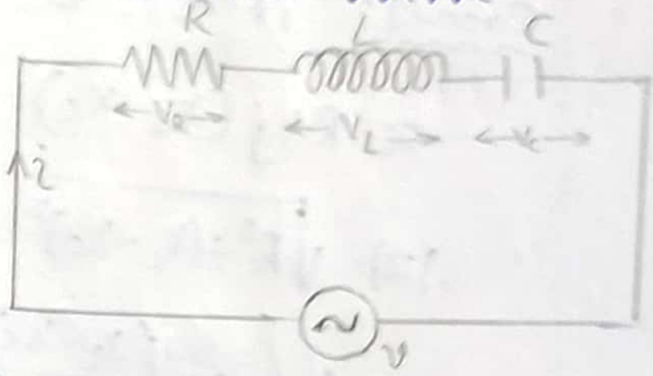
$$I = \frac{V}{Z} = \frac{V\angle 0}{Z\angle -\phi} = I\angle\phi$$

Current leads the voltage at angle φ

Sinusoidal Excitation For R-L-C Series Circuit:-

$v = V_m \sin\omega t.$

$i = I_m \sin\omega t$



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

$$= IR + I(jX_L) + I(-jX_C)$$

$$= I(R + jX_L - jX_C)$$

$$= I(R + j(X_L - X_C))$$

$$= IZ.$$

where

$$Z = R + j(X_L - X_C)$$

= Impedence.

The total opposition offered to the circuit when current flows.

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

$$\phi = \tan^{-1}\left[\frac{X_L - X_C}{R}\right]$$

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

$$= \frac{V}{Z\angle\pm\phi}$$

The supply voltage is the phasor sum of voltage drop across resistor, inductor and capacitor.
If X_L is greater to X_C ($X_L > X_C$) the inductive reactance dominates the capacitive reactance and the entire circuit behaves as inductor.
If X_C is greater to X_L ($X_C > X_L$) the capacitive reactance dominates the inductive reactance and the entire circuit behaves as capacitance.

Case-1:- if $X_L > X_C$

$$Z = R + j(X_L - X_C)$$

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

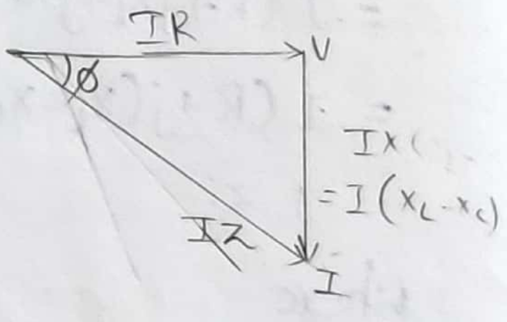
$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$$I = \frac{V}{Z\angle\phi}$$

$$I = I \angle -\phi$$

$$V = V \angle 0^\circ.$$

When $X_L > X_C$
current lags voltage by ϕ.



$v = V_m \sin \omega t$
$i = I_m \sin(90 - \omega t)$ } $X_L \uparrow$

Case-2:

if $X_C > X_L$

$Z = R + j(X_L - X_C)$

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

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

$v = V_m \sin \omega t$
$i = I_m \sin(90 + \omega t)$ $\Big\}\ X_C \uparrow$

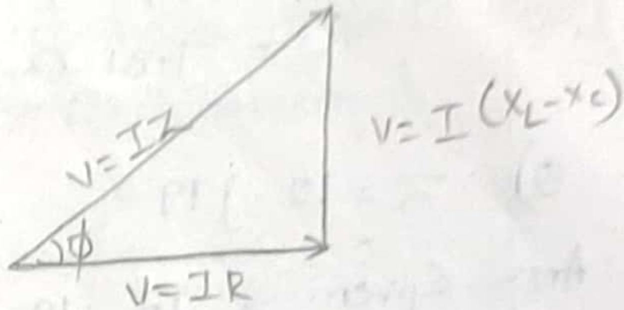
$I = \frac{V}{Z\angle -\phi}$

$= \frac{V}{Z} \angle \phi$

$I = I\angle \phi$

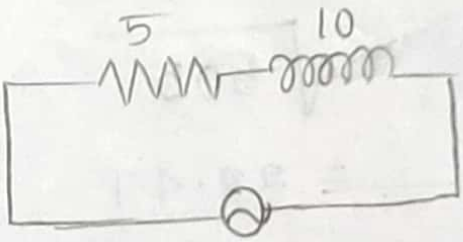
$I = I \angle \phi$

$V = V\angle 0°$.



When $X_C > X_L$

Q) $Z = 5 + j10$.



Ans: Given

$Z = 5 + j10$

$Z = R + jX_L$

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

$= \sqrt{5^2 + 10^2}$

$= \sqrt{125}$

$= 11.18\ \Omega$

$\phi = \tan^{-1}\left(\frac{10}{5}\right)$

$= 63.434°$

Q) $z = 5 + j6$

Ans:- Given $z = 5 + j6$

$$|z| = \sqrt{5^2 + 6^2}$$
$$= \sqrt{25+36}$$
$$= \sqrt{61}$$
$$= 7.81\ \Omega.$$

$$\phi = \tan^{-1}\left(\frac{6}{5}\right)$$
$$= 50.194^\circ.$$

$$z\angle\phi = 7.81\angle 50.19$$

Q) $z = 12 - j19$

Ans:- Given $z = 12 - j19$

$$|z| = \sqrt{12^2 + 19^2}$$
$$= \sqrt{144+361}$$
$$= \sqrt{505}$$
$$= 22.47$$

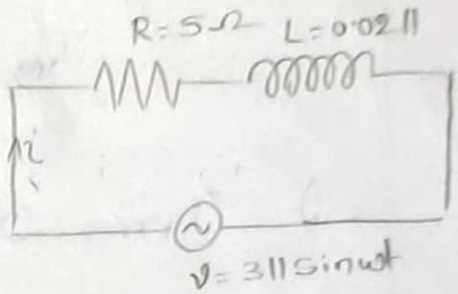
$$\phi = \tan^{-1}\left(\frac{-19}{12}\right)$$
$$= -57.724^\circ$$

$$22.47\angle -57.72^\circ$$

A 50Hz Sinusoidal voltage $v = 311 \sin 2\omega t$ is applied to a series R-L circuit with resistance of 5 Ω and inductance of 0.02 henry. Calculate
i) the rms (or) effective value of steady state current and relative phase angle.
(ii) Obtain the expression for instantaneous current.
(iii) the effective magnitude and phase angle of voltage drop appearing in across each circuit element.

Given

50Hz sinusoidal voltage.



$v = 311 \sin 2\omega t$.

$R = 5\Omega$.

$L = 0.02H$

$2\pi f$.

$\sin 2\pi$

$2\pi f = 50$

100π

$v = 311 \sin 100\pi t$.

$\sin 100\pi t$

~~$|z| = R + jX_L$~~

$X_L = 2\pi f L$

$= 2\pi(50)(0.02)$

$= 6.283\,\Omega$

$\phi = \tan^{-1}\left(\frac{6.283}{5}\right)$

~~$= 52.78$~~

$= 51.4873$

$|z| = \sqrt{R^2 + X_L^2}$

$= \sqrt{5^2 + (6.283)^2}$

$= 8.0297$

$z = R + jX_L$

$= 5 + j(6.283)$

i) $I = \frac{V}{Z}$.

