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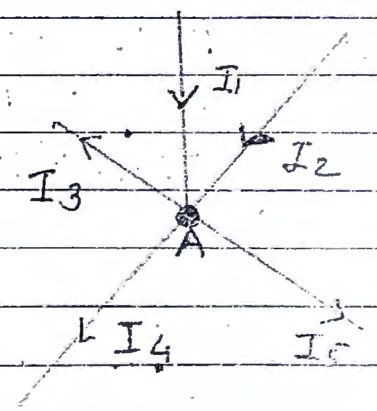
★ Explain Kirchoff's law

KCL (Kirchoff's Current law)

Statement :- " In any Electrical network algebric sum of all currents meeting at a junction OR Node is zero.

$$\therefore \sum I = 0$$

→ Assume that current coming towards point A are (+Ve) Postive & currents leaving the point A are (-Ve) Negative



→ from the above figure & statemen

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

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

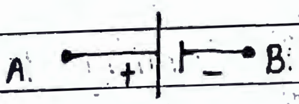
Sum of Incoming Currents = Sum of outgo currents

KVL (Kirchoff's Voltage law)

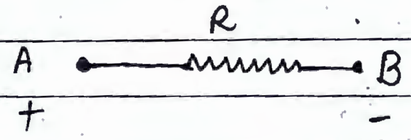
Statement : " In any Electrical Network algebric sum of Voltage (E.M.F) plus algebric Sum of products of Currents & Resistances is zero

$$\Sigma V + \Sigma IR = 0$$

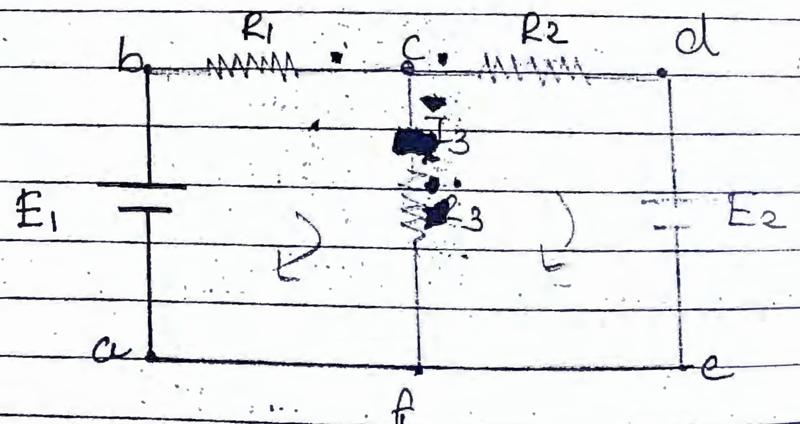
→ some sign Consideration for analysing circuit



1) if current flows from A to B ⇒ $-V$ (fall in Volt
2) if current flows from B to A ⇒ $+V$ (Rise in voltage



→ if terminal A is +ve & B is - if we move A to B voltage drop occurs $-IR$ (fall Vice-versa



for path abcfa :- $+E_1 - I_1R_1 - I_3R_3$
for path cdefc :- $\div E_2 + I_2R_2 + I_3R_3$

★ Explain Thevenin's theorem with Example.

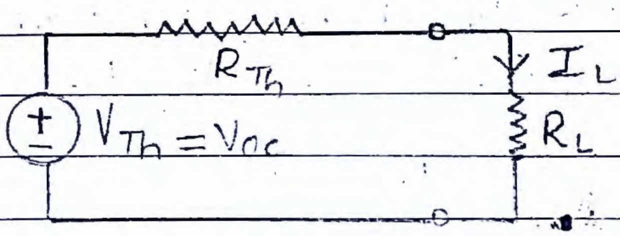
→ Thevenin's theorem is used to find particular branch current.

→ STATEMENT :-

"In any linear active network one or more than one sources replaced by single voltage source (V_{Th} or V_{oc}) in series with resistences (R_{Th})"

→ The voltage V_{Th} is known as Thevenin's voltage or V_{oc} is known as open circuit voltage.

→ R_{Th} is Thevenin's resistence across open circuit terminal.



→ Above figure shows general thevenin's equivalent network.

STEPS: to apply theorem in Network.

Step-1 :. Remove the branch (Resistence R_L) through which current is to be determined.

Step-2 :- Calculate V_{Th} OR V_{oc}

Step-3 :. Calculate R_{Th} by replacing voltage source as short circuit & current source as open circuit

Step-4 :. Draw the thevenin's equivalent Network & find $I_L = \frac{V_{Th}}{R_{Th} + R_L}$

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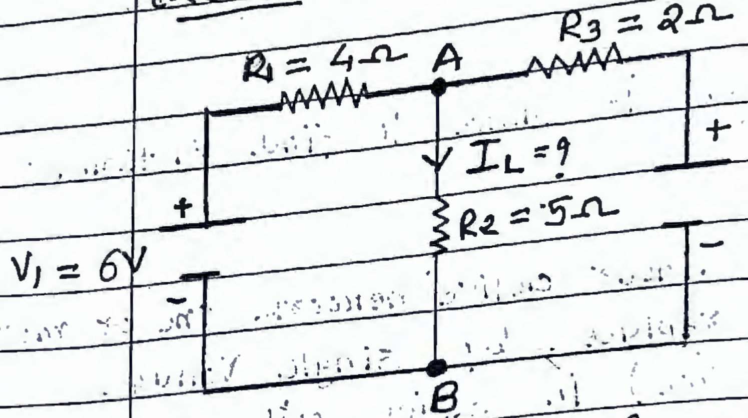
Example : find the current through Branch AB



→ from the above figure $R_2 = R_L$ is Load current I_L flows through it that we have to find. Now apply thevenin's theorem

Step-1 : Remove the branch current through which resistence ($R_2 = R_L$) is determi

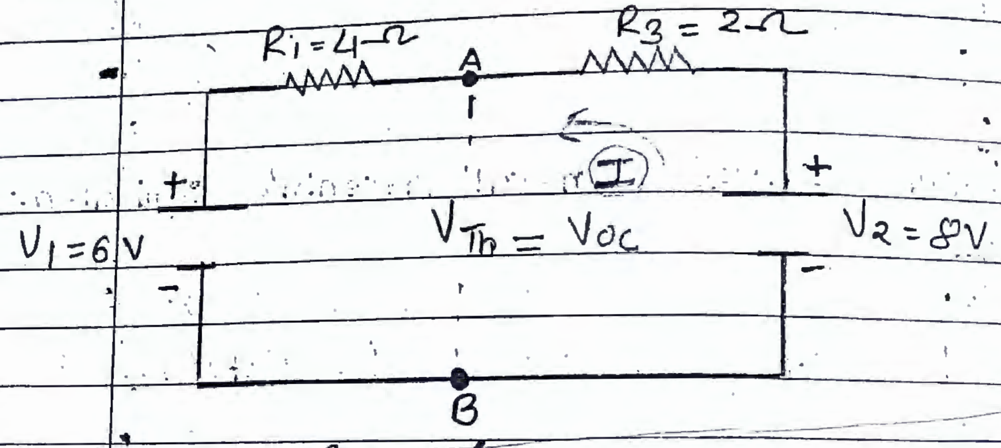


fig : NO : 1

Step 2. Calculate V_{Th} OR V_{oc} from fig 1

→ from the Loop Using KVL

$$8 - 2I - 4I - 6 = 0$$

$$2 = 6I \Rightarrow I = 2/6 \Rightarrow I = 0.3$$

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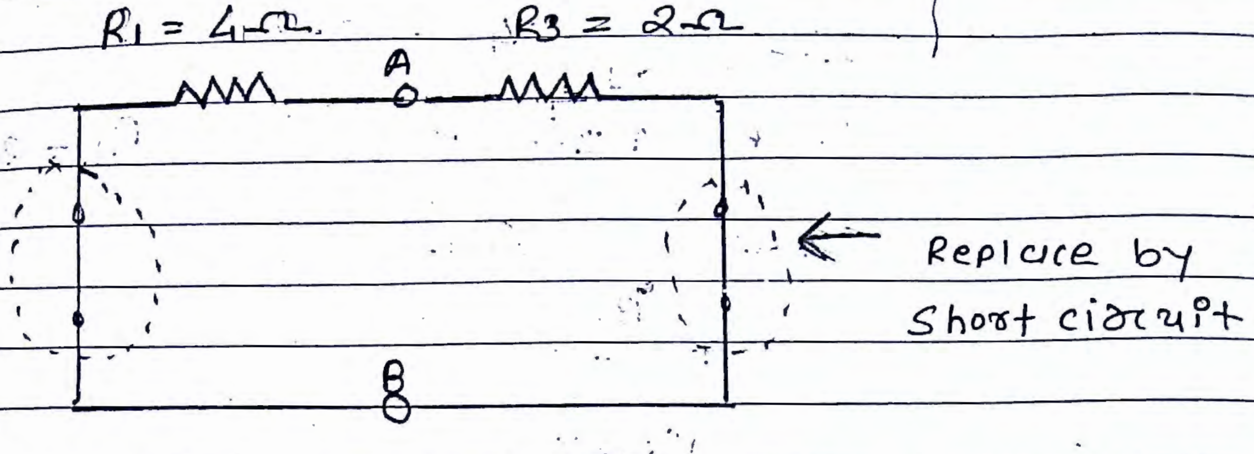
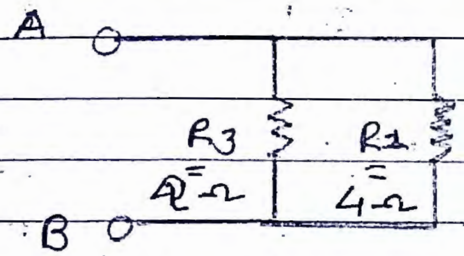
$V_{Th} = V_{oc} = 8 - (2 \times I) = 8 - (0.66) = 7.3V$

Step-3 Calculate R_{Th} by replacing Voltage Source as short circuit & Current source as Open circuit.



→ from the above fig resistors are connected in parallel

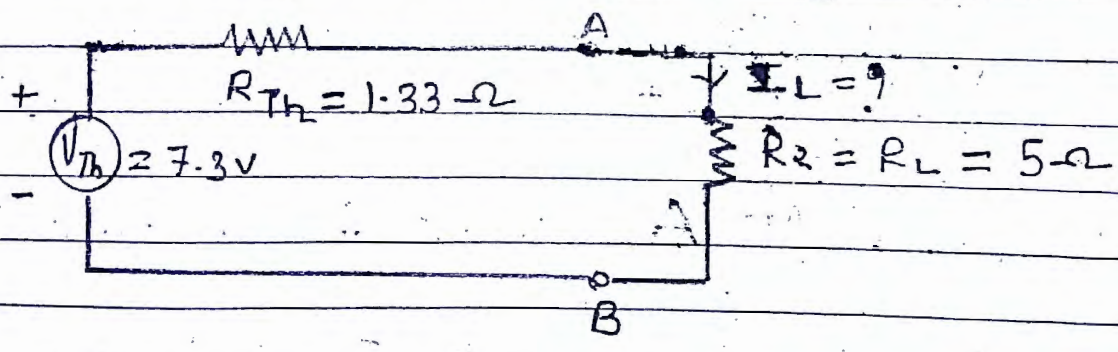


$R_{Th} = R_1 \parallel R_3$

$= 2 \parallel 4 \Rightarrow \frac{2 \times 4}{2+4}$

$R_{Th} = 1.33\,\Omega$

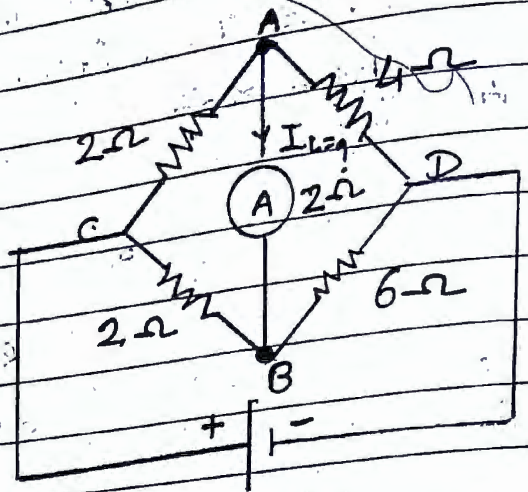
Step-4: Calculate I_L Using thevenin's equivalent Network.



$$I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{7.3}{1.33 + 5} = 1.15$$

ANS Current through Branch AB is 1.15A

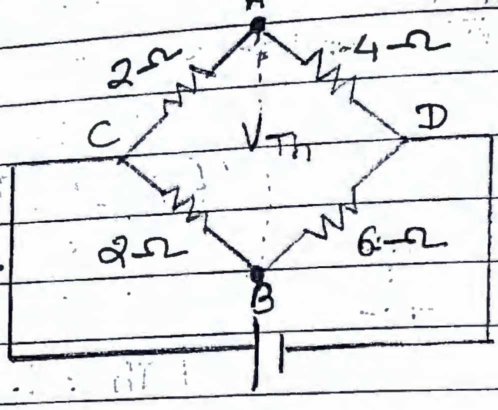
Example: Determine Current through the circuit of Resistence 2Ω connected in Wheastone bridge of below fig.



V = 12V

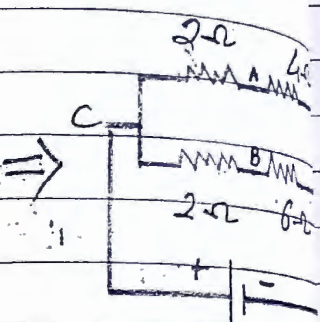
$R_L = 2\Omega$

Step-1:



V = 12V

⇒



V = 12V

Step 2: Determine V_{Th}

$V_{Th} = -V_A + V_B$ from the above

(voltage divider rule)

Potential of A w.r.t D $= 12 \times \frac{4}{6} =$

Potential of B w.r.t D $= 12 \times \frac{6}{8} =$

$V_{Th} = V_B - V_A = 9 - 8 = 1 V$

(with B is +ve)

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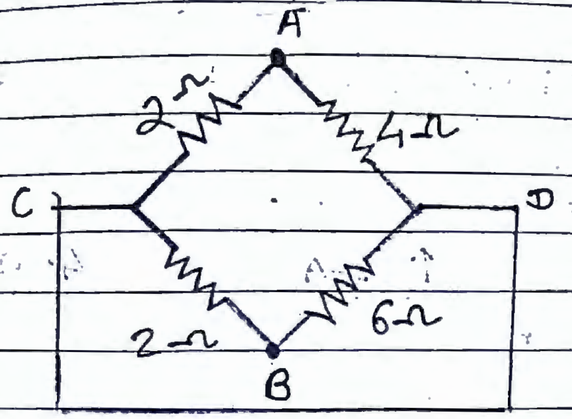
Step 3 : calculate R_{Th}



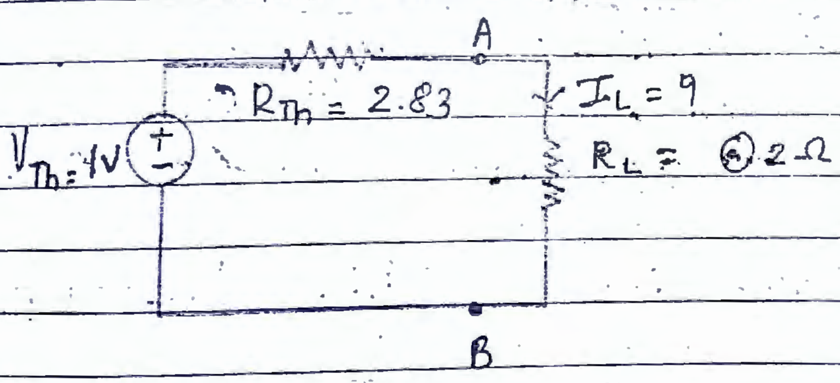
→ from the above circuit
2 ∥ 4 & 2 ∥ 6

$$R_{Th} = (2 \parallel 4) + (2 \parallel 6)$$

$$= \left(\frac{2 \times 4}{2+4}\right) + \left(\frac{2 \times 6}{2+6}\right)$$

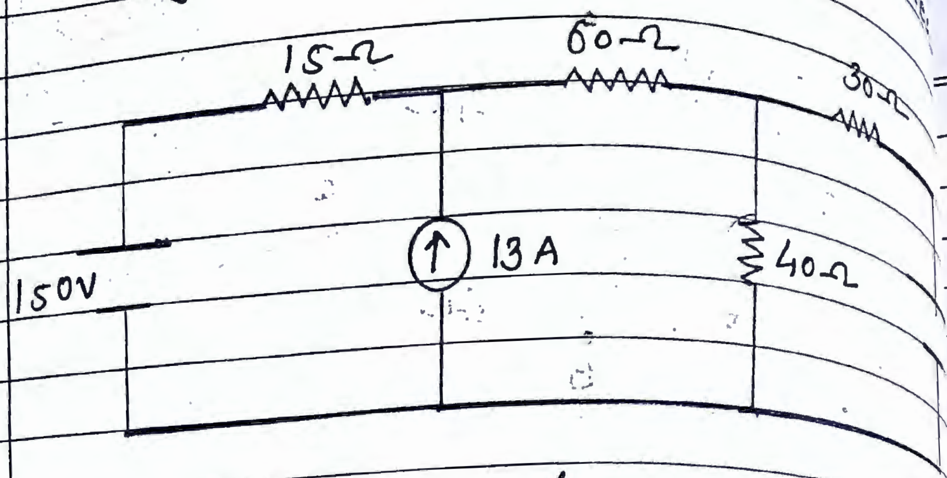
$$= \frac{8}{6} + \frac{12}{8} \Rightarrow 2.83\,\Omega$$

Step 4 Calculate I_L using thevenin's equivalent Network



$$I_L = \frac{V}{R_{Th} + R_L} = \frac{1}{2.83 + 2\Omega} = \frac{1}{4.83} = 0$$

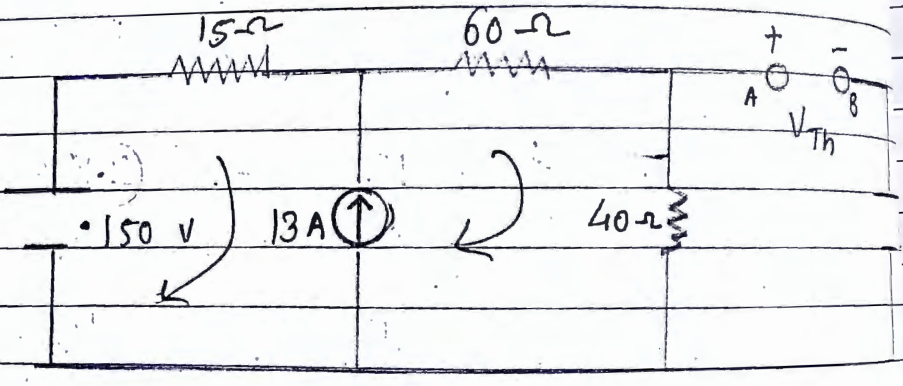
Example : Find Current through the 30Ω using thevenin's theorem



→ from the above fig $R_L = 30\Omega$

step. 1 : Remove ther branch (Resistance) through which current is deter

Step. 2 Calculate V_{Th} OR V_{oc}



→ Both Mesh form supermesh (Supermesh means if current source is common in both Loop or mesh)

→ from the figure writing the equation

$$15I_1 + 60I_2 + 40I_2 = 150$$

$$\Rightarrow 15I_1 + 100I_2 = 150 \quad (1)$$

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→ Writing the equation for Supermesh (current)

$I_2 - I_1 = 13 \longrightarrow (2) \Rightarrow I_2 = 13 + I_1$

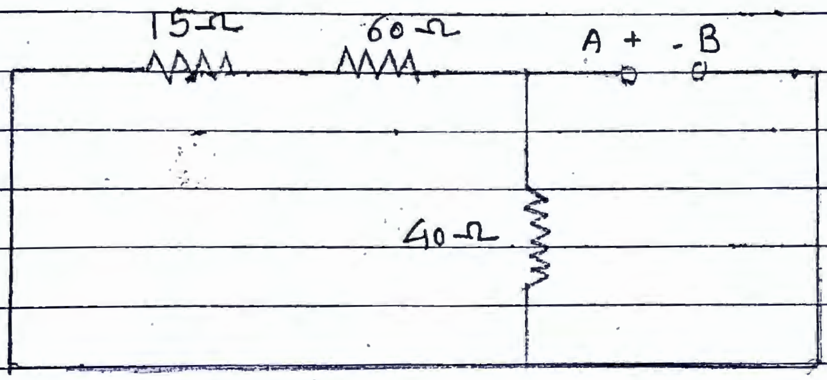
solving equation (1) & (2)

$$15 I_1 + 100 I_2 = 150$$
$$-I_1 + I_2 = 13$$

→ $I_1 = -10A, \quad I_2 = 3A$

$\Rightarrow V_{Th} = 40 I_2 - 50$
$= (40 \times 3) - 50 \Rightarrow V_{Th} = 70V$

Step. 3 Calculate R_{Th} by Voltage source as Open circuit & Current source as Short circuit.



→ From the fig

$$R_{Th} = (15 + 60) \parallel 40$$
$$= 75 \parallel 40$$
$$= \frac{40 \times 75}{40 + 75}$$

$R_{Th} = 26.09\,\Omega$

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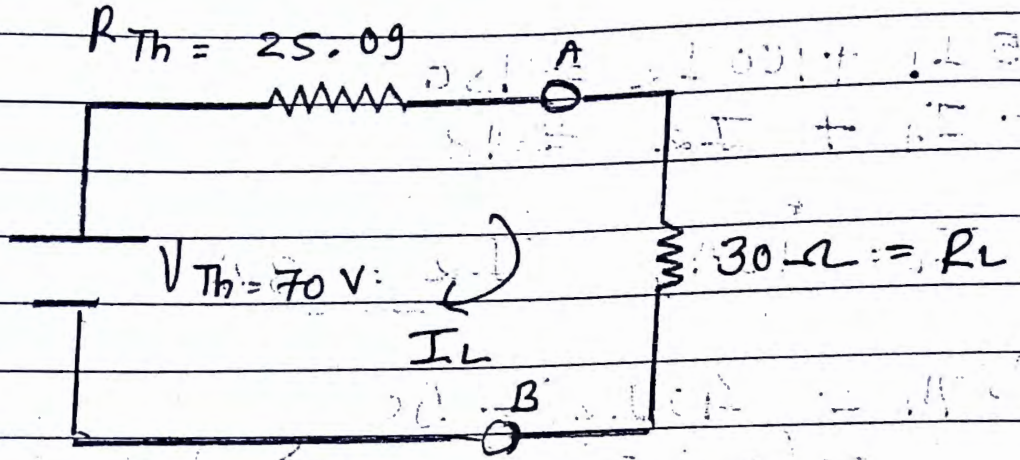
Step-4 Draw the equivalent circuit of thevenin's & find I_L



$$I_L = \frac{V_{Th}}{R_L + R_{Th}} = \frac{70}{25.09 + 30} = 1.25$$

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Explain NORTON's Theorem

→ Norton's theorem is the corollary of thevenin's theorem. we can say it is dual of thevenin's theorem

STATEMENT :

" In any linear active network having one or more than one sources can be replaced by single current source (I_{sc}) with parallel resistance ($R_{eq} = R_{Th} = R_N = Z_N$) "

STEPS to solve (Norton's theorem) Example

Step-1 : Short circuit required branch (Resistance R_L) through which current is to be determined

Step-2 : Calculate short circuit current source I_{sc}

Step-3 : Calculate $R_{Th} = R_{eq} = R_N = Z_N$ by replacing Voltage source as short circuit & current source as open circuit.