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

$= \frac{311}{\sqrt{2}} = 219.91\,V \angle 0°$. (∵ Given V_m)

$I_{rms} = \frac{220 \angle 0°}{8.02 \angle 51.47} = 27.40 \angle -51.47°$

∴ ~~$I = 220$~~

$\boxed{I_{rms} = 27.40 \angle -51.47°}$

ii) $I_{rms} = 27.40$.

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

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

$= 27.40\sqrt{2}$

$= 38.75411\,A$.

$I_m = 38.754\,A$.

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

$= 38.754 \sin(\omega t - 51.47°)$

ii) $\cancel{V_R = I R}$

$\cancel{= (38.754)5}$

$\cancel{= 193.77V}$

iii) $V_{rms} = I_{rms} R.$

$= (27.40 \angle -51.47^\circ) 5$

$= 137 \angle -51.47^\circ.$

$V_L = I (jX_L)$

$= [(27.40)(\angle -51.47)] (0+j\,6.283).$

$= (27.40 \angle 51.47)(6.283 \angle 38.53)$

$= 172.1542$

$\rightarrow$ $\cancel{V = V_R + V_L}$

$\cancel{= 137 + 172.}$

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

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

$= \sqrt{137^2 + (172.1542)^2}$

$= 220.0137V$

Q) A series RC circuit is supplied by a 500Hz 10V rms signal to a 2kΩ resistor in series with 0.1μF capacitor. Determine

i) Impedence, phase angle. (as previous problem)

Ans:- Given,

$f = 500Hz$

$V_{rms} = 10V$

$R = 2k\Omega$

$C = 0.1\mu F.$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\times\pi\times500\times0.1}\times10^6$$

$$= 5183.098 \Omega.$$

$$|z| = \sqrt{R^2 + X_C^2}$$

$$= \sqrt{(2000)^2 + (3183.098)^2}$$

$$= 3759.27$$

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

$$= \tan^{-1}\left(\frac{-3183.098}{2000}\right)$$

$$= -57.858$$

$$Z = R - jX_C$$

$$= 2000 - j(3183.098)$$

$$= 3759.2702 \angle -57.858$$

Given,

$V_{rms} = 10$

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

$$= \frac{10}{\sqrt{2}} = 7.07106\,V \angle 0^\circ$$

$$\rightarrow I_{rms} = \frac{V_{rms}}{Z} = \frac{10}{3759.2702 \angle -57.858}$$

$$= 2.66 \times 10^{-3} \angle 57.858$$

$$I_m = I_{rms} \times \sqrt{2} = 2.66 \times 10^{-3} \times \sqrt{2}$$

$$= 3.7618 \times 10^{-3}$$

$$\rightarrow i = I_m \sin(\omega t + \phi)$$

$$= 3.7618 \times 10^{-3} (\omega t + 57.858)$$

$$\rightarrow V_R = IR$$

$$= \left[(2.66 \times 10^{-3})(\angle 57.858)\right] \times 2000$$

$$= 5.32 \angle 57.858.$$

$$\rightarrow V_C = I(-jX_C)$$

$$= (2.66 \times 10^{-3} \angle 57.858)(-j\,3183.098)$$

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Ans:-

Given

$R = 25\,\Omega$ $\qquad Z = ?$

$L = 0.4H$ $\qquad I = ?$

$C = 250\mu F$ $\qquad P = ?$

$V = 230V.$ $\qquad \cos\phi = ?$

$f = 50Hz.$ $\qquad V_R, V_L, V_C = ?$

$$P = I^2R$$
$$= I\,I\,R$$
$$= \frac{V}{Z} I R.$$
$$= V I R/Z$$
$$P = VI\cos\phi.$$

1) $X_L = \omega L$

$= 2\pi f L$

$= 2\pi(50)(0.4)$

$= 125.66$

2) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

$= \frac{1}{2\pi 50 \times 250} 10^{+6}$

$= \frac{10^6}{1989.436}$

$= \cancel{502.655}$

$= 12.7323$

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

$= \cancel{25 + j(125.66 - 502.655)}$

$= \cancel{377.823 \angle 86.2060}$

1) $Z = R + j(X_L - X_C)$

$= 25 + j(125.66 - 12.7323)$

$= 115.6618 \angle 77.517$

2) $I = \frac{V}{Z} = \frac{230 \angle 0^\circ}{115.6618 \angle 77.517}$

$= 1.9885 \angle -77.517.$

3) $P = VI\cos\phi$

$\cos\phi = \frac{R}{Z} = \frac{25 \angle 0^\circ}{115.6618 \angle 77.517}$

$= 0.216 \angle -77.517$

$P = VI\cos\phi$

$= (230)(1.9885 \angle -77.517)(0.216 \angle -77.517)$

$= 98.788 \angle -155.034.$

4) $\cos\phi = 0.216 \angle -77.517.$

5) $V_R = \frac{I}{\cancel{Z}} R. = 1.9885 \angle -77.517 (25)$

$= 49.9625 \angle -77.517.$

6) $V_L = I(jX_L) = (1.9885 \angle -77.517)(0 + j125.66)$

$= 249.87491 \angle 12.483$

$V_C = I(-jX_C)$

$= (1.9885\angle -77.517)(-j12.7523)$

$= 25.3112\angle -167.517$

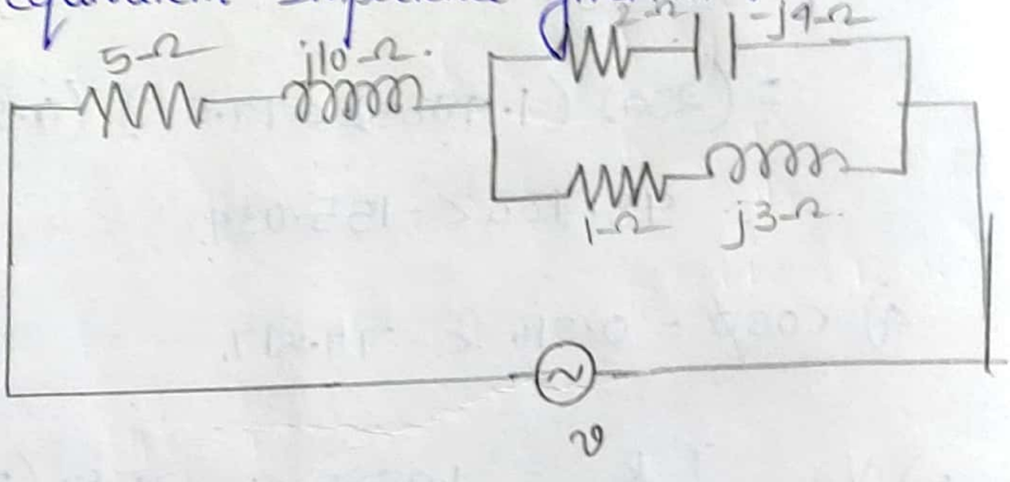
$V = \vec{V_R} + \vec{V_L} + \vec{V_C}$

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

$= 229.993\ \Omega.$

Compound Circuits:-

Q. Find the equivalent Impedence given in the circuit?



Ans:- From the figure,

$Z_1 = 5 + j10$

$Z_2 = 2 - j4$

$Z_3 = 1 + 3j$

$$z = z_1 + \frac{z_2 z_3}{z_2 + z_3}.$$

$$\cancel{z = 5 + j10 + \frac{(14+12i)}{3-j}}$$

$$= 5 + j10 + \cancel{\frac{14}{13} - \frac{1}{3}i} \cdot 4 + 2i$$

$$\cancel{= \frac{29}{3} + \frac{29}{3}i} \quad 9 + 12i$$

$$= \cancel{24.533 \angle 53.2857}$$

$$= \cancel{26.0768 \angle} 57.528$$

$$\therefore \cancel{z = 26.0768 \angle 57.528}$$

$$z = (5 + j10) + \left(\frac{14 + 2j}{3-j}\right)$$

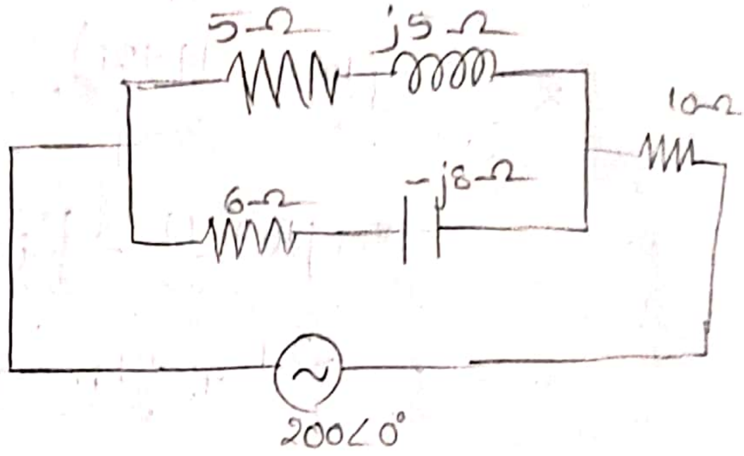
$$= (5 + j10) + (4 + 2i)$$

$$= 9 + 12i$$

$$z = 15 \angle 53.1301$$

Q) Find the total current and total power consumed in the circuit shown below.

Ans:-



Ans:- From the figure,

$Z_1 = 5 + j5\,\Omega$.

$Z_2 = 6 - 8j\,\Omega$.

$$Z_{eq} \text{ of } 1 \& 2 = \frac{(5+5j)(6-8j)}{5+5j+6-8j} = \frac{70-10i}{11-3j}$$

$$= \frac{70}{11} - \frac{43}{11}i$$

$$= 6.2017 \angle 7.1250.$$

$$\cancel{Z = 10 + \frac{70}{11} - \frac{43}{11}i}$$

$$\cancel{Z = \frac{180}{11} - \frac{43}{11}i} = \cancel{16.824 \angle -13.4355}$$

$$\cancel{I = \frac{V}{Z} = \frac{200}{16.824\angle -13.4355}} = \cancel{11.8877}\angle 13.4355$$

P=

$z = 10 + (6.2017 \angle 7.1250)$

$= 16.17211 \angle 2.7262 = 16.1538 + i(0.76914).$

$I = \frac{V}{z} = \frac{200}{16.17211 \angle 2.726}$

$= 12.3669 \angle -2.726.$

$\rightarrow P = IV \cos\phi$

$\cos\phi = 0.9988.$

$\rightarrow P = VI\cos\phi$

$= (200)(12.3669)(0.9988)$

$= 2470.411 \ W.$

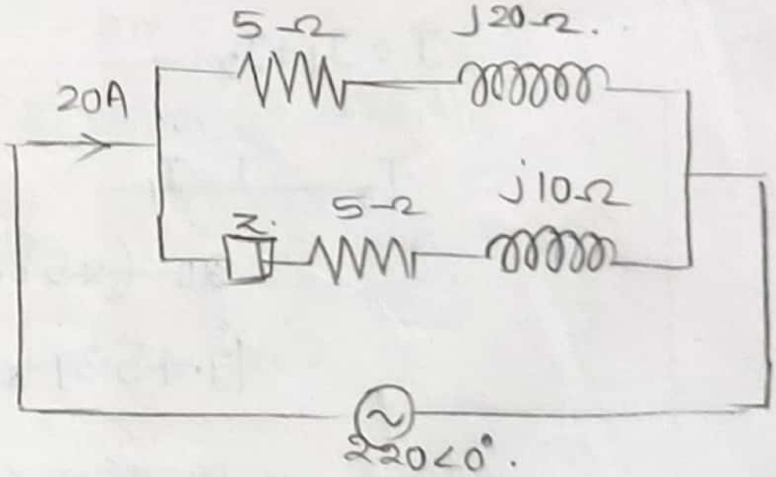
→ Power loss

$P = I^2 R$

$= (12.3669)^2 (16.15)$

$= 2469.984 \ W.$

In the following circuit find the value of unknown impedence z.



Ans

$Z_1 = 5+20j$

$Z_2 = z+5+j10$

$$Z_{eq} = \cancel{\frac{(Z_1 + Z_2)}{Z_1+Z_2}}$$

$$= \cancel{\frac{(5+20j)(z5+j10)}{(5+20j)(z+5+j10)}} = \cancel{\frac{5z+25+50j+20zj+100j-200}{10+30j+z}}$$