Step-4 : Draw the Norton's equivalent ckt diagram

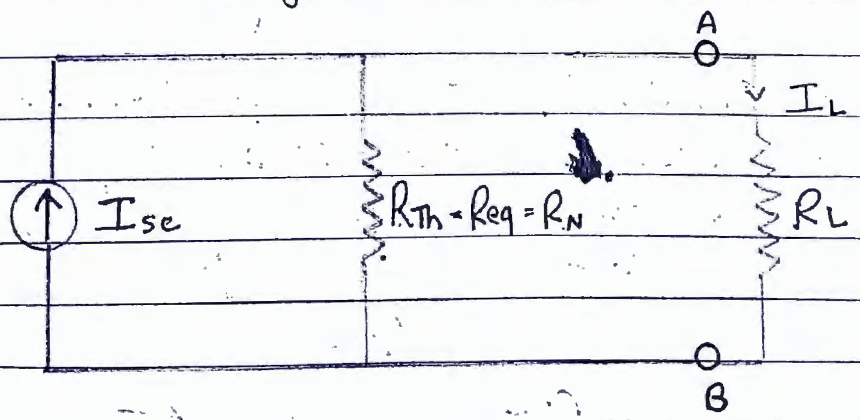
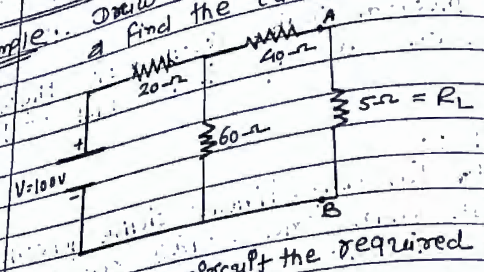
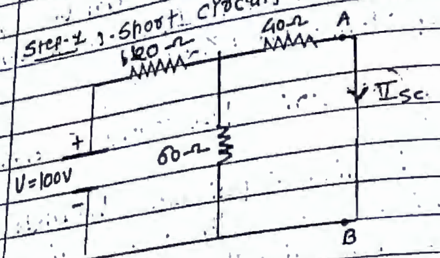


figure shows Norton's equivalent circuit.

Example:- Draw the Equivalent Norton's Network & find the current through 5Ω Resistor.



Step-1:- Short circuit the required branch (Resistor)

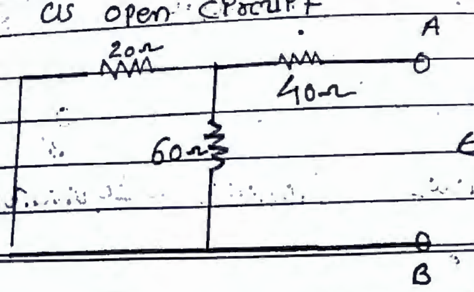


Step-2:- Calculate I_{sc} (Short circuit current)

Total current $I = \frac{V}{R_{Total}} = \frac{100}{(40 \| 60)+20}$

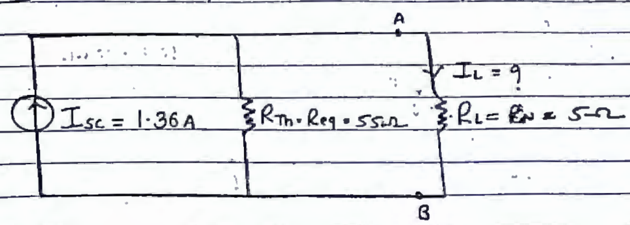
$$I_{sc} = \frac{I \cdot 60}{60+40} = \frac{2.27 \times 60}{100} = 1.36\,A$$

Step-3:- Obtain $R_{eq} = R_{Th}$ by replacing Voltage source as shortcircuit & Current source as open circuit



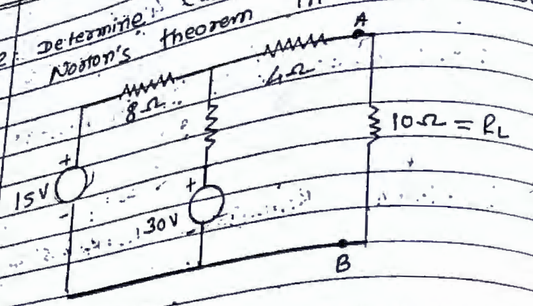
$$R_{Th} = R_{eq} = 40 + (20 \| 60) = 40 + \left(\frac{20 \times 60}{20+60}\right) = 55\,\Omega$$

Step-4 Draw equivalent circuit for Norton's theorem



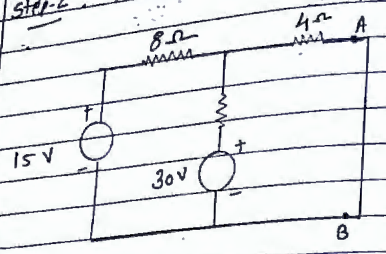
$$I_L = I_{sc} \cdot \frac{R_{Th}}{R_{Th}+R_L} = 1.36 \cdot \frac{55}{(55+5)} = 1.24\,A.$$

Exmple : Determine Current in 10Ω resistence using Norton's theorem in below Network



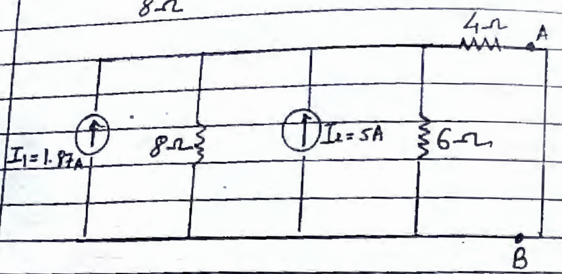
Step-1 : Short circuit required branch (Resistance)

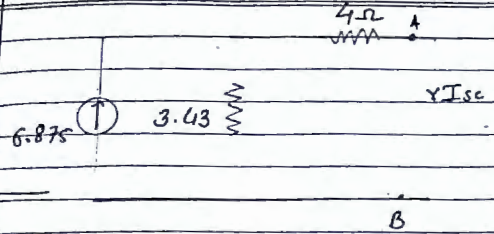
Step-2 : Calculate I_{sc}



Convert voltage sources in to Current Sources

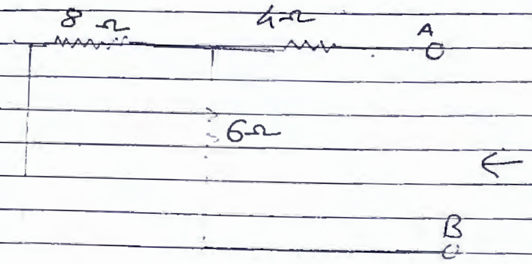
$I_1 = \frac{15V}{8Ω} = 1.87$ A & $I_2 = \frac{30}{8} = 5$ A





$I_{sc} = I . \frac{3.43}{3.43+4} = 3.17$ A

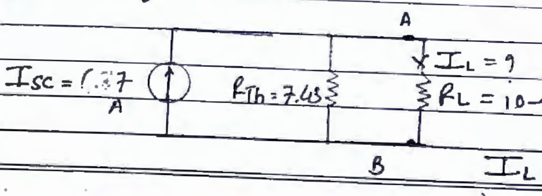
Step-3 Calculate R_{Th} by Voltage source as S/C



→ $R_{Th} = R_{eq} = R_N = (8 || 6) + 4 = \left(\frac{8 \times 6}{8+6}\right) + 4$

$R_{Th} = R_{eq} = R_N = 3.43 + 4 = 7.43$ Ω

Step-4 Draw Norton's equivalent Network & find Current.



$I_L = \frac{I_{sc} . R_{Th}}{R_{Th} + R_L} = 1.35$

* Explain Superpostion theorem with example

→ STATEMENT

"Response [current or voltage] in any element of linear bilateral network having more than one source can be obtained as the algebraic sum of responses [current or voltage] by individual sources keeping other sources set inoperative

→ It is used to find out voltage & current

→ It has two main aspects.

1) Homogeneity
2) Additively property

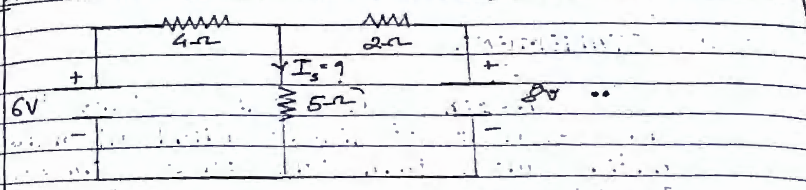
→ Following are STEPS to solve the complex network.

STEP-1: Consider individual source keeping the voltage source as short circuit & current source as open circuit & consider the direction & polarities of resistance

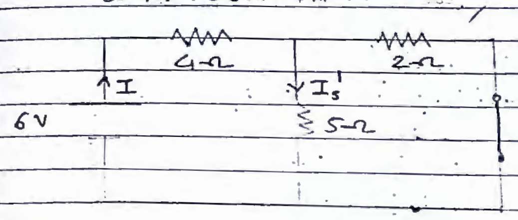
STEP-2
Algebraic sum of response of individual source.

Response
means
- voltage OR current

Example. Find the current through 5 Ω Resistor



Step-1: Consider the individual source (for 6V) replace voltage source as short circuit & current source as open circuit. find the response [current] with direction



$$I = \frac{V}{R} = \frac{6}{4+(5\|2)} = \frac{6}{4+\left(\frac{5\times 2}{5+2}\right)} = \frac{6}{5.4}$$

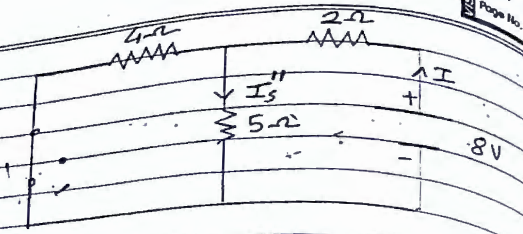
$$\boxed{I = 1.110}$$

(current divider we)

$$I_s = 1.110 \times \frac{2}{2+5} = 0.317$$

$$\boxed{I_s = 0.317} \downarrow$$

For 8V



$$I = \frac{V}{R} = \frac{8}{2 + (4 \| 5)} = \frac{8}{2 + \left(\frac{4\times5}{4+5}\right)}$$

$I = 1.89$ A.

Current divider rule

$$I_s'' = \frac{1.89 \times 4}{5+4} = 0.84 \ (\downarrow)$$

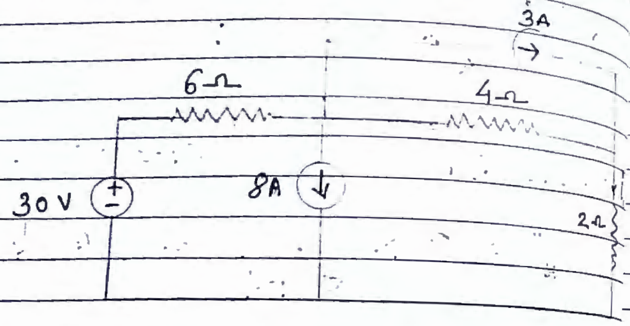
step. 2 Algebraic sum of Response

$I_s = I_s' + I_s''$

$= 0.317 + 0.84$

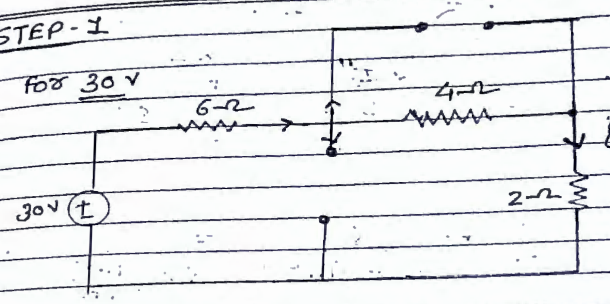
$\boxed{I_s = 1.15 \ \text{A.}}$

Example Determine the value of i_1^0 using theorem in given Network.



STEP - 1

For 30 V

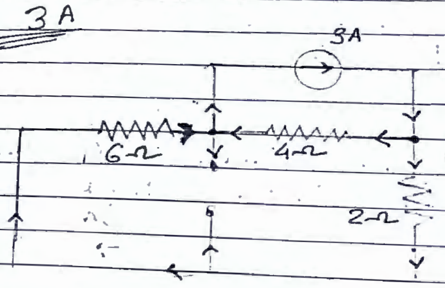


From the figure It looks series circuit

$$i_1' = \frac{V}{R} = \frac{30}{6+4+2} = \frac{30}{12} \quad 2.5$$

$i_1^{0\,\prime} = 2.5$ A $(\downarrow)$

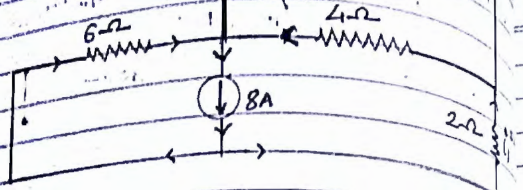
For 3A



From the figure $6+2 = 8\,\Omega$

$$i_R^{0\,''} = 3 \times \frac{4}{8+4} = 1 \ \text{A} \ (\downarrow)$$

FOR 8A



From the figure $4+2 = 6\,\Omega$

$i_3^{0\text{-}III} = 8 \times \frac{6}{6+6} = 4A \Rightarrow i_1^{0\text{-}III} =$

STEP-2:- Sum of Algebraic response

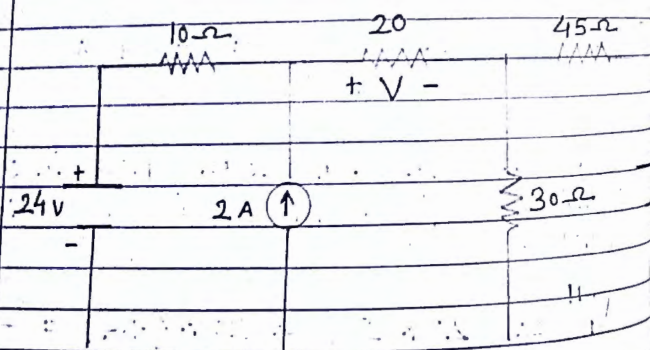
$I_1 = i_1^{0\text{-}I} + i_2^{0\text{-}II} + i_3^{0\text{-}III}$

$= 2.5 + 1 + 4$

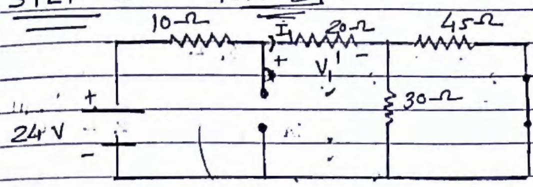
$= -0.5\ A$

$I_1 = -0.5\ A$

Example:- Find the Value of 'V' across 20- given network with Super position theo



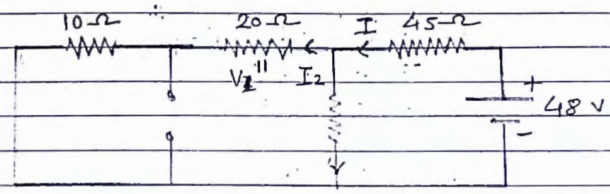
STEP-1 FOR 24 V



$I = \frac{V}{R} = \frac{24}{10+20+(45 \parallel 30)} = 0.5\ A$

$V_1' = 20 \times I_1 = 20 \times 0.5 = 10V$

FOR 48 V



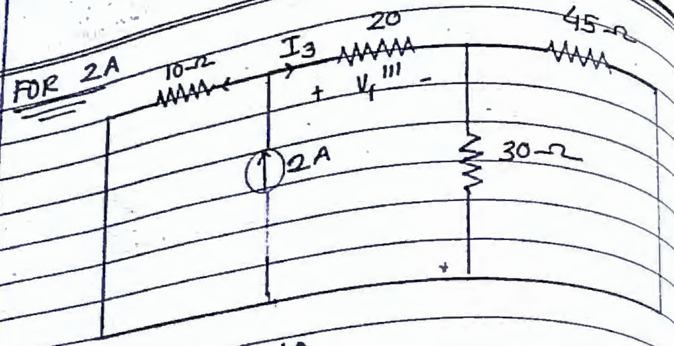
$I = \frac{V}{R} = \frac{V}{} \frac{48}{45+[30 \parallel \{10+20\}]} = \frac{48}{60} = 0.8\ A$

$I_2 = 0.8 \times \frac{30}{30+20} = -0.4\ A$

As current through $20\,\Omega$ flows in opposite direction from the reference direction shown for V

$V_1'' = 20 \times I_2 = 20 \times (-0.4) = -8V$

FOR 2A



$$I_3 = 2 \times \frac{10}{10 + [20 + \{45 \| 30\}]}$$

$$= 2 \times \frac{10}{10 + [20 + 18]} = \frac{5}{12} = 0.41$$

$$V_1''' = 20 \times I_3 = 20 \times 0.416 = 8.33$$

STEP-3

$$V = V_1' + V_1'' + V_1'''$$

$$= 10 + (-8) + 8.33$$

$$V = 10.32 \text{ V}$$

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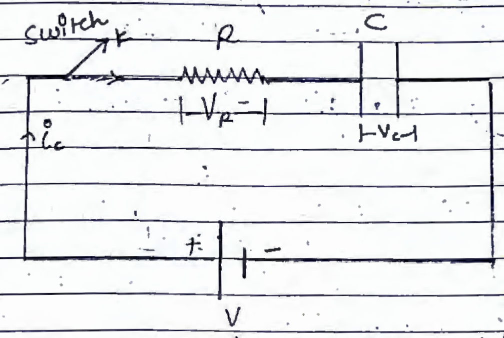
★ Derive the charging Voltage equation

OR

★ Prove that $V_c = V\left[1 - e^{-t/RC}\right]$ OR

★ Explain first order RC circuit



→ If any one storing Energy Element (C OR L) is connected with Resistance then it is first order system

→ As shown in figure when switch K is closed, Capacitor C can be charged through Resistance R from the supply Voltage V (Battery)

→ Initially charge on Capacitor C is zero at $t = 0$ time

→ As R & C are connected in series, The applied voltage (V)

$$V = V_R + V_c$$

$$V = i_c R + V_c$$

$$V = \frac{dq}{dt} \cdot R + V_c$$

$$V = \frac{d}{dt}(CV_c) \cdot R + V_c$$

$$V = RC \frac{dV_c}{dt} + V_c$$

where V_c = Voltage across Capacitor
V_R = Voltage across Resistor
i_c = Charging Current

$\therefore i_c = \frac{dq}{dt}$

$\therefore q = CV_c$

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∴ $V - V_c = RC \frac{dV_c}{dt} \Rightarrow \frac{V-V_c}{dV_c} = \frac{RC}{dt}$

Rearrange step

$\frac{dV_c}{V-V_c} = \frac{dt}{RC}$, Now take integration Negative sign both

$$-\int \frac{dV_c}{V-V_c} = -\int \frac{dt}{RC} \Rightarrow -\left[-\ln(V-V_c)\right] = -\frac{t}{RC}$$

$$\boxed{\ln(V-V_c) = -\frac{t}{RC} + K} \quad \text{....(1)}$$

Where, K = Integration Constant

→ To find the value of K put initial ... in equation No. 1

at initial condition $t=0$, hence

$$\ln(V-0) = 0 + K \Rightarrow \boxed{K = \ln V} \quad \text{...(2)}$$

Put the Value of K (eq. No. 2) in to eq No 1

$$\therefore \ln(V-V_c) = -\frac{t}{RC} + \ln V$$

$$\therefore \ln(V-V_c) - \ln V = \frac{-t}{RC} \Rightarrow \ln\left(\frac{V-V_c}{V}\right) =$$

$$\therefore \frac{V-V_c}{V} = e^{\frac{-t}{RC}} \Rightarrow V-V_c = V.e^{-t/RC}$$

$$\therefore -V_c = V.e^{-t/RC} - V$$

$$V_c = V - V.e^{-t/RC}$$

$$\boxed{V_c = V\left[1-e^{-t/RC}\right]} \quad \text{....(3)}$$

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Now RC is called Time constant of circuit it can be denoted by λ. [∴ $\lambda = RC$]

$$\boxed{V_c = V(1-e^{-t/\lambda})} \quad \text{.....(4)}$$

→ from the above equation V & λ are constants equation shows relation between V_c & t

if we substitute $t = \lambda = RC$ in equation (4)

$$V_c = V(1-e^{-\lambda/\lambda}) = V(1-e^{-1})$$

$$V_c = V\left(1-\frac{1}{e}\right) \Rightarrow V_c = V\left(1-\frac{1}{2.718}\right)$$

$$V_c = 0.632V$$

→ When $t = RC = \lambda$ Voltage across capacitor (charging Voltage V_c) becomes $0.632V$

Definition of Time Constant for Charging the Capacitor

" Time during which Voltage across capacitor (charging Voltage V_c) becomes 63.2 % of battery voltage (Supply voltage) or final steady Value "

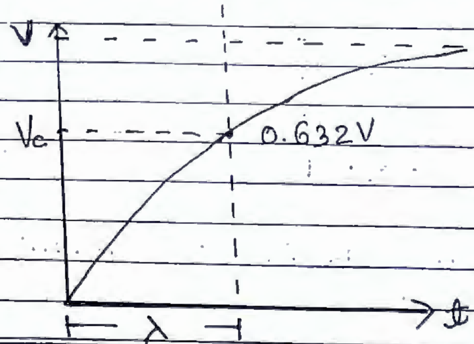


fig:- Charging of Capacitor

* Charging current i_c

$$\boxed{i_c = I_m e^{-t/\lambda}} \quad \text{......(5)} \quad \text{where } I_m = \frac{V}{R}$$

if $t = \lambda = RC$, Put this value in eqn

$$i_c = I_m e^{-\lambda/\lambda} = I_m e^{-1}$$

$$i_c = I_m \left[\frac{1}{e}\right] = I_m \left[\frac{1}{2.718}\right]$$

$$i_c = 0.367\, I_m$$

Time Constant :-

"Time during which charging curr... decrease to 0.37 of its Initial Ma... Value"

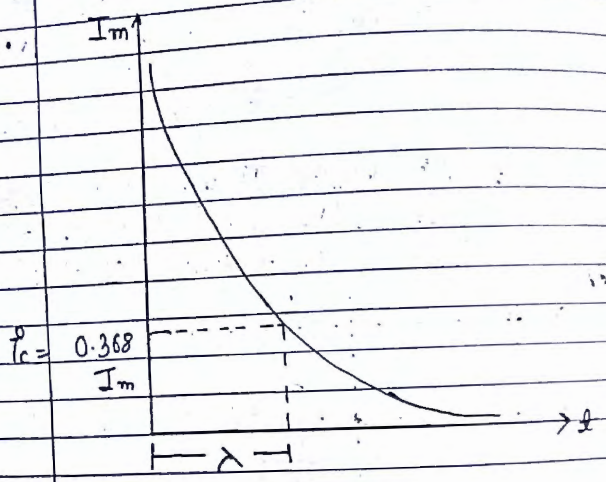


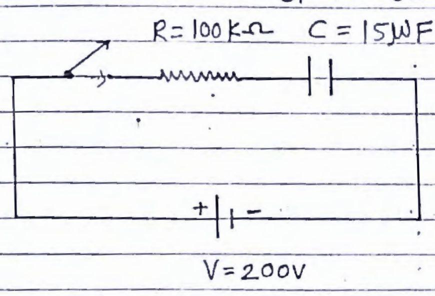
fig :- Charging of Capacitor

* Example

Capacitor of 15 µF is connected in series with resistor of 100 kΩ. The combination is given 200V d.c supply.