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

$$I_1 = \frac{V}{Z_1} = \frac{220}{5+20i}$$

$= \cancel{2.5882 \angle -10.3529}$

$= 10.6715 \angle -75.963$

$I = I_1 + I_2$

$\cancel{I_2 = I - I_1}$

$= \cancel{20 \; (2.5882 \angle -10.3529)}$

$= \cancel{17.4539 \; i \; (0.46512)}$

$= 17.4601 \angle 1.5265$

$\cancel{I_2 = \frac{V}{Z+Z_1}}$

$\cancel{Z+Z_1 = \frac{V}{I_2}}$

$= \frac{220}{17.4601 \angle 1.5265}$

$\cancel{Z+Z_1 = 12.6001 \angle -1.5265}$

$\cancel{Z = (12.6001 \angle -1.5265) - (5+10j)}$

$I = I_1 + I_2.$

$I_2 = I - I_1$

$I_2 = \cancel{20}\ (20.25701)(\angle 30.7354)$

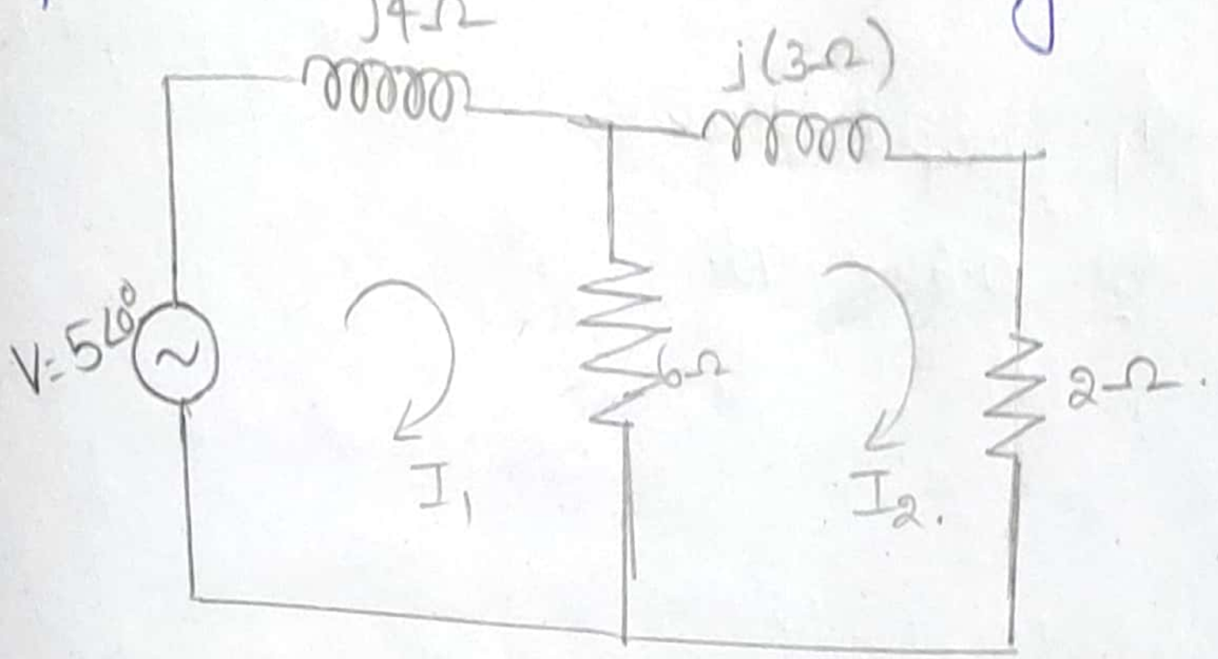
$I_2 = \frac{V}{Z+Z_1}$

$Z+Z_1 = \frac{V}{I2}$

$= \frac{220}{(20.25701)(\angle 30.7354)}$

$Z + (5+ \quad = 10.$

mpute Mesh currents from the given circuit.



$$+5\angle 0^\circ - I_1(4j) - (6)(I_1 - I_2) = 0.$$

$$I_1(6+4j) - 6I_2 = 5 \longrightarrow (1).$$

$$-3jI_2 - 2I_2 - 6(I_2 - I_1) = 0.$$

$$-8I_2 - 3jI_2 + 6I_1 = 0.$$

$$6I_1 - I_2(8+3j) = 0 \longrightarrow (2).$$

① ⇒ $I_1(6+4j) - 6I_2 = 5$

② ⇒ $I_1 6 - (8+3j)I_2 = 0.$

$$\begin{array}{c|cc|c|c|} & I_1 & I_2 & & V \\ I_1 & 6+4j & -6 & = & 5 \\ I_2 & 6 & -(8+3j) & & 0 \end{array}$$

$\cancel{-(6+4j)(8+3j)+36} = \begin{vmatrix} 5 \\ 0 \end{vmatrix}.$

$I_1 = 0.85 \angle 20.55$

$I_2 = 0.6 \angle -98.$

$$10\angle 0^\circ - (2-j2)I_1 - 5j(I_1 - I_2) - 5(I_1 - I_3) = 0$$

$$10\angle 0^\circ - 2I_1 + 2jI_1 - 5jI_1 + 5jI_2 - 5I_1 + 5I_3 = 0$$

$$-7I_1 - 3jI_1 + 5jI_2 + 5I_3 = -10\angle 0^\circ$$

$$I_1(7+3j) - I_2(5j) - 5I_3) = 10\angle 0^\circ \longrightarrow 1.$$

$$-5\angle 30^\circ - 10I_2 - (I_2 - I_3)(-2j+2) - 5j(I_2 - I_1) = 0$$

$$-5\angle 30^\circ - 10I_2 + 2jI_2 - 2I_2 - 5jI_2 + 5jI_1 + I_3(2-2j) = 0$$

$$5jI_1 - I_2(12+3j) + I_3(2-2j) = 5\angle 30^\circ \cdot \longrightarrow 2.$$

$$-5(I_3 - I_1) - (2-j2)(I_3 - I_2) - 10I_3 + 10\angle 90^\circ = 0.$$

$$-5I_3 + 5I_1 - 2I_3 + 2I_2 + 2jI_3 - 2jI_2 - 10I_3 + 10\angle 90^\circ = 0$$

$$5I_1 + (2-2j)I_2 + I_3(-17+2j) = -10\angle 90^\circ \longrightarrow 3.$$

① ⇒ $I_1(7+3j) - I_2(5j) - I_3(5) = 10\angle 0^\circ$

② ⇒ $5j\, I_1 - I_2(12+3j) + I_3(2-2j) = 5\angle 30^\circ$

③ ⇒ $5I_1 + I_2(2-2j) + I_3(-17+2j) = -10\angle 90^\circ$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \begin{bmatrix} 7+j3 & -5j & -5 \\ 5j & -(12+3j) & (2-2j) \\ 5 & (2-2j) & (-17+2j) \end{bmatrix} = \begin{bmatrix} 10\angle 0^\circ \\ 5\angle 30^\circ \\ -10\angle 90^\circ \end{bmatrix}$$

$$\Delta = (7+3j)\left[-(12+3j)(-17+2j) - (2-2j)^2\right] + 5j\left[(5j)(-17+2j) - 5(2-2j)\right]$$
$$-5\left[(5j)(-17+2j) + 25\right]$$

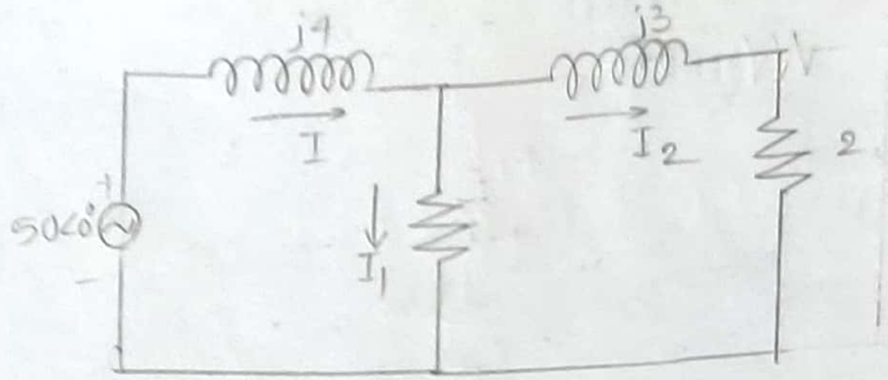
$= 1365 + 875i + 375 - 100i - 75 + 425i$

$= 1665 + 1200i$

$$\Delta_1 = \begin{vmatrix} 10\angle 0^\circ & -5j & -5 \\ 5\angle 30^\circ & -(12+3j) & (2-2j) \\ -10\angle 90^\circ & (2-2j) & (-17+2j) \end{vmatrix} =$$

$$= 10\angle 0^\circ\left((-12+3j)(-17+2j) - (2-2j)^2\right) + 5j\left((5\angle 30^\circ)(-17+2j) + 5(10\angle 90^\circ)\right)$$
$$-5\left((5\angle 30^\circ)(2-2j) + (12+3j)(-10\angle 90^\circ)\right)$$

Q) Find the current in each branch by using Nodal analysis



Ans:-

$$I = I_1 + I_2$$

$$\frac{50\angle 0^\circ - V_A}{j4} = \frac{V_A}{6} + \frac{V_A}{2+j3}$$

$$\frac{50 - V_A}{j4} = \frac{(2+j3)V_A + 6V_A}{6(2+j3)}$$

$$(50 - V_A)(2+3j)6 = (2V_A + j3V_A + 6V_A)j4$$

$$(50 - V_A)(12+18j) = (2V_A j4 + -12V_A + 24jV_A)$$

$$600 + 400i - (12+18j)V_A = (8jV_A - 12V_A + 24jV_A)$$

$$600 + 400j = \cancel{12V_A} - \cancel{12V_A} + 18jV_A + 8jV_A + 24jV_A$$

$$= 50jV_A$$

$$V_A = \frac{600 + 400j}{50j}$$

$$= 8 - 12i$$

$$\frac{50}{4j} - \frac{V_A}{j4} = V_A\left(\frac{2+3j+6}{6(2+j3)}\right)$$

$$\frac{50}{4j} - \frac{V_A}{j4} = V_A\left(\frac{8+3j}{12+18j}\right)$$

$$\frac{50}{4j} = V_A\left(\frac{8+3j}{12+8j} + \frac{1}{j4}\right)$$

$$\frac{50}{\cancel{4j}} = V_A\left(\frac{j4(8+3j)+12+8j}{(12+8j)\cancel{(j4)}}\right)$$

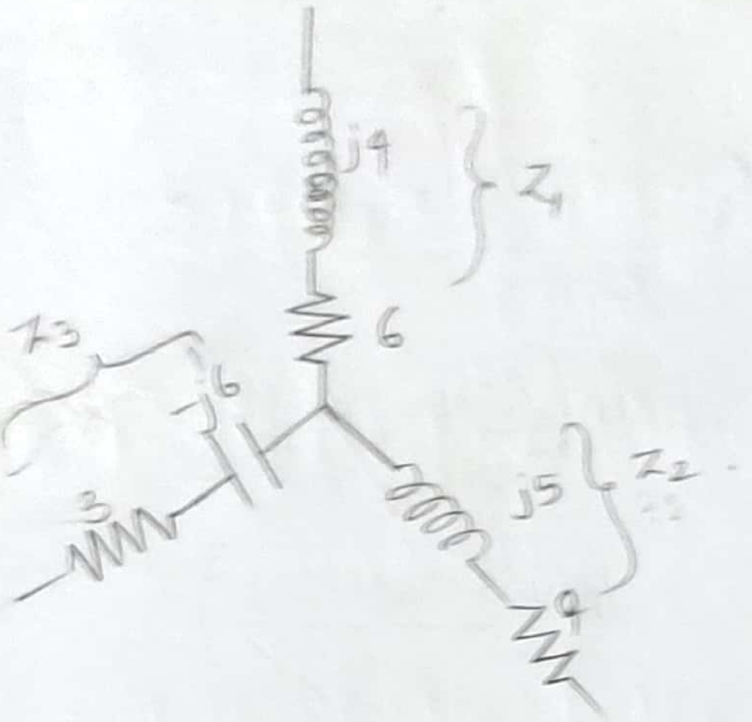
$$V_A = \frac{50(12+8j)}{32j \cancel{-12} \cancel{+12} +8j}$$

$$= \frac{600+400j}{40j}$$

$$= -\frac{60}{4}j + 10$$

$$= \frac{40-60j}{4}$$

Convert the star connection into Delta Connection



Ans:- $Z_1 = 4j + 6$ $Z_2 = 9 + j5$ $Z_3 = 3 - 6j$

$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$Z_{12} = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3}$$

$$= 6 + 4j + 9 + 5j + \frac{(6+4j)(9+5j)}{(3-6j)}$$

$$= (15 + 9j) + \frac{(6+4j)(9+5j)}{(3-6j)}$$

$$= \frac{(15+9j)(3-6j) + (6+4j)(9+5j)}{3-6j}$$

$$= \frac{(45-90j+27j+54)+(54+30j+36j-20)}{3-6j}$$

$$= \frac{99-63j+34+66j}{3-6j}$$

$$= \frac{133+3j}{3-6j}$$

$$Z_{23} = Z_2+Z_3+\frac{Z_2 Z_3}{Z_1}$$

$$= (9+5j)+(3-6j)+\frac{(9+j5)(3-6j)}{(4j+6)}$$

$$= \frac{(12-j)(6+4j)+(27-54j+15j+30)}{(4j+6)}$$

$$= \frac{(72+48j-6j+4)+(57-39j)}{4j+6}$$

$$= \frac{(76+57+42j-39j)}{6+4j}$$

$$= \frac{133+3j}{6+4j}$$

$$Z_{31} = Z_3 + Z_2 + \frac{Z_3 Z_1}{Z_2}$$

$$= 3-6j + 6+4j + \frac{(3-6j)(6+4j)}{(9+j5)}$$

$$= \frac{(9-2j)(9+5j) + (3-6j)(6+4j)}{(9+5j)}$$

$$= \frac{81 + 45j - 18j + 10 + 18 + 12j - 36j + 24}{9+5j}$$

$$= \frac{\overset{133}{\cancel{215}} + 3j}{9+5j}$$

$$= \frac{133+3j}{9+5j}$$

$$\therefore Z_{12} = \frac{133+3j}{3-6j} \quad Z_{23} = \frac{133+3j}{6+4j} \quad Z_{31} = \frac{133+3j}{9+5j}$$

Coupled Circuits And Resonance

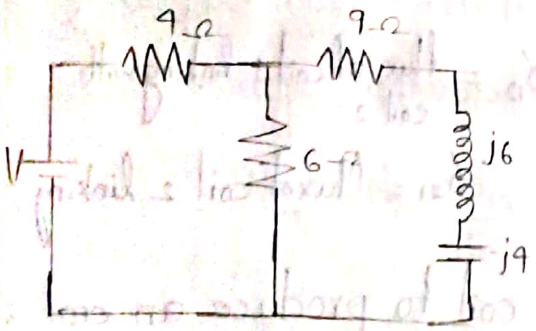
Introduction :-

Coupled Circuits :-

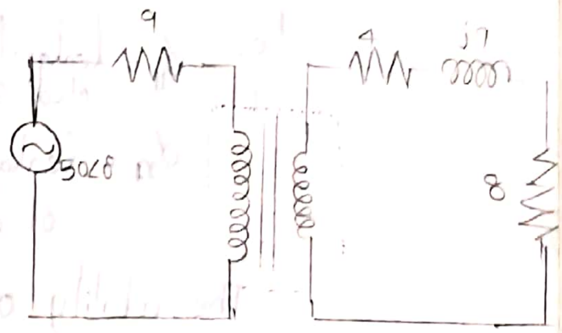
The circuits are said to be coupled when energy is transfered from one circuit to the other when one of them is energise.

Types Of Coupled Circuits :-

1. Conductively coupled / Conductively coupling circuits.
2. Magnetically Coupled Circuits.
3. Magnetically and Conductively coupled circuits.



Conductive coupling



Magnetic coupling.