Find.

a) Time Constant
b) Time required for voltage across capacitor is 100V
c) Voltage across capacitor after 0.2 sec when switch is close (ON)
d) Find Intial current
e) Value of charging current after 0.5 sec when switch is close (ON)
f) Time required for charging current to become 0.2 mA
g) Intial Rate of Rise of voltage across capacitor



a) Time Constant $\lambda = RC$

$$\lambda = 100 \times 10^{3} \times 15 \times 10^{-6} = 1.5 \text{ sec}$$

b) Time required for Voltage across Capacitor is 100V

$$V_c = V\left[1 - e^{-t/RC}\right]$$

$$100 = 200\left[1 - e^{-t/RC}\right]$$

$$\frac{100}{200} = \left[1 - e^{-t/RC}\right]$$

$\therefore\ 0.5 = 1 - e^{-t/1.5}$

$\therefore\ 0.5 - 1 = -e^{-t/1.5}$

$-0.5 = -e^{-t/1.5} \Rightarrow e^{-t/1.5} = 0.5$

$\therefore\ -t/1.5 = \ln 0.5 \Rightarrow \frac{-t}{1.5} = -0.693$

$\therefore\ -t = -0.693 \times 1.5$

$\therefore\ \boxed{t = 1.038 \text{ sec}}$

c) Voltage across capacitor after 0.2 sec when switch is closed (ON)

$V_c = V\left[1 - e^{-t/\lambda}\right]$

$V_c = 200\left[1 - e^{-0.2/1.5}\right] = 200\left[1 - e^{-0.13}\right]$

$\boxed{V_c = 24.38 \text{ volt}}$

d) Initial Current OR Maximum Current

$\rightarrow$ At initial condition $V_c = 0$

$V = V_R + V_c$

$V = V_R + 0 \Rightarrow V = V_R$

$I_m = I = \frac{V_R}{R} = \frac{V}{R} = \frac{200}{100 \times 10^3} = \boxed{2 \times 10^{-3}}$

e) Value of charging current after 0.5 sec when switch is close

$i = I_m e^{-t/RC}$

$i = 2 \times 10^{-3} \cdot e^{-0.5/1.5} = 1.43 \text{ mA}$

f) Time required for charging current to 0.2 mA

$i = I_m e^{-t/\lambda} \Rightarrow 0.2 \times 10^{-3} = 2 \times 10^{-3} \cdot e^{-t/1.5}$

$\therefore\ e^{-t/1.5} = 0.1 \Rightarrow \frac{-t}{1.5} = \ln 0.1$

$\therefore\ \frac{-t}{1.5} = -2.30 \Rightarrow t = 2.30 \times 1.5$

$\boxed{t = 3.45 \text{ sec}}$

g) Initial Rate of Rise of Voltage across capacitor

$\left(\frac{dV_c}{dt}\right)_{t=0} = \frac{V}{RC} = \frac{200}{1.5} = \boxed{133.33 \text{ V/s}}$

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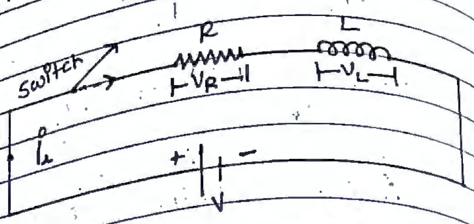
★ Derive the equation for Growth of Current in R-L series first order circuit OR Inductive Circuit

$i = I_m(1 - e^{-t/\lambda})$



→ from the figure R & L are connected in series. It is first order system. When switch is delayed in circuit growth of current of Inductor L

→ Let i is current changes from 0 to i in time t will induce an e.m.f. inductor cause the current to flow opposite direction

→ series circuit (R-L) applying KVL

$$V = V_R + V_L$$

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

where, $L\frac{di}{dt}$ = self in…

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

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

, Now rearrange

$$\frac{di}{\ldots} = \frac{dt}{\ldots}$$

Multiplying both side with R, & take integration & negative sign both side

$$-\int \frac{R\,di}{V - iR} = -\int \frac{R}{L}\,dt$$

$$\therefore -\left(-\ln(V - iR)\right) = -\frac{Rt}{L} + K \quad \text{------ (1)}$$

To find integration constant K, we will put initial condition in equation no. 1

Initial condition ⇒ $t = 0$, $i = 0$

$$\boxed{\ln(V - iR) = -\frac{Rt}{L} + K} \quad \text{------ (2)}$$

$$\ln(V - 0) = 0 + K$$

$$\boxed{K = \ln V} \quad \text{-------- (3)}$$

Put the value of Eq. no (3) into (2)

$$\ln(V - iR) = -\frac{Rt}{L} + \ln V$$

$$\ln(V - iR) - \ln V = -\frac{Rt}{L}$$

$$\ln\left[\frac{V - iR}{V}\right] = -\frac{Rt}{L}$$

$$\frac{V - iR}{V} = e^{-\frac{Rt}{L}}$$

$$V - iR = V \cdot e^{-\frac{Rt}{L}}$$

$$iR = V - Ve^{-Rt/L}$$

$i_R = V[1-e^{-\frac{Rt}{L}}]$

$i = \frac{V}{R}[1-e^{-\frac{Rt}{L}}]$

$\boxed{i = I_m\left[1-e^{-\frac{Rt}{L}}\right]}$ ...... (4) where $I_m =$

$\lambda =$ Time Constant $\therefore \lambda = \frac{L}{R} \Rightarrow \frac{1}{\lambda} = \frac{R}{L}$

$\boxed{i = I_m\left[1-e^{-\frac{t}{\lambda}}\right]}$ ...... (5)

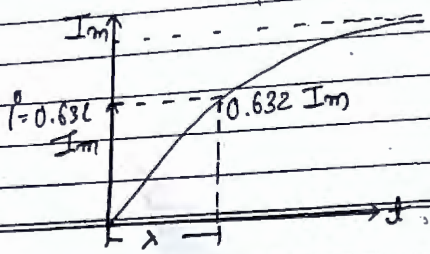
Now take $t=\lambda$ & put in equation No.

$i = I_m\left[1-e^{-\lambda/\lambda}\right] = I_m\left[1-e^{-1}\right]$

$\boxed{i = 0.632\, I_m}$

Time constant is defined as

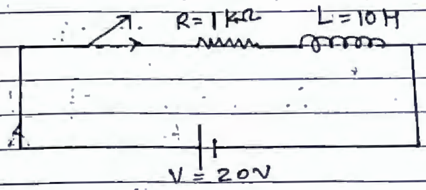
" is Time taken by current to rea
63.2% of its maximum value du
growth of current in R-L circuit "



Example

for given circuit find

a) Time constant (b) Current after 5 m sec, after switch is closed.



(a) Time constant:

$\lambda = \frac{L}{R} = \frac{10}{1000} = 0.01\,\Omega = \boxed{10\,m\Omega}$

b) Current after 5 msec when switch is closed

$i = I_m(1-e^{-t/\lambda})$

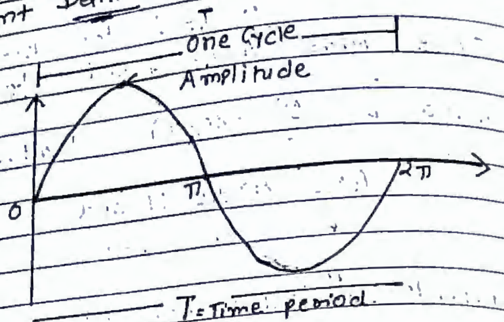
$I_m = \frac{V}{R} = \frac{20}{1000} = 0.02$

$I_m = 20\,m\Omega$

$i = 20\left(1-e^{-5/10}\right) = 20(1-e^{-0.5})$

$\boxed{i = 7.86\,mA}$

★ Important Definition



Instantaneous Value :- "The value of altern. quantity (e.g = e.m.f, voltage, current, flux) a particular instant is called Instantaneous Value"

Cycle :- "Cycle is defined as One com. set of positive & negative values of alternating quantity."
Unit is Radian

Frequency :- "Number of cycles per second of an alternating quantity"

denoted by f & Unit is Hz (Hertz)

$f = \frac{1}{T}$ where T = Time

Time period :- "Time required to complete One cycle of an alternating quantity"
denoted by T, Unit is sec

$T = \frac{1}{f}$

Angular Velocity :- "It is the Ratio of the Cycle spans (Angle turned) to Time taken"

denoted by ω (omega) Unit is radians/second

$$\omega = \frac{\text{Angle turned}}{\text{Time taken}} = \frac{2\pi}{T} = \frac{2\pi}{\frac{1}{f}} = 2\pi f$$

Amplitude :- "Maximum positive OR negative Value of Alternating quantity."

R.M.S Value OR Effective Value OR Active Value

"The value of D.C (Direct Current) OR Steady Current flowing through the given circuit for given time produces the same Heating effect as produced by alternating quantity for same circuit & time."

R.M.S is Root means square

e.g $I_{r.m.s} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$

Average Value OR Mean Value

"The value of D.C which transfer the same charge as transffer by alternating quantity in same circuit & time."

$$\text{Average Value} = \frac{\text{Area under the Curve}}{\text{length of base of Curve}}$$

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

Form Factor :- "It is the ratio of R.M.S Val[ue to] Average Value"

Form factor is denoted by K_f

$$K_f = \frac{R.M.S}{Average} = \frac{0.707\, I_m}{0.637\, I_m}$$

$$K_f = 1.11$$

Crest Factor OR Peak factor OR Ampli[tude factor]

" Ratio of Peak Value to R.M.S Val[ue]"

denoted by K_p

$$K_p = \frac{I_m \ (\text{Peak Value})}{0.707\, I_m \ (\text{R.M.S Value})} = 1.[414]$$

$$K_p = 1.414$$

Active power "Power drawn by acti[ve] Component of Current $(I \cos\phi)$ is c[alled] Active power"

Dented by P, $P = VI\cos\phi$, $P =$ [...]

Unit is Watt OR KW

Reactive power :- "Power drawn due to reactive Component $(I \sin\phi)$ is called Reactive power"

denoted by Q, Unit KVAr

$Q = VI\sin\phi$ OR $Q = I^2 X$

Apparent power :- "Total power in the circuit is called apparent power"

denoted by S, Unit is KVA (Volt Ampere)

$$S = VI$$

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* Generation of E.M.F in A.C
OR
Prove that $e = E_m \sin\omega t$ OR $e = E_m \sin\theta$

→ Alternating E.M.F can be generated by the
1) Rotating conductor (coil) in Magnetic field
2) Conductor (coil) in Rotating Magnetic

→ Alternating quantity always change its magnitude & direction with time as per faraday's law of Electro-magnetic Induction.

$$e = -N\frac{d\phi}{dt} \quad \text{.........} \quad (1)$$

→ The Magnitude of Voltage depends on

1) No. of turns in coil.
2) Strength of Magnetic field.
3) Speed of Rotating Coil.

→ Consider Rectangular coil having N turns & rotating in anticlockwise direction with angular velocity ω (Radians/second) in Uniform magnetic field.

→ Let ϕ_m (Maximum flux) cutting by the coil when its axis concides with XX' axis take it as Reference

→ When the coil is along YY' OR coin
flux linking = 0

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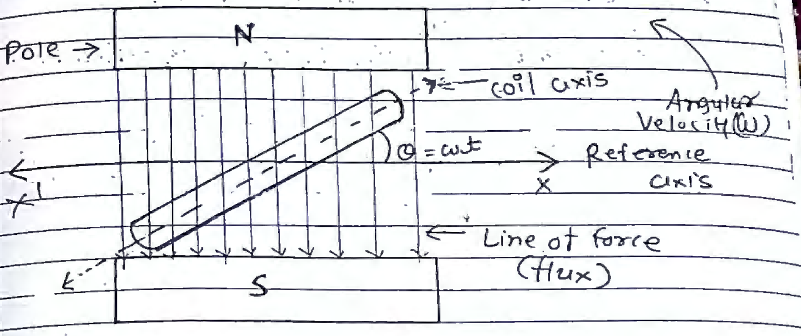


fig :- a

→ from the fig. a, coil rotates in anticlockwise direction from its reference position.

→ In this position componet of flux perpendicular to plane of coil so flux linking in the coil

$$\phi = \phi_m \cos\theta \quad \text{..........} \quad (2)$$

& Angle θ through which coil has rotated in t seconds

$$\theta = \omega t \quad \text{.........} \quad (3)$$

→ put the value (2) & (3) in equation No. 1

$$e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(\phi_m \cos\omega t)$$

$e = -N\phi_m(-\sin\omega t \cdot \omega)$

$e = N\phi_m\omega \cdot \sin\omega t$ $\quad (\because \theta = \omega t)$

$e = N\phi_m\omega\sin\theta$ ------------ (4)

$\Rightarrow$ e (Magnitude of voltage is maximum at $\theta = 90°$)

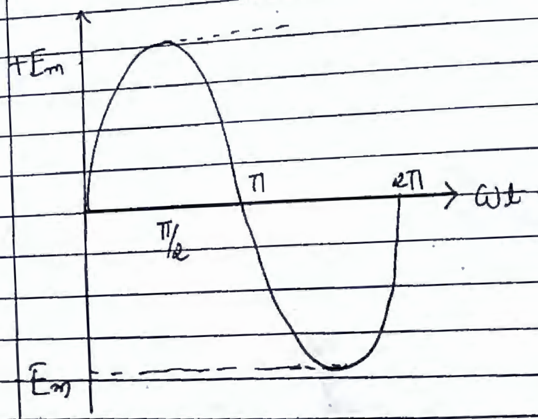
$e = N\phi_m\omega\sin(90°)$

$E_m = N\phi_m\omega$ ------------------ (5)

Put value of eq no. (5) in to (4)

$$\boxed{\begin{array}{l} e = E_m\sin\theta \\ e = E_m\sin\omega t \end{array}}$$

→ By varying angle θ from 0 to 2π we get sinusoidal E.M.F



→ at $\theta = 90 = \pi/2$ E.M.f is Maximum

→ at $\theta = 0 = 180°$ E.M.f is Zero

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★ Derive R.M.S Value of AC Voltage or
OR
Prove that $I_{r.m.s} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$
OR $V_{r.m.s} = \frac{V_m}{\sqrt{2}} = 0.707\, V_m$
Derive R.M.S Value by Analytical Method of Integration Method

Give the definition of R.M.S

→ Heat produced by an alternating current of instantaneous value i in resistor R in time dt is $i^2 R\,dt$

$$H_{a.c} = \int_0^T i^2 R\,dt$$

→ Heat produced by direct current I in same resistor R in time T

$$H_{d.c} = I^2 RT$$

→ By definition of R.M.S Value

$$H_{d.c} = H_{a.c}$$

$$I^2 RT = \int_0^T i^2 R\,dt$$

$$R I^2 T = R \int_0^T i^2\,dt$$

$$I^2 = \frac{1}{T}\int_0^T i^2\,dt$$

$$I = \sqrt{\frac{1}{T}\int_0^T i^2\,dt} \quad \text{------} \quad (1)$$

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→ We know that $i = I_m \sin\theta$ and $T = 2\pi$
put in equation (1)

$$I = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I_m^2 \sin^2\theta \, d\theta} \quad \left(\because \sin^2\theta = \frac{1-\cos 2\theta}{2}\right)$$

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

$$I = \sqrt{\frac{I_m^2}{2\pi \times 2}\int_0^{2\pi} (1-\cos 2\theta)\, d\theta}$$

$$I = \sqrt{\frac{I_m^2}{4\pi}\int_0^{2\pi} (1-\cos 2\theta)\, d\theta}$$

$$I = \sqrt{\frac{I_m^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}}$$

$$I = \sqrt{\frac{I_m^2}{4\pi}\left[\left\{2\pi - \frac{\sin 2(2\pi)}{2}\right\} - \left\{0 - \frac{\sin 2(0)}{2}\right\}\right]}$$

$$I = \sqrt{\frac{I_m^2}{4\pi}\left[\{2\pi - 0\} - \{0-0\}\right]}$$

$$I = \sqrt{\frac{I_m^2}{4\pi} \times 2\pi} = \sqrt{\frac{I_m^2}{2}}$$

$$\boxed{I_{r.m.s} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m}$$

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Q- Derive the equation of Average Value of A.C Voltage or current

(OR)

Prove that $V_{..} = \frac{2V_m}{\pi} = 0.$ V_m

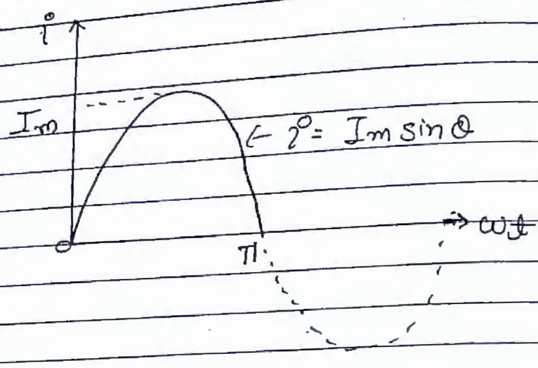
(OR)

$I_{av} = 0.637\, I_m$ or $I_{av} =$

(OR)

Derive the Average value of A.C Voltage by Analytical or Integration Method.

→ The Average Value of symmetrical ... is obtained by considering only half



Average Value = $\frac{\text{Area Under the curve}}{\text{length of base of curve}}$

$$I_{av} = \frac{\int_0^{\pi} i . d\theta}{\pi}$$

$$= \frac{1}{\pi}\int_0^{\pi} I_m \sin\theta . d\theta$$

$$= \frac{I_m}{\pi}\int_0^{\pi} \sin\theta . d\theta$$

$$= \frac{I_m}{\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$= -\frac{I_m}{\pi}\left[\cos\theta\right]_0^{\pi}$$

$$= -\frac{I_m}{\pi}\left[\{\cos(\pi) - \cos(0)\}\right]$$

$$= -\frac{I_m}{\pi}\left[-1 - 1\right]$$

$$= -\frac{I_m}{\pi}\left[-2\right]$$

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

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Q Explain purely Resistive circuit & prove that i...

OR

Prove that power in purely resistive circuit $P = VI$

I $P = V i \sin\omega t$

OR

Prove that power factor of purely resistive circuit is 1 (Unity) $\{\cos\phi = 1\}$

OR

I is inphase with voltage V.

ANS → Consider circuit having R resistance across the alternating voltage source as shown in figure 1

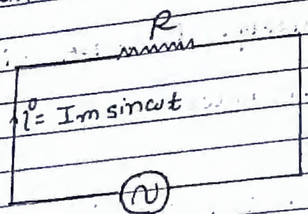

fig. 1 circuit

→ If supply voltage is $V = V_m \sin\omega t$ then apply Ohm's law

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

Now take $\omega t = \pi/2$ for i...

$$i = \frac{V_m}{R} \sin(\pi/2) \Rightarrow \left(I_m = \frac{V_m}{R} \right)$$

$$\boxed{i = I_m \sin\omega t}$$

OR $i = I_m$

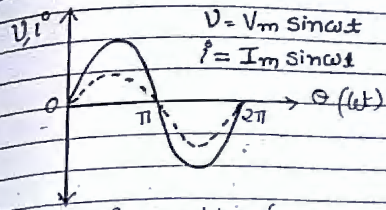

fig. 2 : Wave form

fig. 3 phasor diagram

→ Fig. 2 and fig. 3 shows wave form & phasor diagram of purely resistive circuit respectively

★ **Power in Purely Resistive circuit :-**

→ Instantaneous power

$$P = V i$$

$$P = V_m \sin\omega t \cdot I_m \sin\omega t$$

$$P = V_m I_m \sin^2\omega t$$

$(\omega t = \theta)$

$$\boxed{P = V_m I_m \sin^2\theta}$$

→ Average power

$$P = \frac{1}{2\pi} \int_0^{2\pi} p \, d\theta$$

$$= \frac{1}{2\pi} \int_0^{2\pi} V_m I_m \sin^2\theta \, d\theta$$

$$= \frac{V_m I_m}{2\pi} \int_0^{2\pi} \sin^2\theta \, d\theta$$

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

$$= \frac{V_m I_m}{2\pi \times 2} \int_0^{2\pi} (1-\cos 2\theta)\, d\theta$$

$$= \frac{V_m I_m}{4\pi} \left[\theta - \frac{\sin 2\theta}{2} \right]_0^{2\pi}$$

$$= \frac{V_m I_m}{4\pi} \left[\left\{ 2\pi - \frac{\sin 2(2\pi)}{2} \right\} - \left\{ 0 - \frac{\sin 2(0)}{2} \right\} \right]$$

$$= \frac{V_m I_m}{4\pi} \left[\left\{ 2\pi - 0 \right\} - \left\{ 0 - 0 \right\} \right]$$

$$= \frac{V_m I_m \times \cancel{2\pi}}{2\,\cancel{4\pi}}$$

$$= \frac{V_m I_m}{2}$$

$$P = \frac{V_m I_m}{2}$$

$$P = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \qquad \left(V = \frac{V_m}{\sqrt{2}},\ I = \frac{I_m}{\sqrt{2}} \right)$$

$$\boxed{P = V \cdot I \quad \text{OR} \quad P = V_{r.m.s}\, I_{r.m.s}}$$

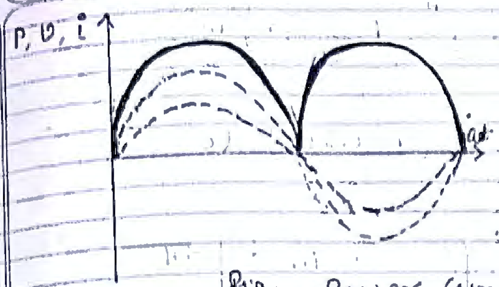

Fig. - Power Curve

Power - factor :-

Power factor is the cosine angle between voltage and current.

→ In purely resistive circuit phase angle (ϕ) between voltage and current is zero

$\phi = 0°$

$P.f = \cos \phi$

$P.f = \cos(0°) = 1$

→ Power factor of purely resistive circuit is unity (1)

→ So in purely resistive circuit current and voltage are in-phase.

Q- Explain purely Inductive circuit
OR
Prove that $i = I_m \sin(\omega t - \pi/2)$ and $\cos\phi$ ...
OR
Derive or prove that power in purely inductive circuit is zero ($P = 0$)
OR
Power factor in purely Inductive circuit is lagging and current lags behind ...

ANS

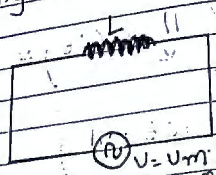

Fig: Circuit diagram

→ Voltage is applied to circuit it produce flux. Due to this
→ Self Induced E.M.F at any instant is given by

$$e = -L\frac{di}{dt}$$

→ Applied Voltage is opposite to self induced E.M.F at any instant

Applied Voltage = − self Induced E.M.F

$$V = -e$$

$$V_m \sin\omega t = -\left(-L\frac{di}{dt}\right)$$

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

$$\therefore di = \frac{1}{L} V_m \sin\omega t \cdot dt$$

Take the integration both side

$$\int di = \int \frac{1}{L} V_m \sin\omega t \cdot dt$$

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

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

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

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

→ for Maximum take $\omega t = \pi$

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

$$\left(\therefore I_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L} = \frac{V_m}{2\pi f L}\right)$$

$$\left(\because \sin\pi/2 = 1\right)$$

$$\boxed{i = I_m \sin\left(\omega t - \pi/2\right)}$$

From the above equation current i lags the voltage. power factor angle $\phi = 90$

power factor $= \cos(\phi) = \cos(90) = 0$

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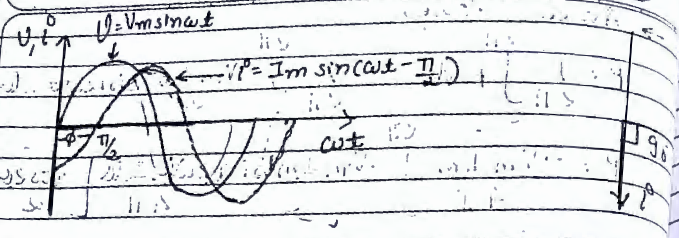


fig:2 Waveform   fig:3 phasor di...