Self Inductance :-

When a current flowing through a coil the magnetic flux linking in the coil also changes and hence an emf is induced in the coil itself is known as Self Induction.

$$V = L\frac{di}{dt} \longrightarrow ①.$$

$$L = \frac{N\phi}{i} \longrightarrow ②.$$

$$i = \frac{N\phi}{L}$$

from ① & ②

$$V = L\frac{d}{dt}\left(\frac{N\phi}{L}\right)$$

$$V = \cancel{L}\frac{N}{\cancel{L}}\frac{d\phi}{dt}$$

$$V = N\frac{d\phi}{dt}.$$

$$L\frac{di}{\cancel{dt}} = N\frac{d\phi}{\cancel{dt}}$$

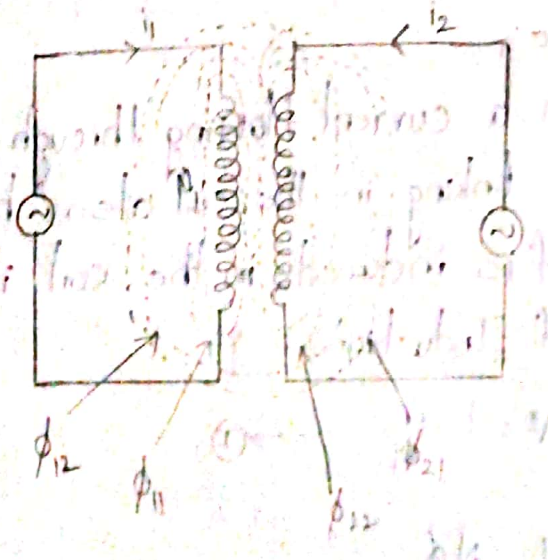
$$\boxed{L = N\frac{d\phi}{di}.}$$

Mutual Inductance:-

Let ϕ_{11} = leakage flux of coil 1 $\quad \phi_{12}$ = flux of coil 1 linking with coil 2

ϕ_{22} = leakage flux of coil 2 $\quad \phi_{21}$ = flux of coil 2 linking

The ability of one coil to produce an emf in the other coil whenever the current through the first coil changes.



Let

ϕ_{11} = leakage flux of coil 1

ϕ_{22} = leakage flux of coil 2.

ϕ_{12} = Flux of coil 1 linking with coil 2.

ϕ_{21} = Flux of coil 2 linking with coil 1.

ϕ_{12} and ϕ_{21} are known as Mutal fluxes

$$\phi_{T_1} = \phi_{11} + \phi_{12}$$

$$\phi_{T_2} = \phi_{22} + \phi_{21}.$$

Mutually induced emf in the coils 1 and 2 are given as follows:

→ As per mutual inductance,

The voltage across second inductance

$$V_{L_2} = N_2 \frac{d\phi_{12}}{dt} \longrightarrow ①.$$

$$V_{L_2} = M \frac{di_1}{dt} \longrightarrow ②.$$

① = ②.

$$M \frac{di_1}{\cancel{dt}} = N_2 \frac{d\phi_{12}}{\cancel{dt}}$$

$$M = N_2 \frac{d\phi_{12}}{di_1}.$$

The voltage across first inductance.

$$V_{L_1} = N_1 \frac{d\phi_{21}}{dt} \longrightarrow ③$$

$$V_{L_1} = M \frac{di_2}{dt} \longrightarrow ④.$$

③ = ④

$$N_1 \frac{d\phi_{21}}{dt} = M \frac{di_2}{dt}$$

$$M = N_1 \frac{d\phi_{21}}{di_2}$$

If the flux in the two coils are change are linearly varying then

$$M = \frac{N_2 \phi_{12}}{i_1} \quad ; \quad M = \frac{N_1 \phi_{21}}{i_2}$$

Co-efficient Of Coupling (k):-

It is defined as the ratio of mutual inductance actually present between the two coils to the maximum possible value.

(or)

It is the fraction of total flux linking in the coils. The co-efficient of coupling equal to efficiency.

$$K = \frac{\phi_{12}}{\phi_1} \qquad k = \frac{\phi_{21}}{\phi_2}$$

$$\phi_{12} = k\phi_1 \qquad \phi_{21} = k\phi_2$$

$$M = \frac{N_2 \phi_{12}}{i_1} = \frac{N_2 K\phi_1}{i_1} \longrightarrow (5)$$

$$M = \frac{N_1 \phi_{21}}{i_2} = \frac{N_1 k\phi_2}{i_2} \longrightarrow (6)$$

(5) × (6)

$$\Rightarrow M^2 = \frac{N_2 k\phi_1}{i_1} \times \frac{N_1 k\phi_2}{i_2}$$

$$= \frac{N_1 N_2 \phi_1 \phi_2}{i_1 i_2} K^2 .$$

$$M^2 = \frac{N_1\phi_1}{i_1} \cdot \frac{N_2\phi_2}{i_2} k^2$$

$$M^2 = L_1 \cdot L_2 \cdot k^2$$

$$k^2 = \frac{M^2}{L_1 L_2}$$

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

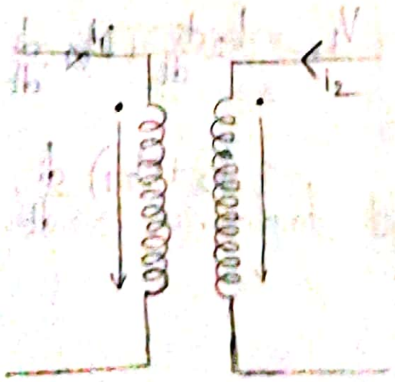
$$\boxed{\therefore k = \frac{M}{\sqrt{L_1 L_2}}}$$

$L_1 L_2 - x_1 x_2$

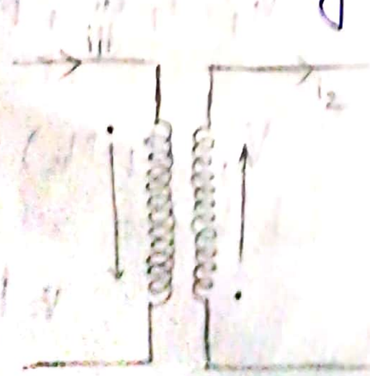
Dot Convention:-

To determine the relative polarity of induced voltage in the coupled coils, the coils are marked with dots. A dot is placed at the terminal which are instantaneously of same polarity with respect to mutual inductance.

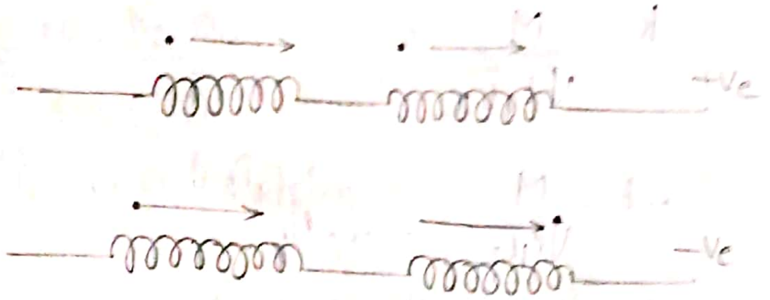
When the currents through the mutually coupled coils are going away from the dot (or) towards the dot the mutual inductance is positive. While when the current through the coil 1 is leaving and the dot and the current entering into the dot from the second coil then the mutual inductance is said to be negative.