★ Power In Purely Inductive Circuit

→ Instantaneous power

$p = v . i$

But $p = V_m \sin\omega t \, . \, I_m \sin(\omega t - \frac{\pi}{2})$

$= V_m I_m \sin\omega t . \sin(\omega t - \frac{\pi}{2})$

$= V_m I_m \sin\omega t \left[-\sin(\frac{\pi}{2} - \omega t) \right]$

$= -V_m I_m \sin\omega t \left[\sin(\frac{\pi}{2} - \omega t) \right]$

$= -V_m I_m \sin\omega t \cos\omega t$

(∵ divide & Multiply)

$= -\frac{1}{2} \times 2 V_m I_m \sin\omega t . \cos\omega t$

(∵ $\sin 2\omega t = 2 \sin\omega t . \cos\omega t$; $\omega t = \theta$)

$p = -\frac{V_m I_m}{2} \sin 2\omega t$

$p = -\frac{V_m I_m}{2} \sin 2\theta$

→ Average Power

$P = \frac{1}{2\pi} \int_0^{2\pi} p . d\theta = \frac{1}{2\pi} \int_0^{2\pi} -\frac{V_m I_m}{2} \sin 2\theta \, d\theta$

$P = -\frac{V_m I_m}{4\pi} \int_0^{2\pi} \sin 2\theta \, d\theta = -\frac{V_m I_m}{4\pi} \left[\frac{-\cos 2\theta}{2} \right]_0^{2\pi}$

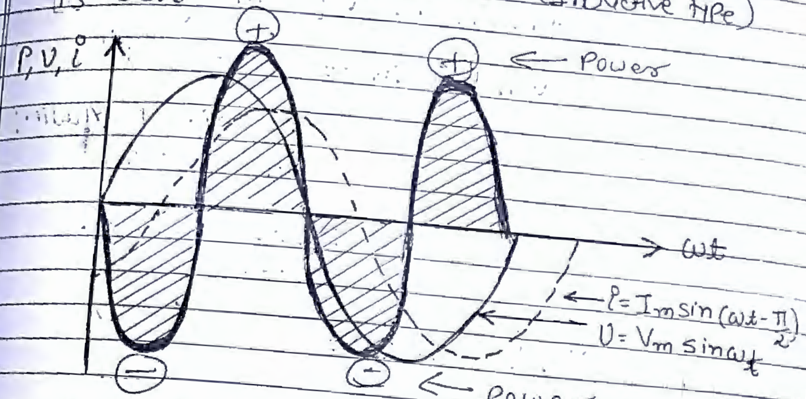
$P = \frac{V_m I_m}{4\pi} \left[\cos 2\theta \right]_0^{2\pi} = \frac{V_m I_m}{4\pi \times 2} \left[\cos 2\theta \right]_0^{2\pi}$

$P = \frac{V_m I_m}{8\pi} \left[\{\cos 2(2\pi)\} - \cos 2(0) \right]$

$P = \frac{V_m I_m}{8\pi} \left[\{1\} - \{1\} \right] = \frac{V_m I_m}{8\pi} [0]$

$\boxed{P = 0}$

→ So Power in purely circuit (Inductive type) is zero



→ Power curve is sine curve of double frequency and with opposite direction.

Q- Explain Purely capacitive circuit
OR
prove that $i = I_m \sin(\omega t + \pi/2)$ and
power factor is leading and current l...
OR
Power (P) is zero in purely capacitive circuit, P=0 prove it.

ANS

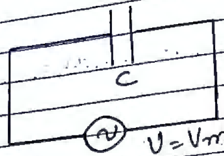


fig:- circuit diagram

→ Let the Applied voltage
$V = V_m \sin\omega t$

and $q = CV$ $\quad (V = V_m \sin\omega t)$

$q = C V_m \sin\omega t$

But $i = \frac{dq}{dt} = \frac{d}{dt}[C V_m \sin\omega t]$

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

$= C V_m (\cos\omega t \cdot \omega)$

$= \omega C V_m (\cos\omega t)$

$= \frac{V_m}{\frac{1}{\omega C}} \cos\omega t$

$i = \frac{V_m}{X_c} \cos\omega t \quad \left(X_c = \frac{1}{\omega C}\right)$

$i = \frac{V_m}{X_c} \cos\omega t = \frac{V_m}{X_c} \sin(\omega t + \pi/2)$

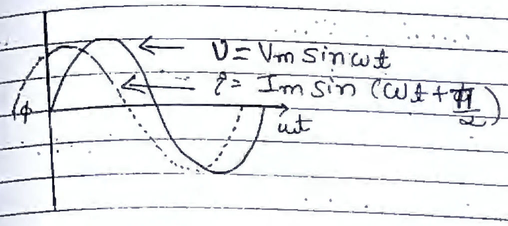
$\left(\because I_m = \frac{V_m}{X_c}\right)$

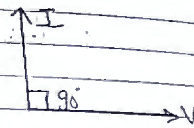
$$\boxed{i = I_m \sin(\omega t + \pi/2)}$$

→ current leads the voltage by 90°

$\phi = 90°$

power factor (p.f) = $\cos\phi \Rightarrow$ p.f = $\cos(90°)$
p.f = 0





* fig:- Waveform

* fig:- phasor dia...

* Power in Purely Inductive circuit

→ Instantaneous Power

$P = V \times i$

$= V_m \sin\omega t \cdot I_m \sin(\omega t + \frac{\pi}{2})$

$= V_m \sin\omega t \cdot I_m \cos\omega t$

Now Multiply & divide with 2

$$P = \frac{V_m I_m}{2} \cdot 2 \sin\omega t \cdot \cos\omega t$$

$(\because \omega t = \theta)$

$$P = \frac{V_m I_m}{2} \cdot 2 \sin\theta \cdot \cos\theta = \frac{V_m I_m}{2} \sin 2\theta$$

$\Rightarrow$ Average power

$$P = \frac{1}{2\pi}\int_0^{2\pi} P \cdot d\theta = \frac{1}{2\pi}\int_0^{2\pi} \frac{V_m I_m}{2} \sin 2\theta$$

$$P = \frac{V_m I_m}{2\pi \times 2}\int_0^{2\pi} \sin 2\theta \cdot d\theta$$

$$P = \frac{V_m I_m}{4\pi}\left[\frac{-\cos 2\theta}{2}\right]_0^{2\pi} = \frac{V_m I_m}{8\pi}\left[-\cos\right.$$

$$P = -\frac{V_m I_m}{8\pi}\left[\cos 2\theta\right]_0^{2\pi}$$

$$P = \frac{-V_m I_m}{8\pi}\left[\{\cos 2(2\pi)\} - \{\cos 2(0)\}\right]$$

$$P = \frac{-V_m I_m}{8\pi}\left[\{\cos(4\pi) - \cos(0)\}\right]$$

$$P = \frac{-V_m I_m}{8\pi}\left[1 - 1\right] = -\frac{V_m I_m}{8\pi}\left[0\right]$$

$$\boxed{P = 0}$$

$\rightarrow$ So power in purely capacitive circuit is

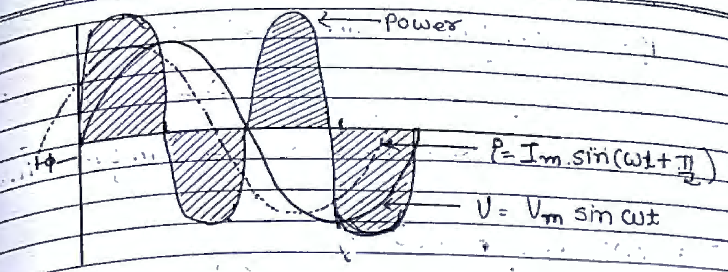
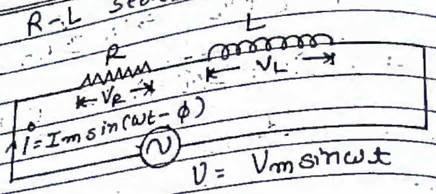


fig: Power curve

$\rightarrow$ power curve is sine curve of double frequency and with same direction.

* Explain R-L Series circuit



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

V = R.M.S Value of Applied Voltage

I = R.M.S Value of Resultant Current

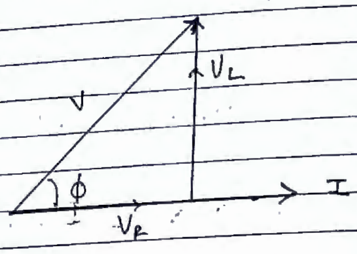
$V_R = IR$ = Voltage across Resistor R

$V_L = IX_L$ = Voltage across inductor L

→ Due to series connection current I are same

→ Current lags the voltage V_L by 90°

Current in phase with V_R by 0°



from Phasor diagram

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

$$\therefore V = \sqrt{V_R^2 + V_L^2} \Rightarrow V = \sqrt{(IR)^2 + (IX_L)^2}$$

$$\therefore V = \sqrt{I^2R^2 + I^2X_L^2} \Rightarrow V = \sqrt{I^2(R^2 + X_L^2)}$$

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

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

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

→ from the phasor diagram

$$\tan\phi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R}$$

$$\phi = \tan^{-1}\frac{X_L}{R}$$

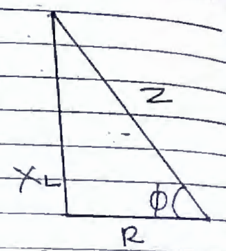
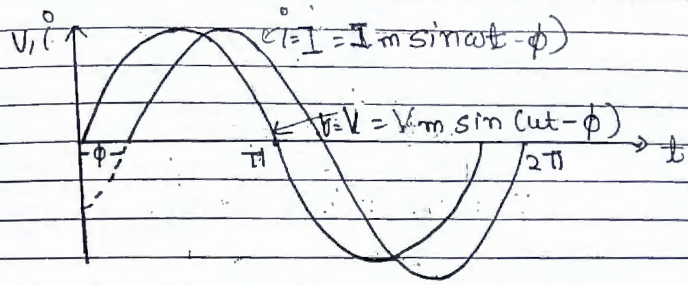


fig:- Impedance Triangle

Current & voltage Waveform



= sin
= cos

$2SS = C - C \Rightarrow 2S(A).S(B) = C(A-B) - C(\ldots$

Power in R-L series circuit

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

$P = vi$

$= V_m \sin\omega t \, I_m \sin(\omega t - \phi)$

$= V_m I_m \sin\omega t \cdot \sin(\omega t - \phi)$

$= V_m I_m \frac{2}{2} \sin\omega t \, \sin(\omega t - \phi)$

$= \frac{V_m I_m}{2} \cdot 2\sin\omega t \cdot \sin(\omega t - \phi)$

$= \frac{V_m I_m}{2}\left[\cos\{\omega t - (\omega t - \phi)\} - \cos\{\omega t + \ldots\right.$

$= \frac{V_m I_m}{2}\left[\cos\{\cancel{\omega t} - \cancel{\omega t} - \phi\} - \cos\{\omega t + \omega t - \phi\}\right]$

$= \frac{V_m I_m}{2}\left[\cos\phi - \cos(2\omega t - \phi)\right]$

$= \underbrace{\frac{V_m I_m}{2}\cos\phi}_{\text{Constant term}} - \underbrace{\frac{V_m I_m}{2}\cos(2\omega t - \phi)}_{\text{Pulsating term}}$

→ $\frac{V_m I_m}{2}\cos\phi$ which is constant term w.r. respect to time, so it will contribute the power is called as Re...

→ $\frac{V_m I_m}{2}\cos(2\omega t - \phi)$ which is pulsatin...

& it has twice frequency that of appli... voltage & current. Its Average valu... over complete cycle is zero

So Average power in one cycle

$P = \frac{V_m I_m}{2}\cos\phi = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos\phi$

$P = VI\cos\phi$

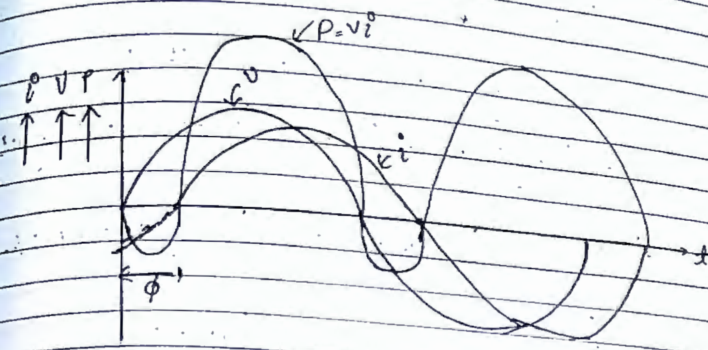
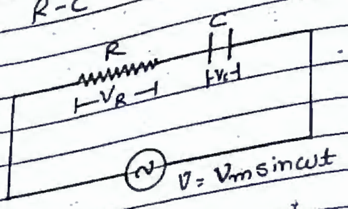


fig: Power, voltage & current wavef...

* Explain R-C circuit



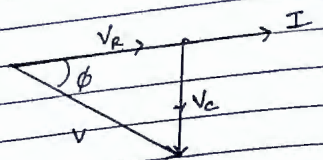
$V = V_m \sin\omega t$ - Applied Voltage

I = R.M.S value of current

$V_R = IR$ voltage across Resistor R

$V_C = IX_C$, voltage drop across C

→ R-C series circuit has current lead to voltage angle ϕ



→ The Magnitude of applied voltage

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

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

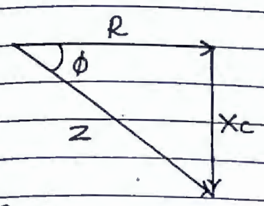
$$\frac{V}{I} = Z = \sqrt{R^2 + X_C^2}$$

→ From the Phasor Impedance triangle

$$\tan\phi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R}$$

$$\phi = \tan^{-1}\frac{X_C}{R}$$

* Impedance triangle



→ Power in R-C series circuit

$$P = Vi$$

$$= V_m \sin\omega t \,.\, I_m \sin(\omega t + \phi)$$

$$= V_m I_m \sin\omega t \,.\, \sin(\omega t + \phi)$$

$$= V_m I_m \frac{2}{2} \,.\, \sin\omega t \,.\, \sin(\omega t + \phi)$$ (∵ Multiply & divide by 2)

$$= \frac{V_m I_m}{2} \,.\, 2\sin\omega t \,.\, \sin(\omega t + \phi)$$

$$= \frac{V_m I_m}{2}\left[\cos\{\omega t - (\omega t + \phi)\} - \cos\{\omega t + (\omega t + \phi)\}\right]$$

$$= \frac{V_m I_m}{2}\left[\cos\{\cancel{\omega t} - \cancel{\omega t} - \phi\} - \cos\{\omega t + \omega t + \phi\}\right]$$

$$= \frac{V_m I_m}{2}\left[\cos\{-\phi\} - \cos\{2\omega t + \phi\}\right]$$

$$= \frac{V_m I_m}{2}\left[\cos\phi - \cos(2\omega t + \phi)\right]$$

$$P = \underbrace{\frac{V_m I_m}{2}\cos\phi}_{\text{Constant}} - \underbrace{\frac{V_m I_m}{2}\cos(2\omega t + \phi)}_{\text{Pulsating}}$$

→ Constant term $\frac{V_m I_m}{2}\cos\phi$ is real power

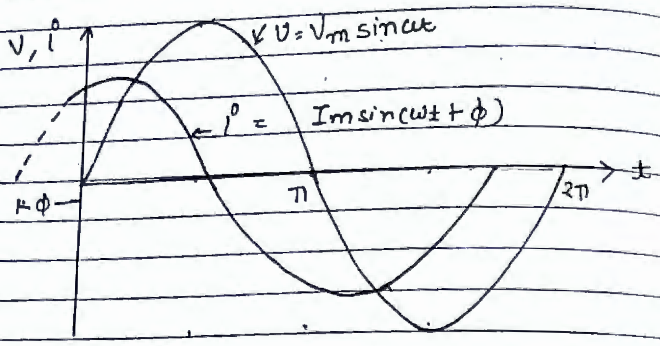
→ Pulsating part $\frac{V_m I_m}{2}\cos(2\omega t+\phi)$ which has twice frequency due to that average value over a complete cycle is zero

→ So the Average power

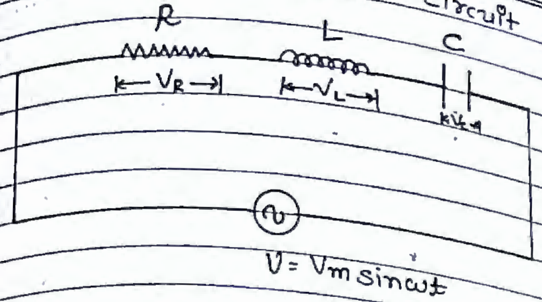
$$P = \frac{V_m I_m \cos\phi}{2}$$

$$P = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cos\phi$$

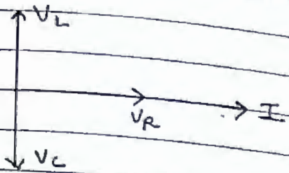
$$P = V i \cos\phi$$



* Explain R-L-C Series circuit

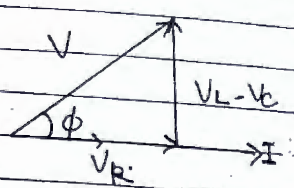


V = R.M.S Value of applied Voltage
i = R.M.S Value of resultant Current
$V_R = iR$ = Voltage drop across R
$V_L = iX_L$ = Voltage drop across L
$V_C = iX_C$ = Voltage drop across C



→ Since V_L & V_C are in opposition to each other so there are two cases
i) $V_L > V_C$ ii) $V_C > V_L$

Consider first case $\underline{V_L > V_C}$



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

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

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

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

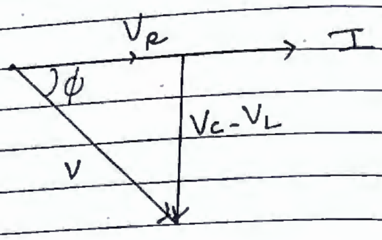
$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{IX_L - IX_C}{IR}$$

$$\tan\phi = \frac{I(X_L - X_C)}{IR} = \frac{X_L - X_C}{R}$$

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

Consider case $\underline{\underline{V_C > V_L}}$

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



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

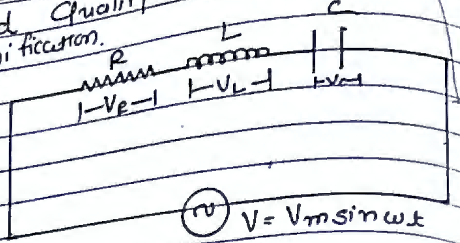
$$\frac{V}{I} = \sqrt{R^2 + (X_C - X_L)^2} = Z$$

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

$$\tan\phi = \frac{I(X_C - X_L)}{IR} = \frac{X_C - X_L}{R}$$

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

★ Explain Resonance in R-L-C Series circuit and derive equation of Resonance frequency (f_r) and Quality factor (Q) (OR) Explain Voltage Magnification.



→ Consider R-L-C series circuit connected to variable frequency sinusoidal voltage source.

→ For series R-L-C circuit impedance (Z)

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

Resonance :-
" When Inductive reactance (X_L) equal to Capacitive reactance (X_C) "

Resonance frequency (f_r) :-
" Frequency at which resonance occurs is called Resonance frequency "

⇒ So, at Resonance, $X_L = X_C$
$X_L - X_C = 0$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (0)^2} = \sqrt{R^2}$$

$$\boxed{Z = R}$$

→ So at Resonance condition impedance of circuit becomes minimum.

→ At Resonance condition, Power factor is unity

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

→ For Resonant frequency

$$X_L = X_C$$

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

$$2\pi f L = \frac{1}{2\pi f C}$$

$$4\pi^2 f^2 = \frac{1}{LC}$$

$$f^2 = \frac{1}{4\pi^2 LC}$$

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

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

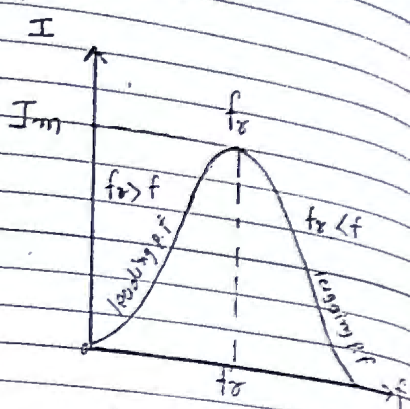


fig: Resonance frequency

→ Q - Factor :-

" It is measure of voltage magnification at resonance in R-L-C Series circuit "

Voltage magnification = $\frac{\text{Voltage applied across C or L}}{\text{Applied Voltage}}$

$$Q\text{-factor} = \frac{V_L}{V} \quad OR \quad \frac{V_C}{V}$$

$$= \frac{I_m X_L}{I_m \cdot Z} \quad OR \quad \frac{I_m \cdot X_C}{I_m \cdot Z}$$

$$= \frac{X_L}{Z} \quad OR \quad \frac{X_C}{Z}$$

($\because$ $Z = R$ at Resonance)

$$= \frac{X_L}{R} \quad OR \quad \frac{X_C}{R}$$

$$= \frac{\omega_r L}{R} \quad OR \quad \frac{1}{\omega_r RC}$$

$$= \frac{2\pi f_r L}{R} \quad OR \quad \frac{1}{2\pi f_r RC}$$

($\because$ put $f_r = \frac{1}{2\pi\sqrt{LC}}$)

$$= \frac{2\pi \times 1 \times L}{2\pi\sqrt{LC}\, R} \quad OR \quad \frac{1}{\frac{2\pi 1}{2\pi\sqrt{LC}} RC}$$

$$= \frac{1}{R}\sqrt{\frac{L}{C}} \quad OR \quad \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$\boxed{Q\text{-Factor} = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

→ Q-factor is also defined as Reciprocal of power factor

$$Q = \frac{1}{\cos\phi} = \frac{1}{R/Z} = \frac{Z}{R}$$

→ Q-factor also known as "Figure of Merit"

$$Q = 2\pi \times \frac{\text{Maximum Energy Stored}}{\text{Energy dissipated per cycle}}$$

→ Q-factor for Coil (L)

$$Q = \frac{X_L}{R} = \frac{\omega L}{R}$$

→ Q factor for Capacitor (C)

$$Q = \frac{X_C}{R} = \frac{1}{\omega RC}$$

Q- Explain Resonance in parallel R-L-C circuit and Q-factor

(OR)

Inductive coil L and Resistance R is connected in parallel with capacitor C then Derive Expression for Resonant frequency f_r and Q-factor (OR) Explain Current Magnification

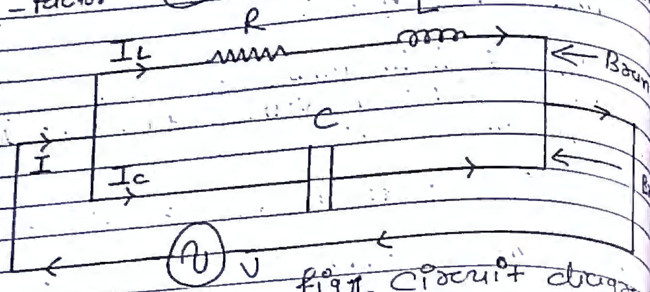


fig I- Circuit diagram

→ Resonance occur in the parallel circuit when $X_L = X_C$ and power factor is U

→ In Branch-1 R-L Series circuit so the (I_L) current is lags the Voltage by ϕ

→ In Branch-2 Capacitor is only connected current (I_C) is leads the Voltage by

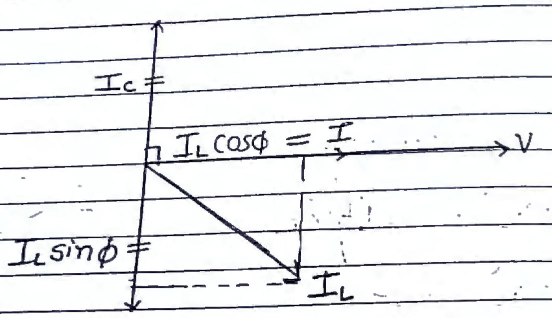


fig 2- Phasor diagram

→ From this phasor diagram I_L has two components

1) $I_L \cos\phi$ on x-axis
2) $I_L \sin\phi$ on y-axis

→ From the phasor diagram

$I_C = I_L \sin\phi$

and $I_L \cos\phi = I$

→ $I_L \cos\phi$ is in phase with Voltage so the angle between Voltage & Current ($I_L \cos\phi$) becomes zero

→ $\phi = 0°$ ⇒ Power factor $= \cos\phi$ ⇒ $\cos 0° = 1$

→ So At Resonance

$I_C = I_L \sin\phi$ ------- (1)

→ $I_L = \frac{V}{Z_L}$ and $\sin\phi = \frac{X_L}{Z_L}$

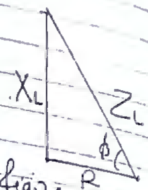


fig 3:- Impedance diagram

Put this Value in equation (1)

$I_C = \frac{V}{Z_L} \cdot \frac{X_L}{Z_L}$ $\left(\because I_C = \frac{V}{X_C} \right)$

$\frac{V}{X_C} = \frac{V \cdot X_L}{Z_L^2}$

$\therefore Z_L^2 = X_L \cdot X_C$

$\therefore R^2 + X_L^2 = \omega L \cdot \frac{1}{\omega C}$ $\left(\because X_L = \omega L, \; X_C = \frac{1}{\omega C} \right)$

→ $R^2 + X_L^2 = \frac{L}{C}$

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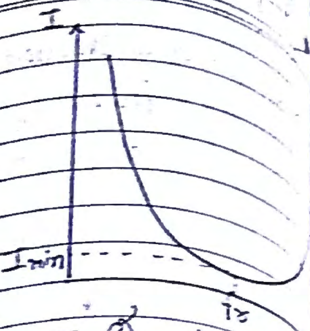

$$\therefore X_L^2 = \frac{L}{C} - R^2$$

$$\therefore (2\pi f_r L)^2 = \frac{L}{C} - R^2$$

$$\therefore (2\pi f_r)^2 L^2 = \frac{L}{C} - R^2$$

$$\therefore (2\pi f_r)^2 = \frac{\cancel{L}}{C}\cdot\frac{1}{\cancel{L^2}} - \frac{R^2}{L^2}$$

$$\therefore (2\pi f_r)^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

$$\therefore 2\pi f_r = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$\therefore f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$\boxed{f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$$

If Resistance negligible So that $\frac{R^2}{L^2}$ ... then $f_r = \frac{1}{2\pi ...}$

→ **Q-factor**

→ Q-factor in parallel circuit is Current Magnification at Resonance.