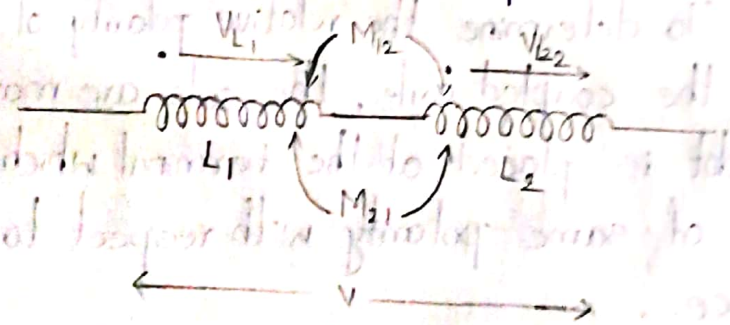
M(+ve)



M(+ve)



Series Connection Of two Coupled coils:-



Let two coils L_1 and L_2 are connected in series with dot connection as shown. The equivalent inductance can be reduced (or) derived as follows:

$$V = V_{L_1} + V_{L_2} \longrightarrow (1).$$

$$V_{L_1} = L_1 \frac{di}{dt} + M_{12} \frac{di}{dt} \qquad V_{L_2} = L_2 \frac{di}{dt} + M_{21} \frac{di}{dt}$$

$$V_{L_1} = (L_1 + M_{12}) \frac{di}{dt} \qquad = (L_2 + M_{21}) \frac{di}{dt}$$

$$V = L_{eq} \frac{di}{dt}$$

from ①

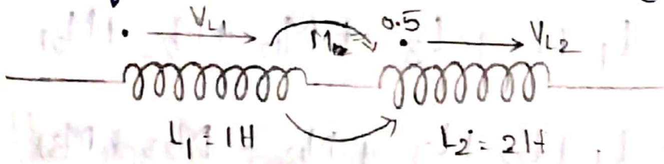
$V = V_{L_1} + V_{L_2}$

$L_{eq} \cancel{\frac{di}{dt}} = (L_1 + L_2 + M_{12} + M_{21}) \cancel{\frac{di}{dt}}$

$L_{eq} = L_1 + L_2 + 2M$ $\quad [(M_{12} = M_{21}) = M]$

$\therefore L_{eq} = L_1 + L_2 \pm 2M$

Q) Find the equivalent conductance between the coupled coils.

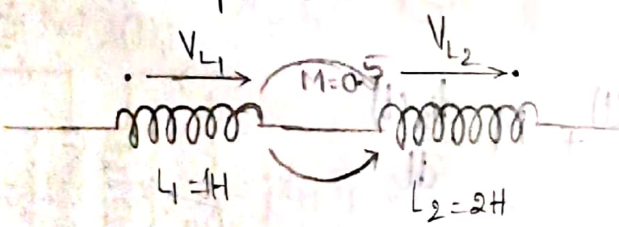


$L_{eq} = L_1 + L_2 + 2M$

$= 1 + 2 + 2(0.5)$

$= 1 + 2 + 1$

$= 4H.$



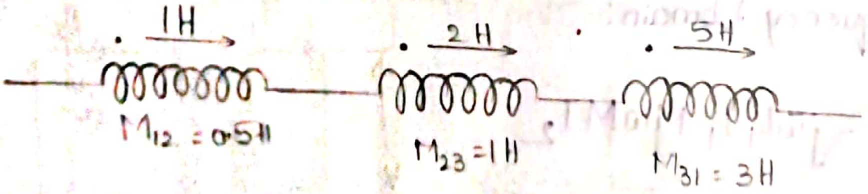
$L_{eq} = L_1 + L_2 - 2M$

$= 1 + 2 - 2(0.5)$

$= \cancel{1} + 2 - \cancel{1}$

$= 2H.$

Q)



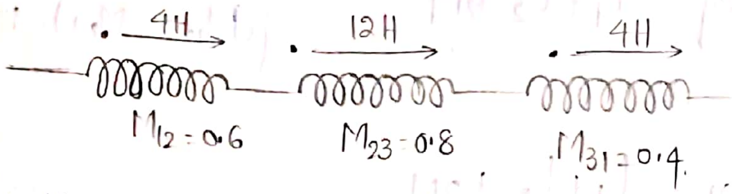
Find the equivalent between the coupled coils.

$$L_{eq} = L_1 + L_2 + L_3 + 2M_{12} + 2M_{23} + M_{31}$$

$$= 1 + 2 + 5 + 0.5 + 1 + 3$$

$$= 12.5H.$$

Q)



Find the equivalent inductance between coupled coils

Ans:-

$$L_{eq} = L_1 + L_2 + L_3 + M_{12} + M_{23} + M_{31}$$

$$= L_1 + L_2 + L_3 + M_{12} - M_{23} + M_{31}$$

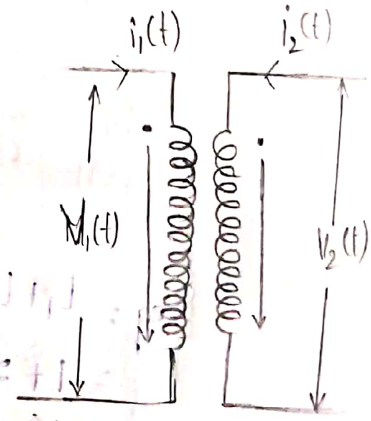
$$= 4 + 12 + 4 + 0.6 - 0.8 + 0.4$$

$$= 20.2 H.$$

*Electrical Equivalent Of Magnetic Circuit :-

$$V_1(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$$

$$V_2(t) = L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}$$

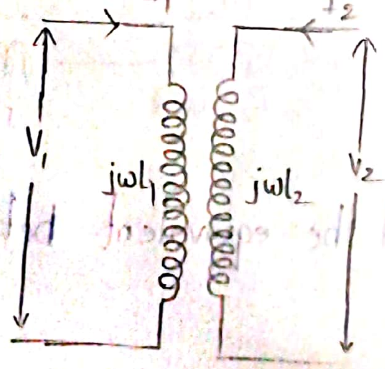


In time domain

Frequency Domain:-

$$V_1 = j\omega L_1 I_1 + j\omega M I_2$$

$$V_1 = j X_1 I_1 + j X_M I_2$$



$$V_2 = j\omega L_2 I_2 + j\omega M I_1$$

$$= j X_2 I_2 + j X_M I_1$$

If the dots in the inductors are in series:-

Aiding : $L_1 + L_2 + 2M$

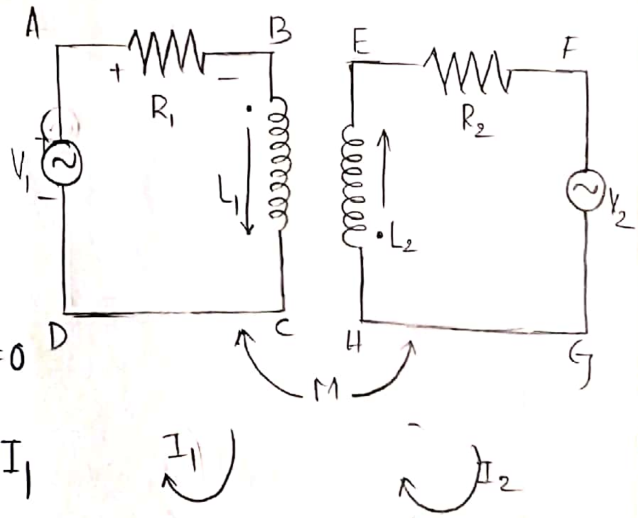
Opposing : $L_1 + L_2 - 2M$.