→ We can derive the Q-factor for the parallel circuit as below

Current Magnification (Q-factor) $= \frac{I_C}{I}$

$$= \frac{I_L \sin\phi}{I_L \cos\phi}$$

$$= \tan\phi$$

$$= \frac{X_L}{R} \quad (\because \text{from the fig-5})$$

$$= \frac{2\pi f_r L}{R}$$

But $f_r = \frac{1}{2\pi\sqrt{LC}}$

So $Q = \dfrac{2\pi \cdot \frac{1}{2\pi\sqrt{LC}} \cdot L}{R}$

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

$$\boxed{\text{Q-factor} = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

Q :- Comparision (OR) Difference between Series Resonance and parallel Resonance

ANS

Description	Series circuit	parallel
→ Resonant frequency (f_r)	$f_r = \frac{1}{2\pi\sqrt{LC}}$	$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$
→ Nature of Circuit	Resistive	Resistive
→ Magnification	Voltage	Current
→ Impedance at Resonance	Minimum ($Z = R$)	Maximum
→ Current at Resonance	Maximum $\left(I = \frac{V}{R}\right)$	Minimum
→ Power factor	Unity (1)	Unity (1)
→ Effective Impedance at Resonance	$Z_{eff} = R$	$Z_{eff} = \frac{L}{RC}$
→ Q-factor	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$
→ Half power frequency	$f_r = \sqrt{f_1 f_2}$	$f_r = \sqrt{f_1 f_2}$
→ Type of Circuit	Accepter	Rejecter
→ Bandwidth	$B.W = f_r/Q$	$B.W = f_r/Q$
→ $f > f_r$	Circuit is inductive	Circuit is Capa...
→ $f < f_r$	Circuit is Capacitive	Circuit is In...
→ Use & Application	Radio, Tunning circuit	Impedance m... filter

Explain Graphical Representation of R-L-C series circuit Resonance

(OR)

Variation of frequency with R, X_L, X_C, Z, I & power factor ($\cos\phi$)

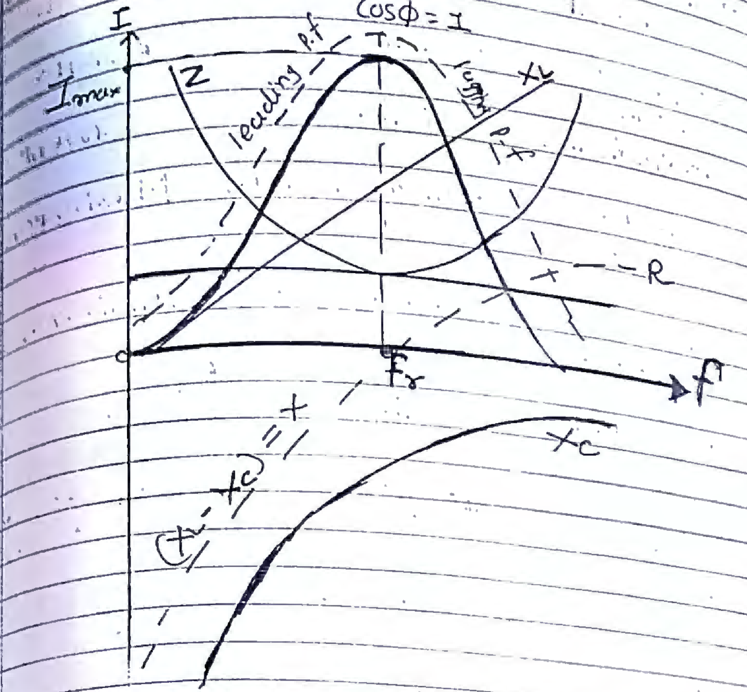

fig :- Graphical Representation of R-L-C Series Resonance

Resistance :-

→ It is independent of frequency so it is represented by straight line

Inductive Reactance (X_L) :-

→ Resistance offered by inductance is called inductive Reactance

$X_L = 2\pi f L$ ⟹ $X_L \propto f$

→ X_L is directly proportional to frequency
→ So increase in frequency causes increase in X_L
→ graph is straight line passing through origin

Capacitive Reactance (X_C) :-

→ Resistance offered by capacitance is called capacitive Reactance.

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

→ Capacitive reactance is inversly proportional to frequency, increase frequency decrease X_C
→ So the graph is rectangular hyperbola

Net Reactance (X) :-

→ Net Reactance $X = X_L - X_C$ OR $X = X_C - X_L$

→ X is negative for all frequency below Resonance + positive for greater than Resonance frequency

Impedance (Z) :-

→ Resistance offered by circuit is called Impedance

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

→ When $X_L >>> X_C$ so Net reactance is inductive, circuit Impedance is high above Resonant frequency.
→ when $X_C >>> X_L$ so Net Reactance is capacitive, circuit impedance is also high below Resonant frequency

Current (I) :-

$I = V/Z$

→ If the impedance is high current is low but impedance is low, current is high at fr (Resonance frequency)

Power factor ($\cos\phi$) :-

→ at Resonance frequency (fr), Power factor is unity
→ $f < f_r$ then power factor is leading
→ $f > f_r$ then power factor is lagging.

Unit

Important Formula

* Angular velocity $(\omega) = 2\pi f$ — rad/s
* frequency $(f) = \dfrac{1}{\text{Time Period }(T)}$ — Hz or α
* Inductive Reactance $(X_L) = 2\pi f L$
  $X_L = \omega L$
  where L = inductance of coil
  $\omega = 2\pi f$
* Capacitive Reactance $(X_C) = \dfrac{1}{2\pi f C} = \dfrac{1}{\omega C}$
  where C = Capacitance
* Net Reactance $(X) = X_L - X_C$ or $X_C - X_L$
* Voltage drop across Resistance $(V_R) = IR$
* Voltage across Inductor (coil) $(V_L) = IX_L$
* Voltage across Capacitor $(V_C) = IX_C$
* Impedance $(Z) = \sqrt{R^2 + (X_L - X_C)^2}$
* supply Voltage $(V) = I.Z$
  = Total current × Impedance
  or
  $V = \sqrt{V_R^2 + (V_L - V_C)^2}$
* Power factor $(\cos\phi) = \dfrac{\text{Resistance}}{\text{Impedance}}$
  $\cos\phi = \dfrac{\text{Active Power}}{\text{Apparent Power}}$

* Phase angle (ϕ) or Power factor angle $= \tan^{-1}\left(\dfrac{X_L - X_C}{R}\right)$ if $(X_L > X_C)$
  $= \tan^{-1}\left(\dfrac{X_C - X_L}{R}\right)$ if $(X_C > X_L)$
* Active power $(P) = VI\cos\phi$.
  $= I^2R$
  Watt (Watt) kW
* Reactive power $(Q) = VI\sin\phi$
  $= I^2X_L$ or I^2X_C — VAr (kVAr)
* Apparent power (S)
  $(S) = VI$
  $= I^2Z$
  VA (kVA)
* Total current $(I) = \dfrac{V}{Z}$
  $I = \sqrt{I_R^2 + (I_L - I_C)^2}$ Amp
* $Z_L = R + j\omega L$
  $= R + jX_L$
* $Z_C = R - jX_C$
  $= R - \dfrac{j}{\omega C}$
* Resonance condition $X_L = X_C$
  $\omega L = \dfrac{1}{\omega C}$

* Resonance frequency $(f_r) = \frac{1}{2\pi\sqrt{LC}}$ for series

$= \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

* Q-Factor (Quality Factor)

$$Q\text{-Factor} = \frac{\omega_r L}{R} = \frac{2\pi f_r L}{R} \quad (OR)$$

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

$$= \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$Q = \frac{1}{\omega_r C R}$$

where f_r = resonance frequency

* Bandwidth $BW = \Delta f$
$= f_2 - f_1$

$$B.W = \frac{f_r}{Q\text{-factor}}$$

$(\therefore B.W = f_2 - f_1)$

$$f_2 - f_1 = \frac{f_r}{Q\text{-factor}} \qquad \Delta F = \frac{f_r}{Q\text{-factor}}$$

Where f_1 = lower frequency
f_2 = higher frequency

At half power frequency

$$f_1 = f_r - \frac{B.W}{2}$$

$$f_2 = f_r + \frac{B.W}{2}$$

Admittance $(Y) = \frac{1}{Z} = \frac{1}{\text{Impedence}}$ — $\mho$ or Ω^{-1} or siemen

$$Y_L = G - jB_L$$

where Y_L = Inductive Admittance
G = Conductence
B_L = Suceptence of Inductor

* $Y_C = G + jB_C$

Y_C = Capacitive Admittance
G = Conductence
B_C = Capacitive Suceptence

* $G = \frac{R}{R^2 + X_L^2}$ for Inductence (or) $= \frac{R}{Z^2}$

$= \frac{R}{R^2 + X_C^2}$ for Capacitence (or) $\frac{R}{Z^2}$

* $B_L = \frac{X_L}{R^2 + X_L^2}$ OR $\frac{X}{Z^2}$

* $B_C = \frac{X_C}{R^2 + X_C^2}$ OR X/Z^2

* $Y = \sqrt{G^2 + (-B_L)^2}$ OR $= \sqrt{G^2 + B_C^2}$

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* Power Factor $\cos\phi = \frac{G}{Y}$

* Power factor angle $\phi = \tan^{-1}\left(\frac{-B_L}{G}\right)$

OR

$\tan^{-1}\left(\frac{B_C}{G}\right)$

* $B_L = Y\sin\phi$
* $B_C = Y\sin\phi$

* $\frac{1}{Z_{eq}} = \frac{1}{Z_1} + \frac{1}{Z_2}$ $\Rightarrow Y = Y_1 + Y_2$ $\Rightarrow Y = \frac{1}{Y_1} + \frac{1}{Y_2}$

* Current $I = VY$
* Admittance $Y = \frac{I}{V}$

Three alternating currents are expressed

$i_1 = 20\sin\omega t$
$i_2 = 30\sin(\omega t + \pi/4)$
$i_3 = 40\cos(\omega t - \pi/6)$

are flowing in three branches of parallel circuit fed from single phase a.c supply. Find Resultant Current, R.M.S Value

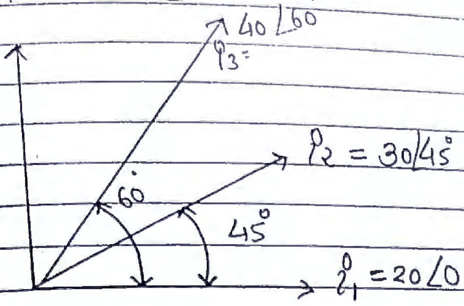
$i_1 = 20\sin\omega t = 20\sin(0^\circ)$
$i_2 = 30\sin(\omega t + \pi/4) = 30\sin(45^\circ)$
$i_3 = 40\cos(\omega t - \pi/6) = 40\cos(-30^\circ)$

$i_3 = 40\sin(90 + (-30^\circ)) = 40\sin(60^\circ)$

$\bar{i}_1 = 20\angle 0^\circ$
$\bar{i}_2 = 30\angle 45^\circ$
$\bar{i}_3 = 40\angle 60^\circ$

For the parallel circuit

$i_r = \bar{i}_1 + \bar{i}_2 + \bar{i}_3$



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→ The sum of horizontal components (Σx)

$I_x = \Sigma x = 20\cos(0) + 30\cos(45) + 40\cos(60)$

$= 20 + 21.21 + 20$

$\boxed{\Sigma x = 61.21}$ Amp

→ The sum of Vertical Components (Σy)

$I_y = \Sigma y = 20\sin(0) + 30\sin(45) + 40\sin(60)$

$= 0 + 21.21 + 34.64$

$\boxed{I_y = \Sigma y = 55.85 \text{ Amp}}$

• Magnitude of Resultant Current (I_m)

$I_m = \sqrt{(\Sigma x)^2 + (\Sigma y)^2} = \sqrt{(I_x)^2 + (I_y)^2}$

$= \sqrt{(61.21)^2 + (55.85)^2}$

$\boxed{I_m = 82.86}$

• Phase angle $\phi = \tan^{-1} \frac{\Sigma y}{\Sigma x}$

$= \tan^{-1} \frac{55.85}{61.21}$

$\boxed{\phi = 42.37^0}$

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• Resultant Current

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

$\boxed{i = 82.86 \sin(\omega t + 42.37^\circ)}$

• $I_{r.m.s} = 0.707 I_m$

$= 0.707 \times 82.86$

$= 58.58$ Amp

$\boxed{I_{r.m.s} = 58.58 \text{ A}}$

Note

4 step

All angle must be in sin

1) Σx (cos compo)

2) Σy (sin compo)

3) $I_m = \sqrt{\Sigma x^2 + \Sigma y^2}$

4) $\phi = \tan^{-1} \frac{\Sigma y}{\Sigma x}$

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

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

Q An alternating Current has r.m.s Value 30 A. and frequency is 50 cycle/second

Calculate

i) Angular Velocity (ω)
ii) Peak (Maximum) Value + Average Value
iii) Write the instantaneous equation of
iv) Time period (T) + Time at which Maximum
v) Calculate Instantaneous Value of Current at 0.0025 seconds after passing the positive maximum Value
vi) To find current at 0.002 seconds after it reaches zero and thereafter decreases.

vii) At what time current passed through positive maximum to be 21.2 Amp

viii) Peak factor & ~~Form~~ Form factor

$f = 50$ cycle/second $\quad I_{r.m.s} = 30$ A

ANS i) Angular Velocity (ω)

$$\omega = 2\pi f = 2\times 3.14 \times 50 = 314 \text{ rad}$$

ii) Maximum (Peak) Value I_m : AMPLITUDE

$$I_{r.m.s} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$$

$$30 = 0.707\, I_m$$

$$I_m = \frac{30}{0.707} = 42.43 \text{ Amp}$$

Average Value I_{av}

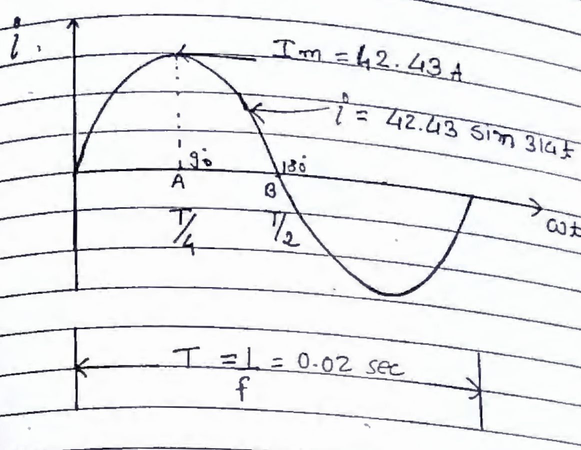
$$I_{av} = 0.637\, I_m$$
$$= 0.637 \times 42.43$$
$$I_{av} = 27.02 \text{ Amp}$$

iii) Instantaneous Equation of Current

$$i = I_m \sin\omega t$$
$$i = 42.43 \sin 314 t$$

iv) Time period (T)

$$T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec}$$



→ Maximum positive value occur at T/4 time

$$t = \frac{T}{4} = \frac{0.02}{4} = 5\times 10^{-3} \text{ sec}$$

Q An alternating current has r.m.s value 30 A. and frequency is 50 cycle/second.

Calculate

i) Angular Velocity (ω)
ii) Peak (Maximum) Value & Average Value
iii) Write the instantaneous equation of current
iv) Time period (T) & Time at which Maximum ...
v) Calculate Instantaneous Value of current at 0.0025 seconds after passing the positive maximum Value
vi) To find current at 0.002 seconds after it reaches zero and thereafter decreases.
vii) At what time current passed through positive maximum to be 21.2 Amp
viii) Peak factor & Form factor

$f = 50$ cycle/second, $I_{r.m.s} = 30\,A$

i) Angular Velocity (ω)

$$\omega = 2\pi f = 2 \times 3.14 \times 50 = 314 \text{ rad}$$

ii) Maximum (Peak) Value I_m : AMPLITUDE

$$I_{r.m.s} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$$

$$30 = 0.707 I_m$$

$$I_m = \frac{30}{0.707} = 42.43 \text{ Amp}$$

Average Value I_{av}

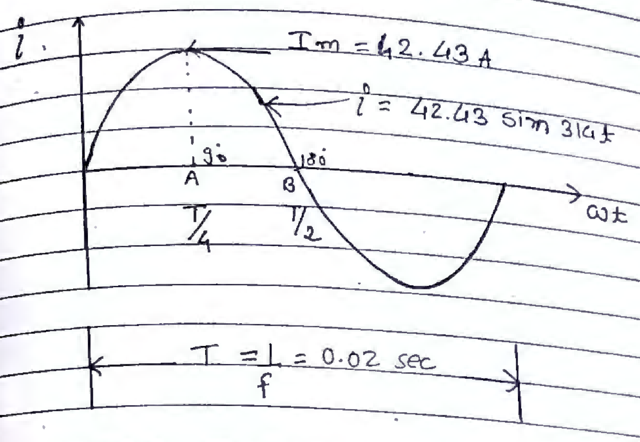
$$I_{av} = 0.637 I_m$$
$$= 0.637 \times 42.43$$
$$I_{av} = 27.02 \text{ Amp}$$

iii) Instantaneous equation of current

$$i = I_m \sin \omega t$$
$$i = 42.43 \sin 314 t$$

iv) Time period (T)

$$T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec}$$



→ Maximum positive value occurs at T/4 time

$$t = \frac{T}{4} = \frac{0.02}{4} = 5 \times 10^{-3} \text{ sec}$$

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v) Find value of i at 0.0025 second. Positive Maximum Value

→ Positive Maximum value occurs at point at T/4 time.

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

$\therefore i = 42.43 \times \cos(314 \times 0.0025) = 42.43 \cos$
$\therefore i = 42.43 \cos(44.97°)$

$(\because 0.785 \text{ Rad} = 44.97$

$i = 30.01$ Amp

vi) To find value of current at 0.002 second after it reaches zero and decreases

→ Current is zero at point B

$i = I_m \sin(\omega t + 180)$
$i = -I_m \sin \omega t$

$i = -42.43 \times \sin(314 \times 0.002)$

$i = -42.43 \times \sin(0.628)$ $(0.628$

$i = -42.43 \times \sin(35.98°)$

$i = 24.92$ Amp

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vii) At what time current passed through maximum positive value to be 21.2 Amp

→ It means find the time after the point A (Maximum) where current is 21.2 Amp

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

$21.2 = 42.43 \cos(314 \times t)$

$\frac{21.2}{42.43} = \cos(314 t)$

$0.5 = \cos(314 t)$

$\cos^{-1} 0.5 = 314 t$

$1.04 = 314 t$

$t = \frac{1.04}{314} = 3.33 \times 10^{-3}$ sec

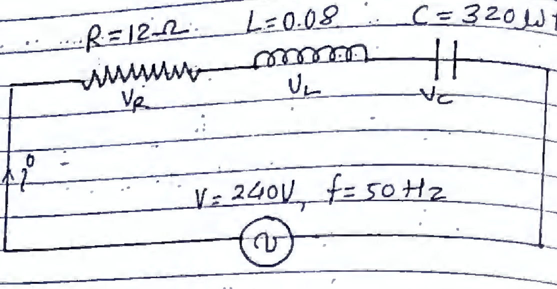
viii)

Peak Factor $(K_P) = \frac{I_m}{I_{r.m.s}} = \frac{42.43}{30}$
OR
Crest Factor
OR
Amplitude factor $K_P = 1.414$

Form Factor (K_f) $\frac{I_{r.m.s}}{I_{av}} = \frac{30}{27.02} = 1.11$

* A circuit consists of resistance of 12 Ω, Capacitance of 320 μF, Inductance of 0.08 H all are connected in series with the circuit with supply voltage of 240 V, 50 Hz to the circuit. Calculate

1) Inductive Reactance, X_L
2) Capacitive Reactance, X_C
3) Impedance, Z
4) Current, I
5) Frequency at which current is maximum
6) Voltage drop (across) R, L, C (V_R, V_L, ...)
7) Q-factor and power factor ($\cos\phi$) ...
8) Band width (B.W) (OR) Δf (OR) $f_2 - f_1$
9) Lower half frequency (f_1)
10) Upper half frequency (f_2)
11) Active power (P)
12) Reactive power (Q)
13) Apparent power (S)



$R = 12\ \Omega$
$L = 0.08\,H$
$C = 320\ \mu F = 320 \times 10^{-6} F$
$V = 240\ V$
$f = 50\ Hz$

1) Inductive Reactance (X_L)

$X_L = 2\pi f L$
$= 2 \times 3.14 \times 50 \times 0.08$
$\boxed{X_L = 25.12\ \Omega}$

2) Capacitive Reactance (X_C)

$X_C = 2\pi f C = 2 \times 3.14 \times 50 \times 320 \times 10^{-6}$
$\boxed{X_C = 9.952\ \Omega}$

3) Impedance (Z)

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(12)^2 + (25.12 - 9.952)^2}$
$\boxed{Z = 19.34\ \Omega}$

4) Current (I)

$I = \frac{V}{Z} = \frac{240}{19.34}$
$\boxed{I = 12.41\ A}$

5) Frequency at which current is maximum is known as Resonance frequency (f_r)

$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14 \sqrt{320 \times 10^{-6} \times 0.08}}$
$\boxed{f_r = 31.47\ Hz}$

Voltage across R (V_R) $= I \times R = 12.41 \times 12$
$\boxed{V_R = 149\ V}$

Voltage across L, (V_L) $= I \times X_L = 12.41 \times 25.12$
$\boxed{V_L = 311.73\ V}$

Voltage across C, (V_C) $= I \times X_C = 12.41 \times 9.952$
$\boxed{V_C = 123.50\ V}$

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7) Q-factor $= \frac{\omega_r L}{R} = \frac{2\pi f_r L}{R} = \frac{2 \times 3.14 \times 31.47}{12}$

$\boxed{Q\text{-factor} = 1.31}$

Note: $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ OR $Q = \frac{1}{2\pi f_r C R}$

8) Power factor $\cos\phi = R/Z$

$\cos\phi = \frac{12}{19.34}$

$\boxed{\cos\phi = 0.62}$

9) Phase angle OR Power factor angle (ϕ)

$\phi = \cos^{-1} 0.62$

$\boxed{\phi = 51.68°}$

) Bandwidth (B.W) OR Δf OR $f_2 - f_1$

$B.W = \frac{f_r}{Q\text{-factor}} = \frac{31.47}{1.31} =$

OR

$f_2 - f_1 = \frac{f_r}{Q\text{-factor}}$ where f_1 = lower freq

OR f_2 = Upper freq

$\Delta f = \frac{f_r}{Q\text{-factor}}$

$\boxed{B.W = 24.02 \text{ Hz}}$

) lower half frequency (f_1)

$f_1 = f_r - \frac{B.W}{2} = 31.47 - \frac{24.02}{2}$

$\boxed{f_1 = 19.46 \text{ Hz}}$

10) Upper half frequency (f_2)

$f_2 = f_r + \frac{B.W}{2} = 31.47 + \frac{24.02}{2}$

$\boxed{f_2 = 43.48 \text{ Hz}}$

) Active power (P)

$P = VI\cos\phi = 240 \times 12.41 \times 0.62$

$\boxed{P = 1846 \text{ Watt} \quad \text{OR} \quad P = 1.846 \text{ kW}}$

) Reactive power (Q)

$Q = VI\sin\phi = 240 \times 12.41 \times \sin(51.68°)$

$\boxed{Q = 2336 \text{ VAr} \quad \text{OR} \quad 2.336 \text{ kVAr}}$

$\cos\phi = 0.62$
$\phi = \cos^{-1} 0.62$
$\phi = 51.68°$

) Apparent Power (S)

$S = V \cdot I$

$= 240 \times 12.41$

$\boxed{S = 2978 \text{ VA} \quad \text{OR} \quad S = 2.978 \text{ kVA}}$

Note:

$\angle \Rightarrow$ Polar form

$j \Rightarrow$ Rectangular Form

Multiplication & Division possible only in POLAR — Angle (Addition) — Angle (Subtraction)

Subtraction & Addition possible only in RECTANGULAR

→ Two impedances $Z_1 = 10 - j6\,\Omega$ & $Z_2 = 8 + j4$ are connected in parallel across (230+j0). Calculate

i) Current in Each branch

ii) Current I & Equivalent Impedance

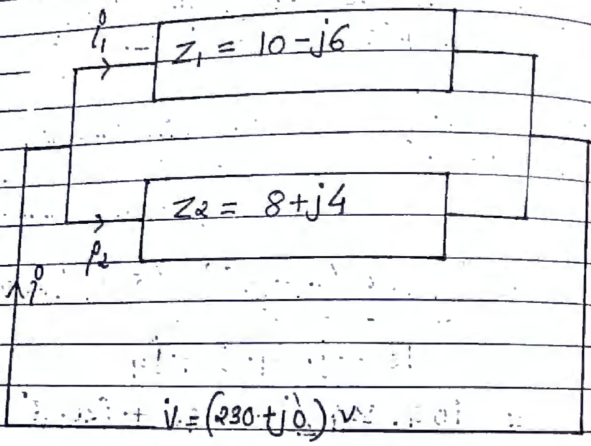
iii) Power factor $\cos\phi$

iv) Admittance Y_{eq} & Admittance of Each

v) Conductance G of Each branch

vi) Suceptence B of Each branch

vii) Power consumed by circuit (Active power) & Power consumed in Each branch



i) Current in Each branch

$$I_1 = \frac{V}{Z_1} = \frac{230 + j0}{10 - j6}$$

Note: Division possible only in Polar Form. Convert in to Polar

$$= \frac{230\angle 0}{11.66\angle -30.96^\circ}$$

Note: in Division Angle (Subtraction)

$$I_1 = 19.72\angle 0 - (-30.96)$$

$$I_1 = 19.72\angle 30.96^\circ$$

$$I_2 = \frac{V}{Z_2} = \frac{230 + j0}{8 + j4} = \frac{230\angle 0}{8.94\angle 26.56}$$

$$I_2 = 25.72\angle 0 - (26.56)$$

$$I_2 = 25.72\angle -26.56^\circ$$

ii) Equivalent Impedance Z_{eq}

$$Z_{eq} = \frac{Z_1 \cdot Z_2}{Z_1 + Z_2} = \frac{(10 - j6)(8 + j4)}{(10 - j6) + (8 + j4)}$$

$Z_1 = 11.66\angle -30.96^\circ$

$Z_2 = 8.94\angle 26.56^\circ$

Note: Multiplication possible in Polar and Angle (Addition)

$$= \frac{(11.66\angle -30.96^\circ)(8.94\angle 26.56^\circ)}{10 - j6 + 8 + j4}$$

$$= \frac{104.24\angle -30.96^\circ + (26.56^\circ)}{18 - j2}$$

$= \frac{104.24\angle -4.4^\circ}{18 - j2} = \frac{104\angle -4.4^\circ}{18.11\angle 6.34^\circ}$

$= 5.75\angle -4.4 - (6.34^\circ)$

$\frac{Z_1 Z_2}{Z_1 + Z_2} = Z_{eq} = 5.75\angle -10.74$

ii) Current $I = \frac{V}{Z_{eq}} = \frac{230\angle 0^\circ}{5.75\angle -10.74^\circ}$

$I = 40\angle 0^\circ - (-10.74^\circ)$

$I = 40\angle 10.74^\circ$

iii) Power Factor $\cos\phi$

"P.f is cosine angle between Voltage & (curr..."

Here $I = 40\angle \underbrace{10.74^\circ}$

cosine angle (if Angle is positi... then leading p...

$\phi = 10.74^\circ$

Power factor (P.f) = $\cos\phi$

$P.f = \cos(10.74^\circ)$

power factor $= 0.9825$ (lead)

v) Admittance in Each branch

$Y_1 = \frac{1}{Z_1} = \frac{1}{\frac{V}{I_1}} = \frac{I_1}{V}$

Note: Another method

$Y_1 = \frac{1}{Z_1}$

$= \frac{1\angle 0}{11.66\angle -30.96}$

$Y_1 = 0.085\angle 30.96$

$Y_1 = \frac{I_1}{V}$

$= \frac{19.72\angle 30.96^\circ}{230\angle 0} = 0.085\angle 30.96 - (0)$

$Y_1 = 0.085\angle 30.96$ OR $Y_1 = (0.072 + j0.043)$

$Y_2 = \frac{1}{Z_2} = \frac{1}{8.94\angle 26.56} = \frac{1\angle 0^\circ}{8.94\angle 26.56}$

$Y_2 = 0.11\angle 0 - (26.56^\circ)$

$Y_2 = 0.11\angle -26.56^\circ$ OR $Y_2 = (0.098 - j0.049)$

Admittance $Y_{eq} = Y_1 + Y_2$

OR

$= \frac{1}{Z_{eq}}$

$Y = Y_1 + Y_2 = (0.072 + j0.043) + (0.0989 - j0.049)$

$= 0.072 + j0.043 + 0.098 - j0.049$

$Y_{eq} = (0.171 - j0.006)$ OR $0.171\angle -2.83^\circ$

(V) Conductance G in Each branch

$G_1 = \frac{R_1}{Z_1^2}$

$\left(\because Z_1 = R_1 \pm jX_1 \quad \therefore Z_1 = 10 - j6 \Rightarrow R_1 = 10 \Rightarrow X_1 = -6\right)$

$G = \frac{R}{Z^2}$

$= \frac{10}{11.66}$

$\left(Z_1 = \sqrt{R_1^2 + X_1^2}\right)$

$Z_1 = 11.66$

$G_1 = 0.0769$ ℧ (OR) siemens

Note
(If you have Z_1 in Polar form then its Magnitude (e.g. $Z_1 = 11.66$, $Z_2 = 8.94$))

$G_2 = \frac{R_2}{Z_2^2}$ $\left(\because Z_2 = 8 + j4\right)$

$= \frac{10}{8.94}$

$G_2 = 1.11$ ℧ (OR) Siemens

(VI) Susceptance B in Each Branch

$Z_1 = R_1 + X_1$

$B_1 = \frac{X_1}{Z_1^2}$ $\quad \because Z_1 = 10 - j6$, $R_1 = 10$, $X_1 = -6$

$= \frac{X}{Z^2}$

$B_1 = \frac{-6}{11.66}$

$Z_2 = R_2 \pm jX_2 = 8 + j4$

$B_1 = -0.514$

$R_2 = 8$, $X_2 = 4$

$B_2 = \frac{X_2}{Z_2^2} = \frac{4}{8.94} = 0.44$

Power Consumed by circuit OR Active power

$P = VI\cos\phi$

$= 230 \times 40 \times 0.98$

$P = 9016$ W

$P = 9.016$ kW

(i) power consumed in Each branch

$P_1 = I_1^2 R_1$

$= (19.72)^2 \times 10$

$P_1 = 3888.78$ W $= 3.8$ kW

(Note that take only Magnitude of current)

$P_2 = I_2^2 R_2$

$= (25.72)^2 \times 8$

$P_2 = 5292.14$ W $= 5.3$ kW

NOTE

$P = P_1 + P_2$

$= 3.8\text{ kW} + 5.3\text{ kW}$

$\boxed{P = 9.1\text{ kW}}$

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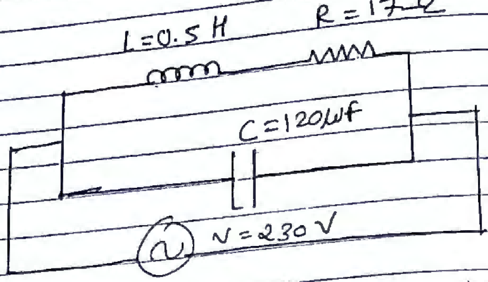
Q. An inductive coil having Resistence of 17 Ω & Inductence of 0.5 H, it is connected in parallel with capacitor 120 μF with supply 230 V

Find 1) f_r (Resonance frequency)

2) I (current) at Resonance

3) Dynamic Impedence



$R = 17\,\Omega$, $L = 0.5\,H$, $C = 120 \times 10^{-6}\,F$

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} = \frac{1}{2 \times 3.14}\sqrt{\frac{1}{0.5 \times 120 \times 10^{-6}} - \dots}$$

$f_r = 19.83\ Hz$

→ Current at Resonance

$$I = \frac{VCR}{L} = \frac{230 \times 120 \times 10^{-6} \times 17}{0.5}$$

$I = 0.94A$

3) Dynamic Impedance

→ "Impedance at Resonance"

for parallel circuit

$$Z = \frac{L}{CR}$$

$$Z = \frac{0.5}{120 \times 10^{-6} \times 17} = 245\ \Omega$$

★ Establish Relationship between LINE & Phase Voltages and LINE & PHASE Current STAR (WYE)(Y) connected balanced system

→ STAR (WYE) connection : is obtained when all the windings or coils are connected common point.

→ Common point (N) is known as Star (OR) Neutral

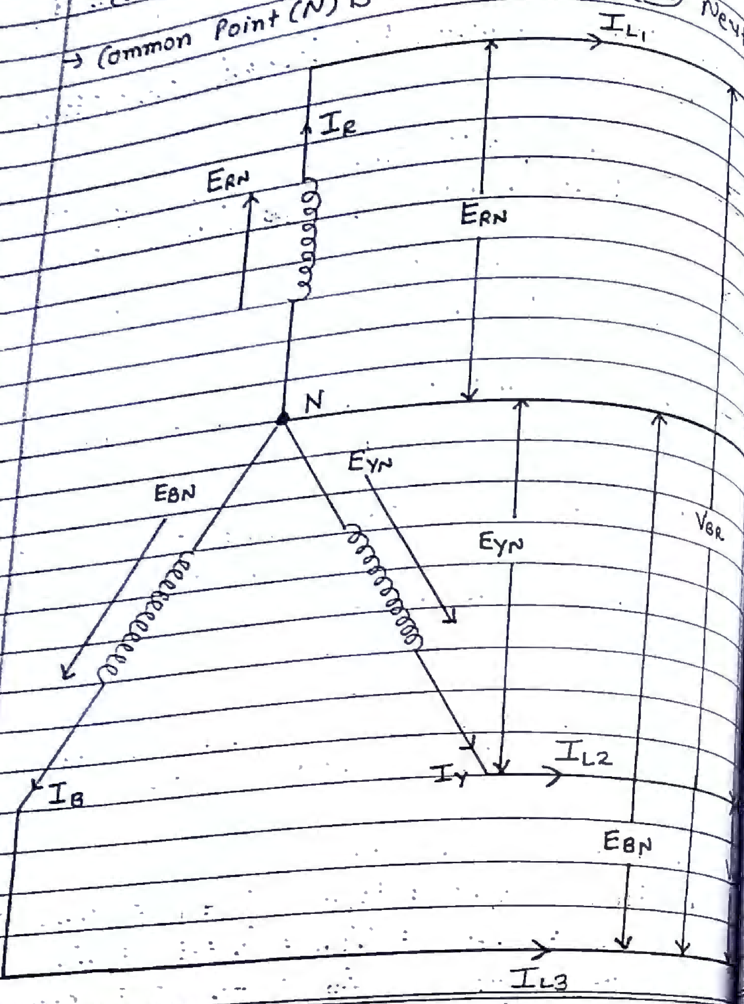


fig:- 3-ϕ Star connection for balance lo

→ form the figure it is 3-Phase, 4 wire star connected system.

→ Phase voltage :- "Voltage or E.M.F induced in winding is called Phase voltage"

OR

"Voltage between Line & Neutral is also called phase voltage".

→ Phase voltage denoted by E_{RN}, E_{YN}, E_{BN} in figure

→ Line Voltage :- "Voltage between any two line" denoted by V_{RY} V_{YB} V_{BR} in fig.

→ Phase Current :- "Current delivered by each winding" denoted by I_R, I_Y I_B in fig

→ Line Current :- "Current flowing in each line" denoted by I_{L1}, I_{L2}, I_{L3}

→ Phase voltages OR E.M.F of each coils are taken as positive direction from Neutral point's outwards.

→ In star connection, there are two windings or coils between two line produces the E.m.f in opposite directions.

→ Balanced system :-

$E_{RN} = E_{YN} = E_{BN} = E_{ph} = V_{ph}$ = Phase Voltage

$V_{RY} = V_{YB} = V_{BR} = V_L = E_L$ = line Voltage

$I_R = I_Y = I_B = I_{ph}$ = Phase Current

$I_{L1} = I_{L2} = I_{L3} = I_L$ = line Current

$E_{RN} = V_R = E_R$
$E_{YN} = V_Y = E_Y$
$E_{BN} = V_B = E_B$

⇒ **Relation between line & Phase Current**

from figure
$I_R = I_{L1}$ ⇒ $I_{Ph} = I_{L1}$
$I_Y = I_{L2}$ ⇒ $I_{Ph} = I_L$
$I_B = I_{L3}$ ⇒ $I_{Ph} = I_L$

→ So, In star connection

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

Phase current = Line current

⇒ **Relation between line & Phase Voltage**

V_{RY} is Phasor sum of (E_{RN}) & $(-E_{YN})$

$$V_{RY} = E_{RN} + (-E_{YN})$$

Similarly,
$V_{BR} = E_{BN} - E_{RN}$
$V_{YB} = E_{YN} - E_{BN}$

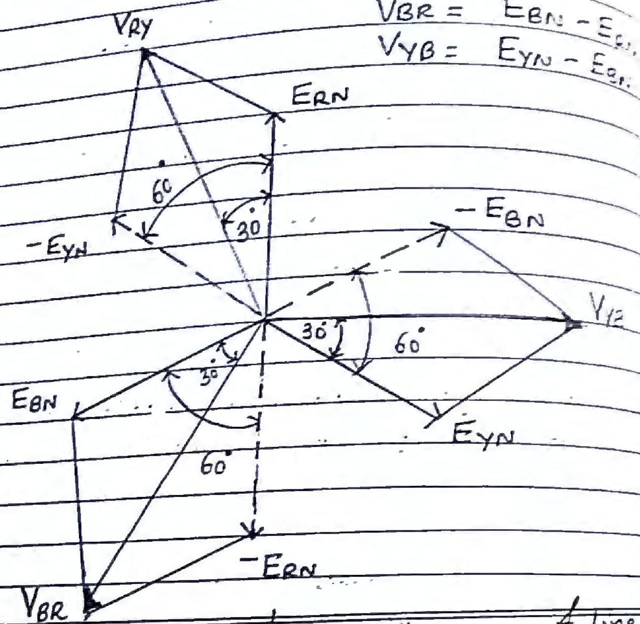


fig: Phasor diagram / Vector diagram of Line & phase V..

→ To find Magnitude of V_{RY} consider parallelogram with E_{RN} & E_{YN}

$$V_{RY} = \sqrt{E_{RN}^2 + E_{YN}^2 + 2E_{RN}E_{YN}\cos\phi}$$

from the figure & balanced system

$$V_{RY} = \sqrt{E_{Ph}^2 + E_{Ph}^2 + 2E_{Ph}E_{Ph}\cos(60°)}$$

$$V_{RY} = \sqrt{E_{Ph}^2 + E_{Ph}^2 + 2E_{Ph}^2 \times \frac{1}{2}}$$

$$V_{RY} = \sqrt{3E_{Ph}^2}$$

$$V_{RY} = V_L = \sqrt{3}E_{Ph}$$

$$\boxed{V_L = \sqrt{3}\,E_{Ph}} \Rightarrow \boxed{E_{Ph} = \frac{V_L}{\sqrt{3}} = V_{Ph}}$$

Line voltage = $\sqrt{3}$ × Phase Voltage

→ Power $P = 3 \times$ Power in each phase
$= 3 \times V_{Ph} I_{Ph} \cos\phi$
$= 3 \times \frac{V_L}{\sqrt{3}} \times I_L \cos\phi$

$$\boxed{P = \sqrt{3}\,V_L I_L \cos\phi}$$

→ In Star Connection Phase Voltage lags by 30° to Line Voltage (respective)

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Derive Relationship between LINE & PHASE Voltage and LINE & PHASE Currents in DELTA or MESH (Δ) Connected Sys.

→ Delta (Mesh) connection is obtained by connecting Starting Point to Ending Point of other coil.

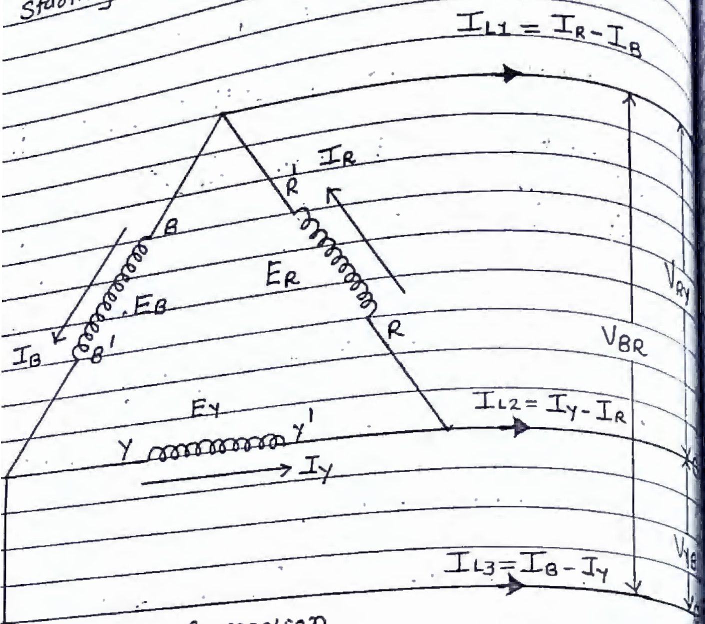

fig : Delta Connection

In this connection there is NO Neutral so it is called 3-Phase, 3-Wire system.

Direction E.M.F or Phase Voltages taken as positive from starting (R, Y, B) to End point (R', Y', B') of coil as shown in figure.

As system is balanced,

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→ Let phase Voltages are
$E_R = E_Y = E_B = E_{Ph} = V_{Ph}$

→ line voltages are
$V_{RY} = V_{YB} = V_{BR} = E_L = V_L$

→ phase currents are
$I_R = I_Y = I_B = I_{Ph}$

→ Line currents are
$I_{L1} = I_{L2} = I_{L3} = I_L$

⇒ Relation between LINE & PHASE Voltage

$V_{RY} = E_R = V_{RY} \Rightarrow E_{Ph} = V_L$
$V_{YB} = E_Y = V_{YB} \Rightarrow E_{Ph} = V_L$
$V_{BR} = E_B = V_{BR} \Rightarrow E_{Ph} = V_L$

So, $\boxed{E_{Ph} = V_L}$
Phase voltage = Line Voltage

⇒ Relation between LINE & PHASE Current

from the figure

Current in Line-1 $I_{L1} = I_R - I_B$

Current in Line-2 $I_{L2} = I_Y - I_R$

Current in Line-3 $I_{L3} = I_B - I_Y$

→ Let, I_R & I_B the sides of parallelogram with I_{L1} is the Resultant (diagonal)

→ $I_{L1} = \sqrt{I_R^2 + I_B^2 + 2 I_R I_B \cos\phi}$

$I_{L1} = \sqrt{I_R^2 + I_B^2 + 2 I_R I_B \cos\phi}$

$(\because \phi = 60°$ Balance$)$

$I_{L1} = \sqrt{I_{ph}^2 + I_{ph}^2 + 2 I_{ph}^2 \cdot \frac{1}{2}}$

$I_{L1} = \sqrt{3}\, I_{ph}$

$\boxed{I_L = \sqrt{3}\, I_{ph} \Rightarrow I_{ph} = \frac{I_L}{\sqrt{3}} \quad \text{Line current} = \sqrt{3}\ \text{phase current}}$

→ power, $P = 3 \times$ power in each phase

$= 3 \times V_{ph} \times I_{ph} \cos\phi$

$= 3 \times V_L \times \frac{I_L}{\sqrt{3}} \cos\phi$

$P = \sqrt{3}\, V_L I_L \cos\phi$

$\boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$

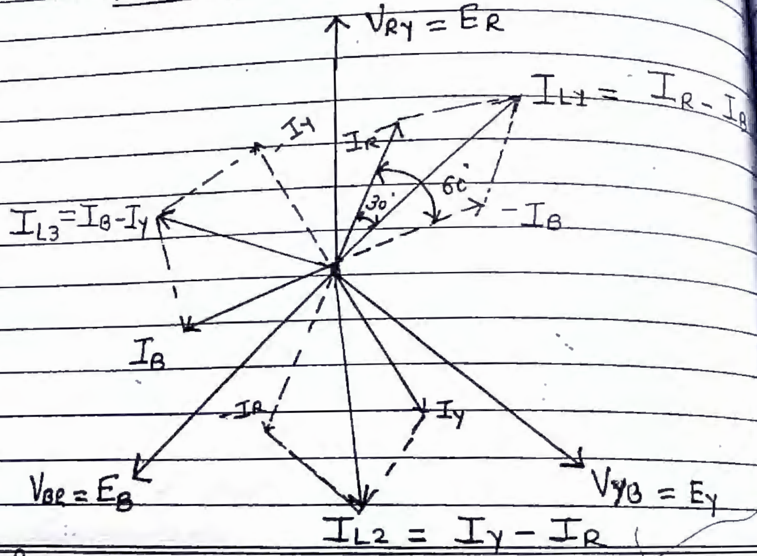

fig: Phasor diagram of Delta Connection

→ Line current (I_L) lags the phase current (I_{ph}) by 30°

★ Measurement of 3-ϕ power by Two-Wattmeter method for Star Connected balanced

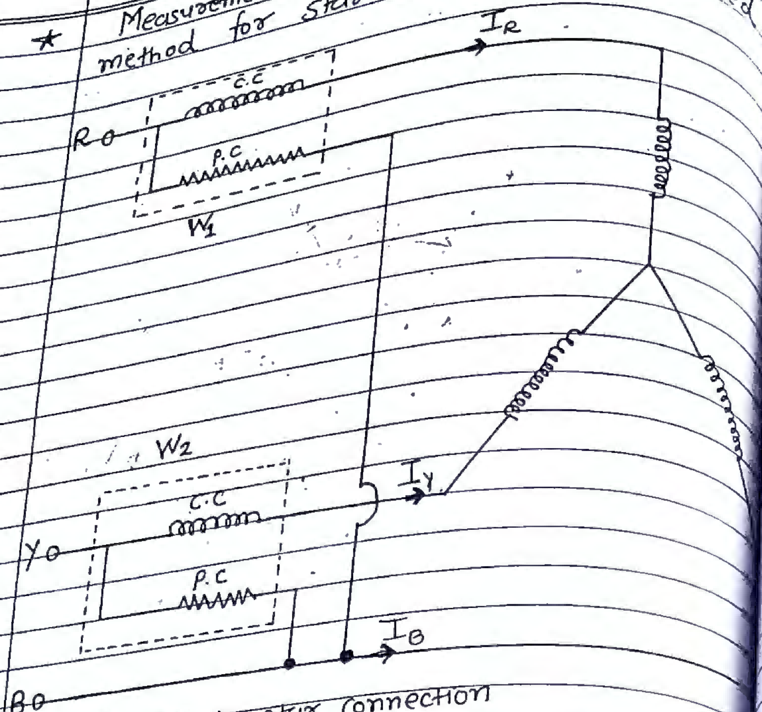

fig:- 3-ϕ star connection

→ Wattmeter consists of C.C (Current coil) and P.C (Pressure coil OR Potential coil) to measure current & voltage respectively.