If the dots in the inductors are in parallel :-

Aiding : $\frac{L_1 + L_2 - M^2}{L_1 + L_2 - 2M}$

Opposing : $\frac{L_1 + L_2 - M^2}{L_1 + L_2 + 2M}$.

Q) Write the mesh equation for the following coupled magnetic circuits.



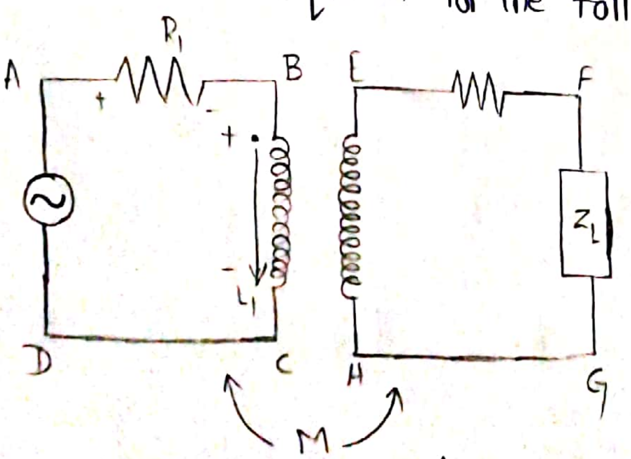
Ans:- $V_1 - i_1 R_1 - jx_1 I_1 - jx_M I_2 = 0$

$V_1 = i_1 R_1 + jx_1 I_1 + jx_M I_2$

$V_2 - i_2 R_2 - jx_2 I_2 - jx_M I_1 = 0$

$V_2 = i_2 R_2 + jx_2 I_2 + jx_M I_1$

Q) Write the mesh equation for the following circuit.



Ans: $V_1 = i_1 R_1 + jx_1 I_1 + jX_M I_2$

$I_2 R_2 + jX_2 I_2 + jX_M I_1 + Z_L I_2 = 0$.

Q) Write down the voltage equation for the given network and determine the effective inductance

Ans:-

$v(t)$

As we know that

$$V_{Leq} = V_{L_1} + V_{L_2} + V_{L_3}.$$

$$V_{L_1} = L_1 \frac{di_1}{dt} + \left[M_A \frac{di_2}{dt}\right] + \left[-M_C \frac{di_3}{dt}\right]$$

$$V_{L_2} = L_2 \frac{di_2}{dt} + \left[M_A \frac{di_1}{dt}\right] + \left[-M_B \frac{di_3}{dt}\right]$$

$$V_{L_3} = L_3 \frac{di_3}{dt} + \left[-M_C \frac{di_1}{dt}\right] + \left[-M_B \frac{di_2}{dt}\right]$$

$$V = V_1 + V_2 + V_3.$$

$$L_{eq} \cdot \frac{di}{dt} = L_1 \frac{di_1}{dt} + \left[M_A \frac{di_2}{dt}\right] + \left[-M_C \frac{di_3}{dt}\right] + L_2 \frac{di_2}{dt} + \left[M_A \frac{di_1}{dt}\right] + \left[-M_B \frac{di_3}{dt}\right] + L_3 \frac{di_3}{dt} + \left[-M_C \frac{di_1}{dt}\right] + \left[-M_B \frac{di_2}{dt}\right]$$

$\because$ they are in series. So,

$$\frac{di}{dt} = \frac{di_1}{dt} = \frac{di_2}{dt} = \frac{di_3}{dt}$$

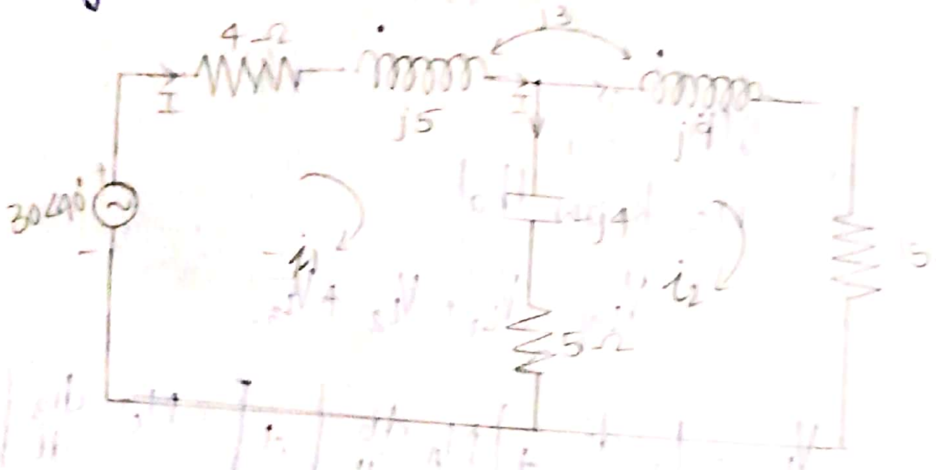
$$L_{eq} \cancel{\frac{di}{dt}} = \cancel{\frac{di}{dt}} \left[L_1 + M_A - M_C + L_2 + M_A - M_B + L_3 - M_C - M_B\right]$$

$\therefore L_{eq} = L_1 + L_2 + L_3 + 2M_A + 2M_B - 2M_C$

$\therefore L_{eq} = L_1 + L_2 + L_3 + 2(M_A - M_B - M_C)$

Q) Determine the voltage across the 15-Ω resistor in the magnetic coupled circuits?

Ans:



$30\angle 40^\circ - 4i_1 - j5i_1 - (j3i_2) - (-j4(i_1 - i_2)) - 5(i_1 - i_2) = 0$

$30\angle 40^\circ - 4i_1 - j5i_1 - j3i_2 + j4i_1 - j4i_2 - 5i_1 + 5i_2 = 0$

$-9i_1 - ji_1 + 5i_2 - 7ji_2 + 30\angle 40^\circ = 0$

$-i_1(9+j) + i_2(5-7j) + 30\angle 40^\circ = 0$ —— (1)

$-15i_2 - 5(i_2 - i_1) - (-j4(i_2 - i_1)) - j9I_2 - (j3I_1) = 0$

$-15i_2 - 5i_2 + 5i_1 + j4i_2 - j4i_1 - j9I_2 - j3I_1 = 0$

$5i_1 - 7ji_1 - 20i_2 + 5jI_2 = 0$

$i_1(5 - 7j) + i_2(-20 + 5j) = 0$ —— (2)

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$$-i_1(9+j) + i_2(5-7j) = -30\angle 90^\circ$$

$$i_1(5-7j) + i_2(-20+5j) = 0$$

$$\begin{bmatrix} -(9+j) & (5-7j) \\ (5-7j) & (-20+5j) \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} -30\angle 90^\circ \\ 0 \end{bmatrix}$$