→ Make sure that both P.C (Pressure coil) is connected to line in which Watt meter is not connected.

→ Above figure shows measurement of 3-ϕ star connection using two-Wattmeter method.

→ From the Watt meter W_1

$V_{RB} = V_R - V_B$

→ From the Watt meter W_2

$V_{YB} = V_Y - V_B$

→ The angle between I_R & V_R is ϕ

Similarly angle between I_Y & V_Y is ϕ.

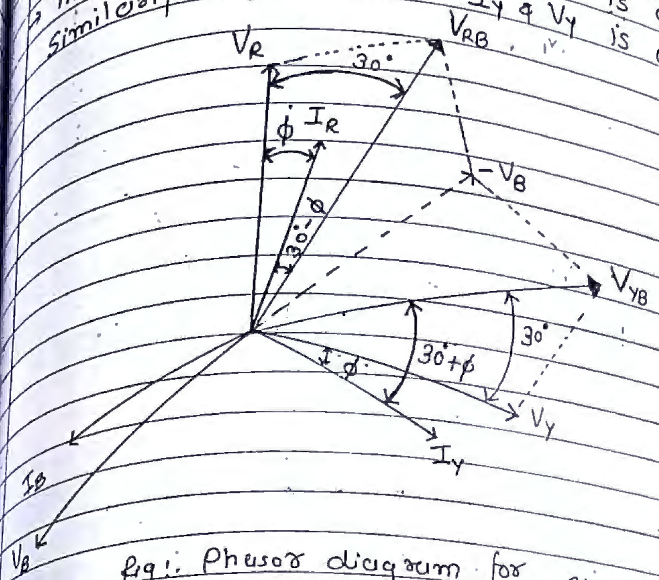

fig:- Phasor diagram for star connected load

→ Here we consider balanced load

$V_R = V_Y = V_B = V_{Ph} = E_{Ph}$ = Phase Voltage

$V_{RB} = V_{YB} = V_{RY} = V_L = E_L$ = Line Voltage

$I_R = I_Y = I_B = I_{Ph} = I_L$ = Line current = Phase current

→ Form the figure, Angle between I_R & $V_{RB} = 30 - \phi$

Similarly Angle between I_Y & $V_{YB} = 30 + \phi$

$\cos A + \cos B = 2\cos\frac{A+B}{2} \cdot \cos\frac{A-B}{2}$

So, Power $(W_1) = V_{RB} I_R \cos(30° - \phi)$

$$\boxed{W_1 = V_L I_L \cos(30° - \phi)} \quad \text{--- } 1$$

Similarly Power $(W_2) = V_{YB} I_Y \cos(30° + \phi)$

$$\boxed{W_2 = V_L I_L \cos(30° + \phi)} \quad \text{--- } 2$$

→ We have two possibilities (I) $W_1 + W_2$, (II) $W_1 - W_2$

(I) $W_1 + W_2 = V_L I_L \cos(30° - \phi) + V_L I_L \cos(30° + \phi)$

$W_1 + W_2 = V_L I_L \left[\cos(30° - \phi) + \cos(30° + \phi)\right]$

$= V_L I_L \left[2\cos\left\{\frac{30° - \cancel{\phi} + 30° + \cancel{\phi}}{2}\right\} \cdot \cos\left\{\frac{30° - \phi - 30° - \phi}{2}\right\}\right]$

$= V_L I_L \left[2\cos\left(\frac{60°}{2}\right) \cdot \cos\left(\frac{-\cancel{2}\phi}{\cancel{2}}\right)\right]$

$= V_L I_L \left[2\cos 30° \cdot \cos\phi\right]$

$= V_L I_L \left[\cancel{2} \times \frac{\sqrt{3}}{\cancel{2}} \cos\phi\right]$

$$\boxed{W_1 + W_2 = \sqrt{3} V_L I_L \cos\phi} \quad \text{--- } 3$$

$W_1 - W_2 = V_L I_L \left[\cos(30° - \phi) - \cos(30° + \phi)\right]$

$W_1 - W_2 = V_L I_L \left[-2\sin\left\{\frac{30° - \cancel{\phi} + 30° + \cancel{\phi}}{2}\right\} \sin\left\{\frac{30° - \phi - 30° - \phi}{2}\right\}\right]$

$W_1 - W_2 = V_L I_L \left[-2\sin\left\{\frac{60°}{2}\right\} \cdot \sin\left\{\frac{-\cancel{2}\phi}{\cancel{2}}\right\}\right]$

$W_1 - W_2 = V_L I_L \left[-2\sin 30° \sin(-\phi)\right]$

$= V_L I_L \left[2\sin 30° \sin\phi\right]$

$= V_L I_L \left[\cancel{2} \cdot \frac{1}{\cancel{2}} \sin\phi\right]$

$$\boxed{W_1 - W_2 = V_L I_L \sin\phi} \quad \text{--- } 4$$

→ Dividing equation (4) by (3) for finding p.f angle

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{\cancel{V_L I_L} \sin\phi}{\sqrt{3} \cancel{V_L I_L} \cos\phi} = \frac{\tan\phi}{\sqrt{3}}$$

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{\tan\phi}{\sqrt{3}}$$

$$\tan\phi = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$$

$$\boxed{\phi = \tan^{-1} \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)} \quad \text{--- } 5$$

→ From the Watt meters reading we can determine power factor $(\cos\phi)$ power factor angle (ϕ) also.

Q- Effect of Power factor on wattmeter

ANS → we have

$W_1 = V_L I_L \cos(30-\phi)$
$W_2 = V_L I_L \cos(30+\phi)$

1) when $(\phi = 0)$ i.e p.f is unity $(\cos\phi = 1)$

$W_1 = V_L I_L \cos(30-0) = V_L I_L \cos 30$
$W_2 = V_L I_L \cos(30+0) = V_L I_L \cos 30$

$\boxed{W_1 = W_2}$

→ Both wattmeter give positive and equal reading.

2) when power factor $\cos\phi = 0.5$ i.e $(\phi =$

→ $W_1 = V_L I_L \cos(30-60) = V_L I_L \cos 30$
$W_2 = V_L I_L \cos(30+60) = V_L I_L \cos 90$

→ Entire power is measured by only watt
→ $\boxed{W_1 \text{ is positive}}$, $\boxed{W_2 \text{ is zero}}$

3) when power factor is zero $(\cos\phi = 0$ i.e

→ $W_1 = V_L I_L \cos(30-90) = V_L I_L \cos 60$
→ $W_2 = V_L I_L \cos(30+90) = V_L I_L \cos 120 = -V$

$\boxed{W_1 = -W_2}$

→ Equal and opposite readings by wattmeter.

4) when the p.f > 0. and p.f < 0.5

$0.5 > \cos\phi > 0$

$\Rightarrow 60 < \phi < 90$ i.e

→ W_1 is Negative & W_2 is Positive

Total power is $W_2 - W_1$

One wattmeter W_2 is positive & wattmeter W_1 is Negative.

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Ex Find the reading of two wattmeter for 3-ϕ delta connected load having power factor 0.707 when connected across 415 V, 50 Hz supply. The line (Load) current is 20 A.

ANS Total Power consumed $= \sqrt{3} V_L I_L \cos\phi$

$= \sqrt{3} \times 415 \times 20 \times 0.707$

$= 10164$ Watt

$W_1 + W_2 = 10164$ watt. —— (1)

→ Now for lagging load power factor 0.707

$\tan\phi = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$

$\tan(0.707) = \sqrt{3}\left(\frac{W_1 - W_2}{10164}\right)$

$W_1 - W_2 = 5868$ watt —— (2)

Comparing Equation (1) & (2)

$W_1 = 8016$ Watt

$W_2 = 2148$ Watt.

For 415 V 3-ϕ system power measured by two wattmeter and reading were 10.5 kW and -2.5 kW. Calculate (1) power factor (2) Line current.

→ $\tan\phi = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$

here $W_1 = 10.5$ kW

$W_2 = -2.5$ kW

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$\tan\phi = \sqrt{3}\left[\frac{10.5 - (-2.5)}{10.5 + (-2.5)}\right]$

$\tan\phi = \sqrt{3}\left[\frac{10.5 + 2.5}{10.5 - 2.5}\right]$

$\tan\phi = 2.811$

$\phi = \tan^{-1}(2.811)$

$\phi = 70.41°$

→ power Factor $= \cos\phi$

$P.f = \cos(70.41)$

$P.f = 0.335$ lagging

→ Total Power Consumed $P = W_1 + W_2$

$P = 10.5 + (-2.5)$

$P = 8$ kW.

→ $P = \sqrt{3} V_L I_L \cos\phi$

$I_L = \frac{P}{\sqrt{3} V_L \cos\phi} = \frac{8 \times 10^3}{\sqrt{3} \times 415 \times 0.335}$

$I_L = 33.26$ A.

Q. Classification of Magnetic Materials

→ There are 5 types of Magnetic Materials

1) Diamagnetic
2) Paramagnetic
3) Ferromagnetic
4) Antiferromagnetic
5) Ferrimagnetic

1) Diamagnetic Material :⇒

→ "The Material in which dipoles (Magnetic dipoles) are absent are known as Diamagnetic Material."

→ The Materials having their relative permeability (μ_r) less than 1 ($\mu_r < 1$)

→ Such Materials are actually repelled by Magnet.
e.g. Sulphur, bismuth

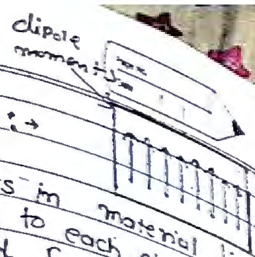
2) Paramagnetic Materials :⇒

→ " If the dipole moments are randomly oriented and if the dipole moments interaction is zero or negligible then Material is called Paramagnetic Materials.

→ Materials having relative permeability (μ_r) equal to one or ~~more~~ more than one ($\mu_r = 1$ to 10)
e.g. Aluminium, platinum.

fig:-

3) Ferromagnetic Materials :→

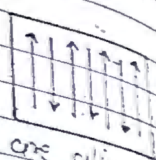


→ If the dipole moments in material line themselves up in parallel to each other in same direction is called Ferromagnetic Materials.

→ Materials having relative permeability (μ_r) is 100 to 100000 ($\mu_r = 100$ to $100,000$)

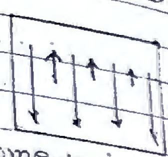
→ Materials Strongly attracted by Magnet
e.g. Steel, Iron, Nickel

4) Antiferromagnetic Materials :→



→ If the neighboring dipole moments are aligned in antiparallel then the Material is known as an Antiferromagnetic Material."

5) Ferrimagnetic Materials :→



→ If the order of Magnetic moments are shown in figure then it is known as Ferrimagnetic Material.

Q-* Construction & working of 1-ϕ Transformer

→ Transformer is a static device. The Main parts of transformer as shown in fig.

CONSTRUCTION

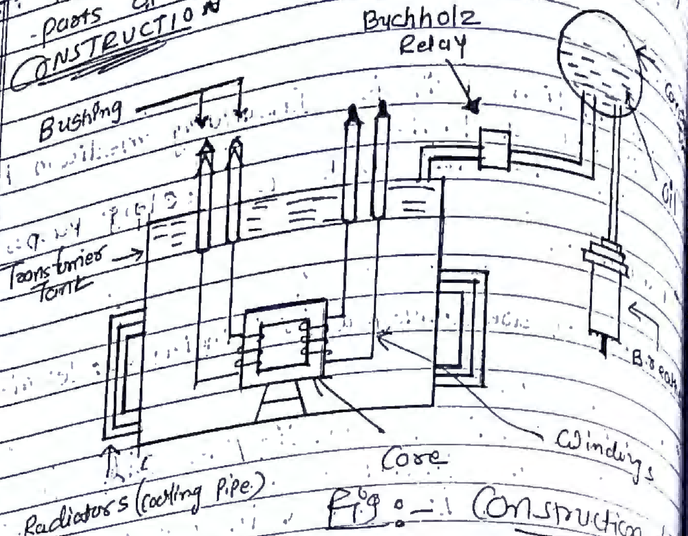


Fig :- Construction of T

* Magnetic core :-

→ core is made up of silicon steel & it is laminated to reduce hysteresis & Eddy current loss.

→ There are generally two type of transformer

1) Core Type
2) Shell Type

* Winding :-

→ Winding is made up of copper.

→ Both windings are Electrically isolated but Magnetically coupled.

→ L.V windings carries high current & H.V windings carries low current.

Conservator Tank :-

→ The function of Conservator tank is to allow the Expansion and Contraction of oil

Oil :-

→ The function of oil is Insulating medium between winding & tank.

→ oil is also used as cooling purpose.

Bushing :-

→ Bushing are Employed for bringing out terminals.

Breather :-

→ function is to purify the air from tank.

→ Absorb the Moisture and dust from Environment.

→ Silica gel is placed in breather to absorbing Moisture

WORKING

Working :-

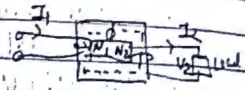
→ Transformer is a static device, consider two winding, say primary & secondary winding

→ There is no Electrical connection, only Magnetically coupled to the winding.

→ If supply voltage (A.C) is given to primary winding alternating flux is produce. this flux links with other (secondary) winding and E.M.F is induced According to Faraday's law of Electromagnetic Induction

→ If secondary winding is closed the current starts flowing in circuit

→ from the figure ϕ = flux,



I_1 = Primary Current, V_1 = Primary Voltage

I_2 = secondary current / V_2 = secondary voltage

N_1 = Primary turn
N_2 = secondary turn

A Derive the E.M.F equation for Transformer

OR

Prove that

$E = 4.44 f N \phi_m$

OR

$E = 4.44 f N B_m . A$

→ When the Alternating Voltage (A.C Voltage) supplied to primary winding to produce sinusoidal (Alternating) flux in the core.

→ figure - 1 shows the sinusoidal flux in core.

Where ϕ_m = Maximum value of flux

f = Frequency of Voltage

N_1 = Number of turns in primary

N_2 = Number of turns in Secondary winding

E_1 = E.M.F in primary winding

E_2 = E.M.F in secondary winding

B_m = flux density in core

A = Cross-section Area of core

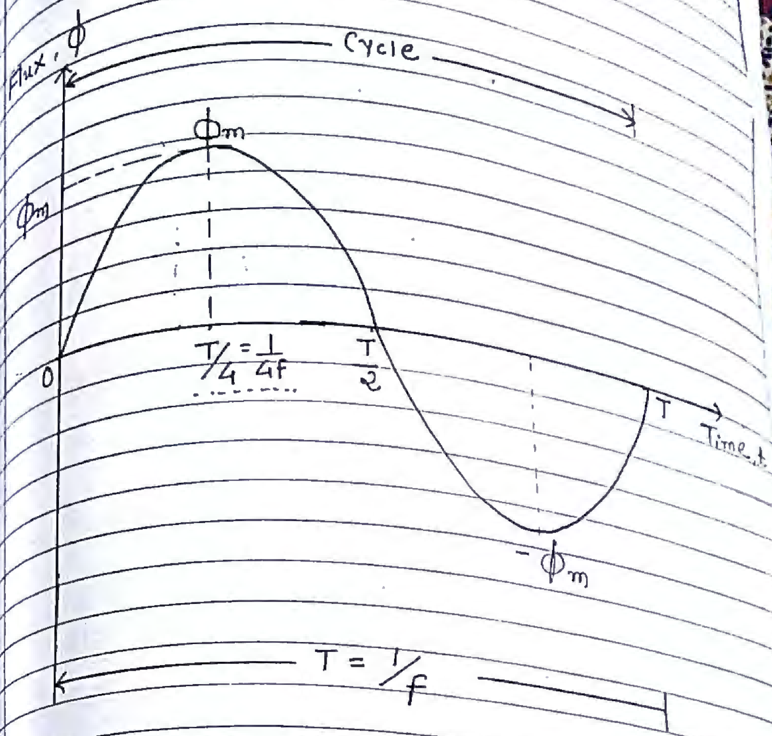


fig. 1 shows the Alternating (Sinusoidal flux)

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Let, $\phi = \phi_m \sin\omega t$ ------- (1)

→ According to Faraday's law of Electromagnetic Induction

$$E = -N\frac{d\phi}{dt} = \frac{-Nd(\phi_m \sin\omega t)}{dt} \quad (\because \text{From the equation})$$

$$E = -N\phi_m \omega \cos\omega t \quad (\because \omega t = \theta)$$

$$E = -N\phi_m \omega \cos\theta \quad (\because \cos\theta = \sin \ldots)$$

$$E = -N\phi_m \omega \sin(90 - \theta)$$

$$E = N\phi_m \omega \sin(\theta - 90^\circ)$$

$$E = N\phi_m \omega \sin(\omega t - 90^\circ) \quad (\because \theta = \omega t)$$ ------- (2)

→ From the above equation Maximum E.M.F

$$E_m = N\phi_m \omega$$

The R.M.S value of Induced E.M.F

$$E_{r.m.s} = \frac{E_m}{\sqrt{2}} = \frac{N\omega\phi_m}{\sqrt{2}} = \frac{N 2\pi f \phi_m}{\sqrt{2}}$$

$$= N\sqrt{2} \times 3.14 \times f\phi_m$$

$$\boxed{E_{r.m.s} = 4.44 N f \phi_m}$$

E.M.F induced in Primary winding

$$\boxed{E_1 = 4.44 N_1 f \phi_m = 4.44 N_1 f B_m . A}$$

E.M.F induced in secondary winding

$$E_2 = 4.44 N_2 f \phi_m = 4.44 N_2 f B_m . A$$

From the eq no. 2 E_1, E_2 lags behind ϕ by 90°

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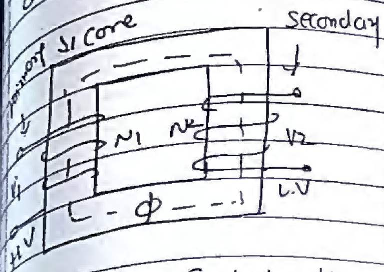
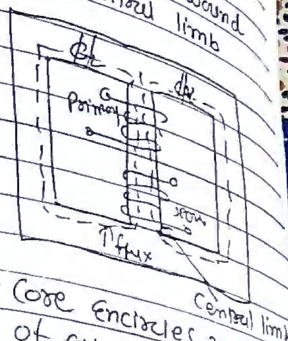
Comparison (OR) Difference between core type and shell type transformer

Core Type	Shell Type
→ Two limbs for single phase transformer	→ Three limbs for 1-ϕ transformer
→ Windings are wound on two limbs	→ Windings are wound on central limb
	
→ Winding Encircles the core	→ Core Encircles most part of winding
→ Single Magnetic circuit	→ Double Magnetic Circuit
→ Cylindrical coils are used	→ Sandwiched, disc type coils are used
→ Prefered for low voltage side	→ Prefered for high voltage
→ Rarely used	→ widely used.

★ Explain "HYSTERESIS" Curve (Loop)

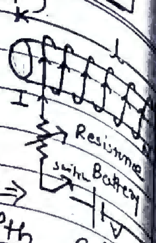
OR

Explain Magnetising Curve

OR

Explain B - H curve (LOOP)

(fig - 1) ⇒



⇒ Iron bar (core) is wound with coil N Numbers of turns. Variable resistor (R) connected to vary the current. Shown

→ When switch (K) is closed, current I flowing in coil (solenoid).

→ Due to that Magnetising Force $(H) = \frac{NI}{l}$ also increasing with increase in current

→ so increase in H causes increase in flux density $B = \frac{\phi}{A}$

$H \propto B \Rightarrow B = \mu H \Rightarrow B = \mu H$

→ so, H increases due to current I, B also increase with it linearly shown in fig I (0 - 1)

→ Now further increase in current increase in H increase B Non-linear (1-2).

* Iron bar begins to attain magnetic saturation at point 2

→ At point 2 flux density B_m is Maximum

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→ Now, 'H' is gradually decrease by decreasing current I then flux density B also decrease (2-3)

→ Now at point 3 when H = 0 B is not become the zero some flux (Magnetism) is present in material is called "Residual Magnetism" (0 - 3)

→ The property of retaining Residual Magnetism is called "Retentivity"

→ To completely demagnetise (B = 0) Iron bar Magnetic Force H is applied in reverse direction by current in opposite direction with help of changing the polarity of battery.

→ H is increased in Reversed direction then at point 4 the B = 0

→ so the Force required to completely demagnetise iron bar is called "Coercive force" this property is called "Coercivity" (3-4)

→ Now further increase in reverse direction at point 5 Magnetic saturation occurs (4-5)

→ (0 - 6) is residual magnetism in reverse

→ (6 - 7) is coercive force in reverse direction

→ close loop obtained 2-3-4-5-6-7 is called Hysteresis Loop

→ Area under the Hysteresis loop is [illegible] occur in material.

→ "laging of Magnetisation or flux density (B) behind Magnetising force is known as Magnetic Hysteresis"

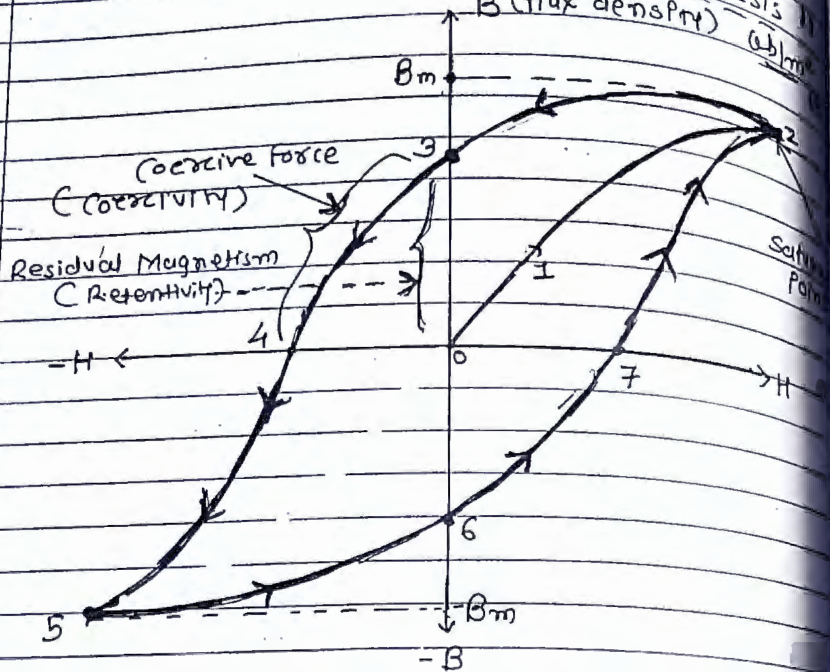

fig :- 2 :- Hysteresis Loop.

→ Soft magnetic materials like Iron which is used to make core of transformer & Other electrical machine having small hysteresis loop area.

→ Loop is small, Loss (waste of Energy) is small.

→ Hysteresis loss is given by

$$\boxed{W_h = \eta B_m^{1.6} f V}$$

where η = Steinmetz Constant
f = frequency of reversal Magnetisation
V = Volume of core in m^3
B_m = Maximum flux density
W_h = Hysteresis loss.

★ **Transformer ON NO-LOAD with Phasor diagram**

→ When transformer is said to be on No-load means "Secondary winding is open circuit" No current flows in Secondary winding.

→ When Voltage is applied to primary winding small amount of (I_0) No load current flows in it. show in fig-1

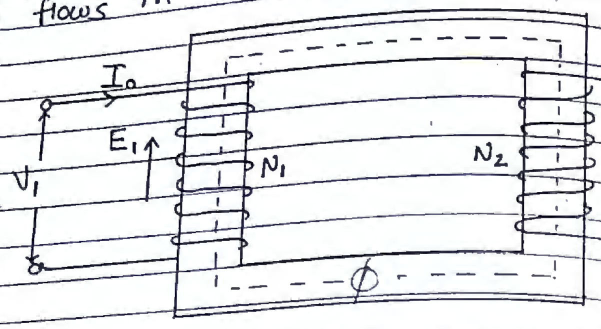

Fig-1

→ I_0 (No-Load current) has two component

I_0

I_μ (Magnetizing Component) | I_w (Working Component)

→ I_0 (No-Load) current lags behind the Voltage V_1 by angle $\phi_0 < 90°$

→ I_μ (Magnetizing Component) magnetize or produce the flux in core.

→ so I_μ is in phase with flux ϕ_m

→ I_w (Working Component) supplies iron loss in core. Cu loss is negligible.

→ I_w is in-phase with V_1

→ E_1 E_2 are produce by same flux

→ E_1 they lag behind flux ϕ by 90°

→ so E_1 & E_2 are in-phase with each other

→ $V_2 = E_2$ As there is No-load OR No-voltage drop in secondary

→ Applied Voltage V_1 to Primary winding leads the flux by 90° & in-phase opposite (out of phase) with E_1 show in fig.2

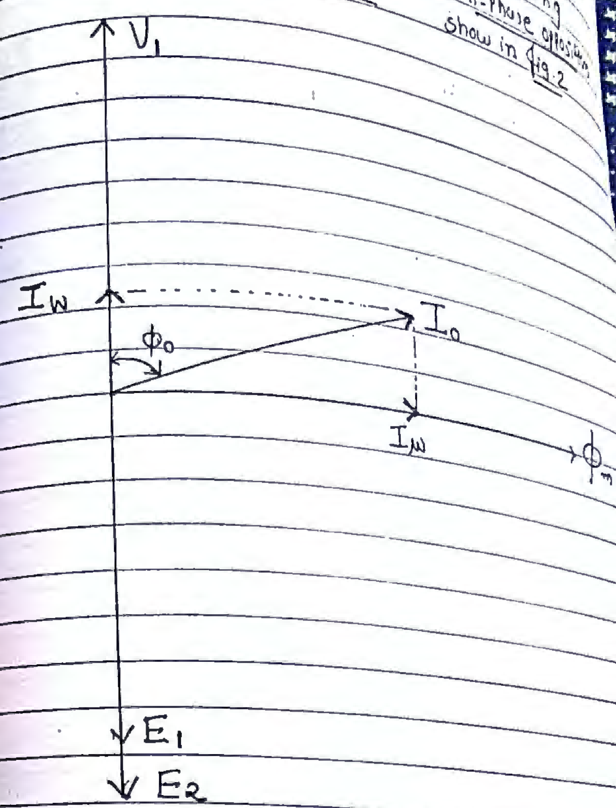

Fig.2 : Phasor diagram

→ From the diagram

$$\boxed{I_\mu = I_0 \sin\phi_0}$$

$$\boxed{I_w = I_0 \cos\phi_0} \Rightarrow \boxed{\cos\phi_0 = \frac{I_w}{I_0}}$$

$$\boxed{I_0 = \sqrt{I_\mu^2 + I_w^2}}$$

$$\boxed{\text{Iron loss OR Core loss } (P_c) = V_1 I_0 \cos\phi_0}$$

where ϕ_0 = No-Load Power Factor
OR
Hysteresis angle of adv

→ No Load Current (I_0) is 3% to 5% rated current in primary.

Note :-

→ I_μ is called ⇒ "Magnetizing Component"
"Reactive Component"
"Wattless Component"
"Quadrature Component"

→ I_w is called ⇒ "Working Component"
"Active Component"
"Wattfull Component"
"In-Phase Component"
"Energy Component"
"Iron loss OR Core loss Compon"

→ I_0 is called ⇒ "No-load Current"
⇒ "Exciting Current"

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* Explain the phasor diagram OR Vector diagram of Transformer ON LOAD

OR

* Explain phasor diagram of transformer for unity, lagging, leading power factor

OR

* Explain phasor diagram of transformer for Resistive, Inductive & Capacitive load

OR

* Explain OR Justify OR Prove that why the flux remain constant in transformer.

OR

* Explain OR Justify OR Prove that Iron loss OR core loss is constant irrespective of Load in transformer.

⇒ When transformer is on load, secondary current I_2 flows in it

→ I_2 in phase with V_2 for unity power factor (Resistive

→ I_2 lags with V_2 for Lagging power factor (Inductive

→ I_2 leads with V_2 for leading power factor (Capacitive

→ When primary Voltage (V_1) is applied to primary winding at No-load condition it produce flux ϕ_0 & current in primary winding is I_0

→ Now LOAD is connected in secondary winding I_2 (secondary current) flows in it. MMF (N_2I_2) produce flux ϕ_2 which is opposite of ϕ_0

→ Due to weaken the main flux (ϕ_0), E.M.F of primary E_1 is reduced & Voltage V_1 is momentarily increased that causes flow of additional current I_2' in primary which set up N_2I_2' (MMF) produce flux ϕ_2' which is opposite to ϕ_2

→ from the above we conclude that Main flux (ϕ_0) is remain constant.

→ Magnetic effect of secondary current I_2 due to load immediately nuetralized by additional primary current I_2'. So the Core loss OR Iron loss is always constant.

→ For the phasor diagram

→ I_1 lags behind V_1 by ϕ_1 angle

→ I_2 lags behind V_2 by ϕ_2 angle

→ I_2 & I_2' opposite to each other (180°)

→ E_1 & E_2 lags behind the flux (ϕ) by 90°

→ I_1 is vector OR phasor sum of I_0 & I_2'

→ From the figure 1

$$\phi_2' = \phi_2$$

$$N_1 I_2' = N_2 I_2$$

$$I_2' = \frac{N_2 . I_2}{N_1}$$

$$I_2' = K I_2$$

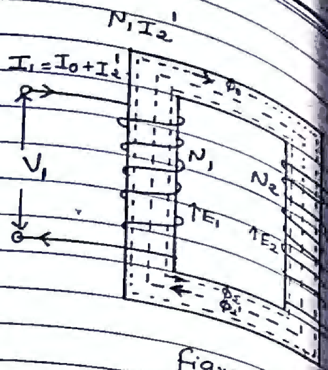


figure. 1

→ Primary Current

$$I_1 = I_0 + I_2'$$

→ I_2' is also called Load component of Primary"

→ I_2' is opposite (Anti-phase) with I_2

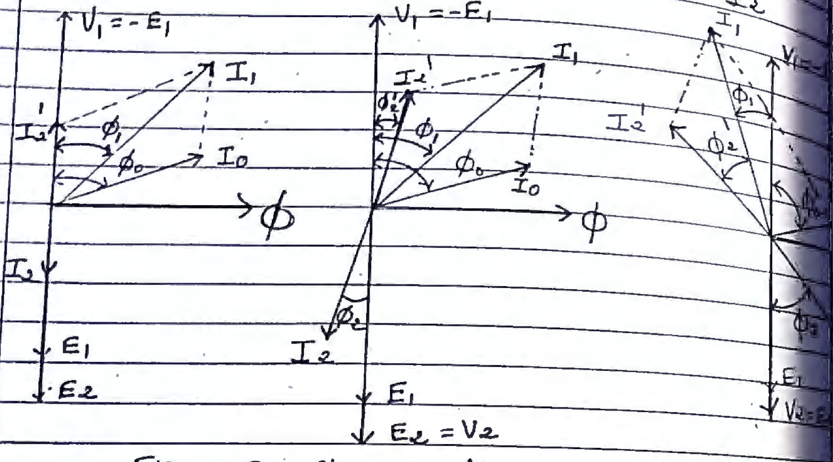


Figure - 2 Phasor diagram

Resistive Load — Inductive load — Capacitive

Explain Auto transformer with application & advantages & disadvantages

OR

Derive equation OR Explain Cu (copper) saving in AutoTransformer.

Auto transformer has one winding. Primary winding & secondary winding are electrically connected by tappings. Primary part of winding above tapping is primary & below is secondary here we are assuming that.

Fig. 1 shows the Auto transformer one winding is AB connected to supply V_1 & has N_1 turns

→ To obtain primary & secondary winding Tapping is provided at C

→ No. of turns in AC called Primary turns ($N_1 - N_2$)

→ No. of turns in CB called Secondary turns (N_2)

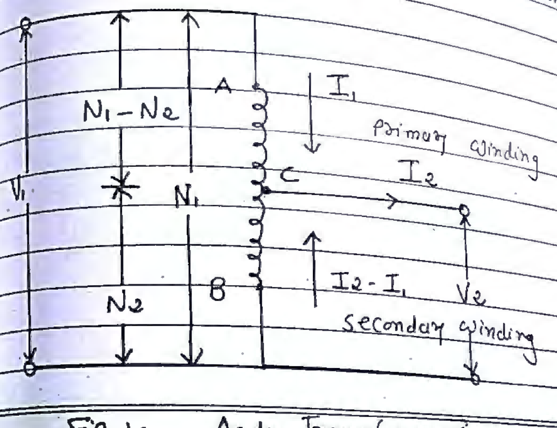


Fig 1:- Auto-Transformer

→ Equation for Copper (Cu) Saving

→ Weight of copper in two-winding (conventional) transformer

$W_t \propto IN$

∴ W_t = Weight of Copper of two winding transformer

→ $W_t = I_1N_1 + I_2N_2$

→ In Auto-transformer

Weight of copper in AC portion of winding & CB portion of winding is

$$W_a = I_1(N_1-N_2) + (I_2-I_1)N_2$$

$\frac{W_a}{W_t}$ = $\frac{\text{Weight of copper (conductor) in Auto transformer}}{\text{Weight of copper (conductor) in two-winding transformer}}$

$$\frac{W_a}{W_t} = \frac{I_1(N_1-N_2) + N_2(I_2-I_1)}{I_1N_1 + I_2N_2}$$

$$\frac{W_a}{W_t} = \frac{I_1N_1 - I_1N_2 + I_2N_2 - I_1N_2}{I_1N_1 + I_2N_2}$$

[We know that $\left[\frac{N_2}{N_1} = \frac{I_1}{I_2}\right]$ ⇒ $N_1I_1 = N_2I_2$]

$$\frac{W_a}{W_t} = \frac{I_2N_2 - 2I_1N_2 + I_2N_2}{2I_2N_2}$$

$$= \frac{2I_2N_2 - 2I_1N_2}{2I_2N_2}$$

$$= \frac{2I_2N_2}{2I_2N_2} - \frac{2I_1N_2}{2I_2N_2}$$

$$\frac{W_a}{W_t} = 1 - \frac{I_1}{I_2}$$

$\left(\because \frac{I_1}{I_2} = K\right)$

$$\frac{W_a}{W_t} = 1 - K$$

$$\boxed{W_a = W_t(1-K)}$$

Saving in Copper (Cu) in Auto transformer

$= W_t - W_a$

$= W_t - [W_t(1-K)]$

$= W_t - [W_t - W_tK]$

$= W_t - W_t + W_tK$

$$\boxed{\text{Saving in Copper} = W_t.K}$$

Advantages

- Only one (common) winding is required
- Size is compact.
- Cost is less due to less copper
- Losses are small
- Efficiency is very high
- require less space.
- Continuously varying Voltage can be obt...

Disadvantages :

- There is no Electrical isolation
- They windings are connected conductive...
- Chance of short circuit.
- Limited application due to one windi... for higher Voltage

Application

- Laboratory Equipments
- Starting of Induction Motor
- Also can be used as Booster in A.C fe...

How Rotating Magnetic Field (R.M.F) is produced ?

OR

Derive the equation OR prove that

ϕ_T OR ϕ_R $= \frac{3}{2}\phi_m$ OR $1.5\,\phi_m$

where ϕ_T = Total flux OR Resultant flux

ϕ_R = Resultant flux OR Total flux

3-φ (Three phase) windings are displaced by 120° shown in figure 1

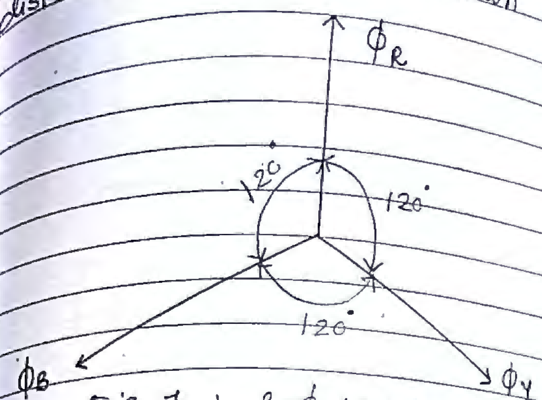


Fig. 1 : 3-φ winding displaced by 120°

- When 3-φ supply is given to stator winding it produce Rotating Magnetic field (R.M.F) with constant Magnitude & speed.
- flux produce by 3-φ winding assumed to be sinusoidal & shown in fig. 2

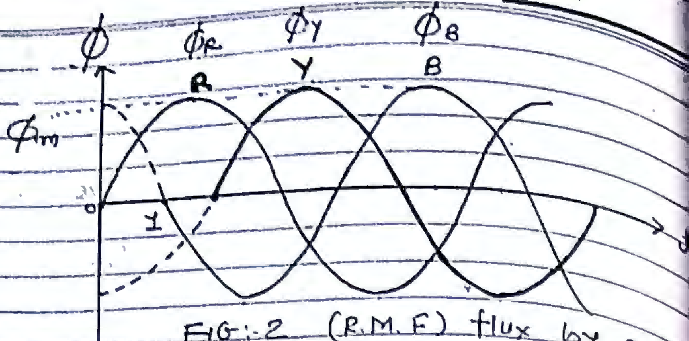


FIG:-2 (R.M.F) flux by 3-ϕ [illegible]

→ From the fig. 2

$\phi_R = \phi_m \sin\omega t = \phi_m \sin\theta$

$\phi_Y = \phi_m \sin(\omega t - 120^\circ) = \phi_m \sin(\theta - 120^\circ)$

$\phi_B = \phi_m \sin(\omega t - 240^\circ) = \phi_m \sin(\theta - 240^\circ)$

→ where flux ϕ_m is Maximum flux by any phase.

→ Total flux (OR) Resultant flux (ϕ_T) at any instant given by Vector sum of individual flux ϕ_R, ϕ_Y, ϕ_B

→ take $\theta = 60^\circ$ at point -1 Instant

$\phi_R = \phi_m \sin\theta \Rightarrow \phi_R = \phi_m \sin 60 = \frac{\sqrt{3}}{2}\phi_m$

$\phi_Y = \phi_m \sin(\theta - 120^\circ) \Rightarrow \phi_Y = \phi_m \sin(60^\circ - 120^\circ) = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_B = \phi_m \sin(\theta - 240^\circ) \Rightarrow \phi_B = \phi_m \sin(60 - 240^\circ) =$

$\phi_R = \frac{\sqrt{3}}{2}\phi_m$, $\phi_Y = -\frac{\sqrt{3}}{2}\phi_m$, $\phi_B = 0$

$(\because)\ \phi_Y = \sqrt{3}/2$

Taking vector sum ϕ using fig. 1

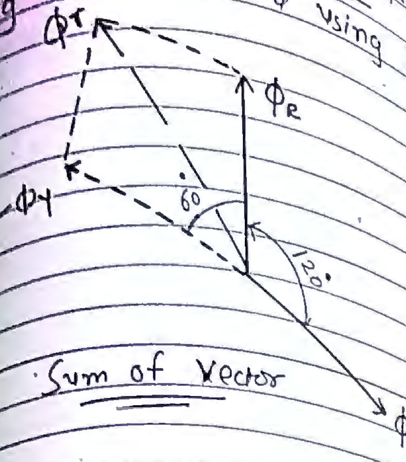


Fig. 3 Sum of Vector

Using Parallelogram

$\phi_T = \sqrt{\phi_R^2 + \phi_Y^2 + 2\phi_R\phi_Y\cos\theta}$

(where $\theta = 60$ $\therefore \phi_R = \phi_Y$)

$\phi_T = \sqrt{\phi_R^2 + \phi_R^2 + 2\phi_R\phi_R\cos 60}$

$\phi_T = \sqrt{\phi_R^2 + \phi_R^2 + 2\phi_R^2 \times \frac{1}{2}}$ $(\because \cos 60^\circ = 1/2)$

$\phi_T = \sqrt{\phi_R^2 + \phi_R^2 + \phi_R^2}$

$\phi_T = \sqrt{3\phi_R^2}$

$\phi_T = \sqrt{3}\,\phi_R$ $(\because \phi_R = \frac{\sqrt{3}}{2}\phi_m)$

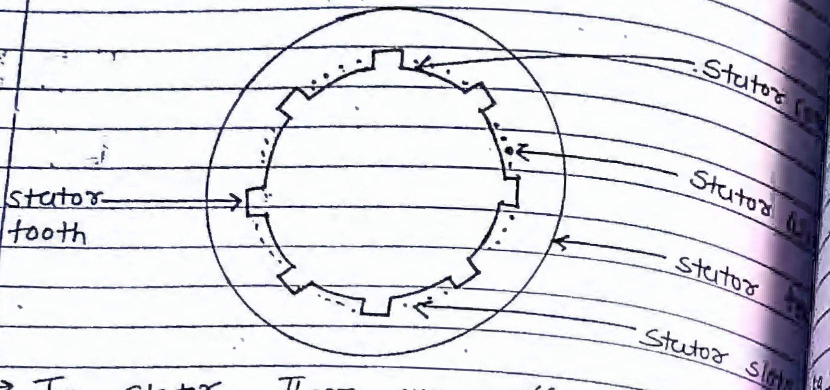
$\phi_T = \sqrt{3}\cdot\frac{\sqrt{3}}{2}\phi_m$

$\phi_T = 3/2\,\phi_m \Rightarrow \phi_T = 1.5\phi_m$

Q Explain Construction & working of Induction Motor (OR) Why I.M is self start

→ Basically 3-ϕ Induction Motor has two Main parts
1) STATOR
2) ROTOR.

→ 1) STATOR :- (Stationary Part)



→ In Stator There are different Parts
a) Stator core
b) Stator winding.
c) Stator frame
d) Stator tooth (slots)

→ Stator core is made up of silicon steel & function is to contains (house) winding
→ Stator winding is made up of copper function is to produce rotating magnetic field
→ Stator frame is made up of cast iron function is to support the core & protects inner parts.
→ Stator tooth (slots) holds the stator winding

ROTOR :- I.M. rdw (g)

There are two type of Rotors
1) Squirrel cage Rotor
2) Slip ring (OR) Wound Rotor

Rotor is rotating Part. There are different parts in Rotor

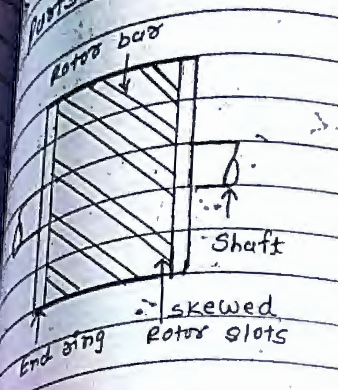


fig:- Squirrel cage Rotor

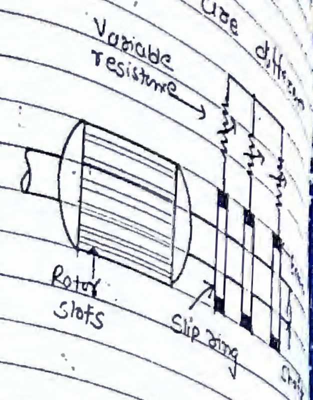


fig:- Slip ring Rotor

→ Rotor winding :- is made up of copper produce Rotor current.

→ Brush :- is made up of carbon. function is provide connection between Resistance & slip ring

→ Slip ring :- is made up of phosphorus bronz (OR) Copper function is connect the resistence to Rotor circuit through brushes.

Shaft :- is made up of Mild steel function is support the Rotor.

End rings : is used to short circuit the copper bars.

WORKING :-

→ When 3-ϕ A.C supply given to the stator winding, Rotating magnetic field is produced

→ Rotating magnetic field is also known Synchronus Speed ($N_s = \frac{120f}{P}$)

→ This rotating magnetic field (flux) passes through air gap to Rotor

→ Rotating magnetic field (flux) cut by the stationary Rotor winding (conductor). So change in flux occurs that produce E.M.F according to Faraday's law of Electromagnetic Induction.

→ E.M.f is proportional to Relative speed between stationary conductor & Rotating Magnetic field. (R.M.F)

→ Direction of E.M.f is given by Fleming's Left hand Rule

→ Rotor circuit is closed then Current flows in Rotor

Direction of Current is given by Lenz's law

According to Lenz's law Current is such that is oppose the cause who producing it

Cause is E.M.f (OR) Relative speed between Stationary conductor & Rotating Magnetic field

→ To reduce the relative speed (OR) To oppose the relative Speed, rotor starts rotating in the same the direction of R.M.F

→ As Current flows in Rotor circuit produce torque on Motor & Rotor Rotates in direction of R.M.F

→ Rotor speed (N) is less than Synchronus Speed (N_s).

→ That is why Induction Motor is self started Motor.

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Q- Explain Construction & Working of single phase Induction Motor (1-ϕ I.M)

⇒ Construction of 1-ϕ I.M is similar to 3-ϕ Induction Motor except following

1) Stator is supplied with single phase winding

II) Centrifugal switch is used to cut out a winding used for starting purpose

⇒ Stator :-

→ Stator slots are distributed uniformly and usually 1-ϕ double layer winding is used

→ Stator has two winding and displaced by
1) Main winding
2) Auxiliary OR Starting winding

⇒ Rotor

→ Rotor is made up of silicon steel
→ Rotor slots are provided to house the Rotor winding.

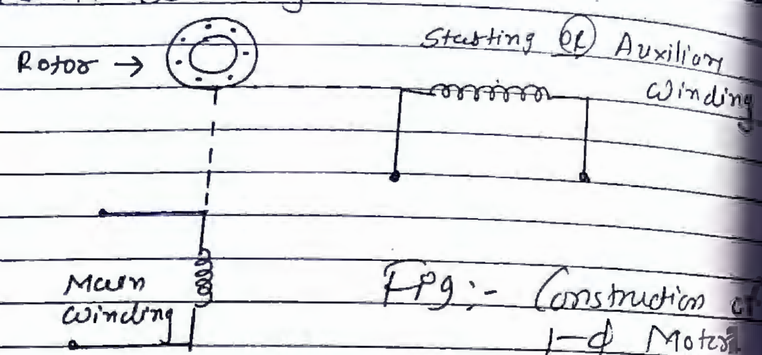


Fig :- Construction of 1-ϕ Motor

Working (Operating Principle) :-

When 1-ϕ supply is given to stator it produce alternating flux and it cuts the rotor conductor. Due to that torque is produced

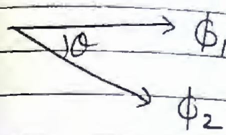
Rotor is subjected to rapid reversal & due to that its inertia can't move. This type of torque is known as pulsating torque. That is why single phase Induction Motor is not self starting.

To make rotor move in one direction we use Double field Revolving theory.

For that we need one auxiliary winding to split the phase and make the rotor in one direction.

Generally in 1-ϕ Motor Auxiliary winding is used for starting purpose

Centrifugal switch is used to cut out the Auxiliary (Starting) winding after the starting of Motor to reduce the losses



ϕ_1 = flux by Main winding
ϕ_2 = flux by Auxiliary winding

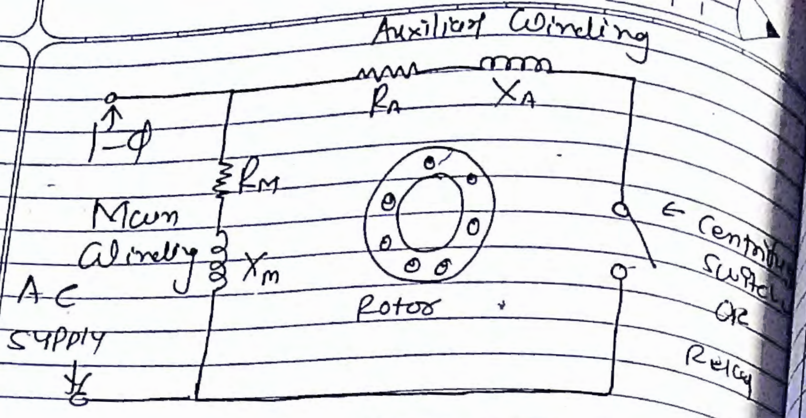
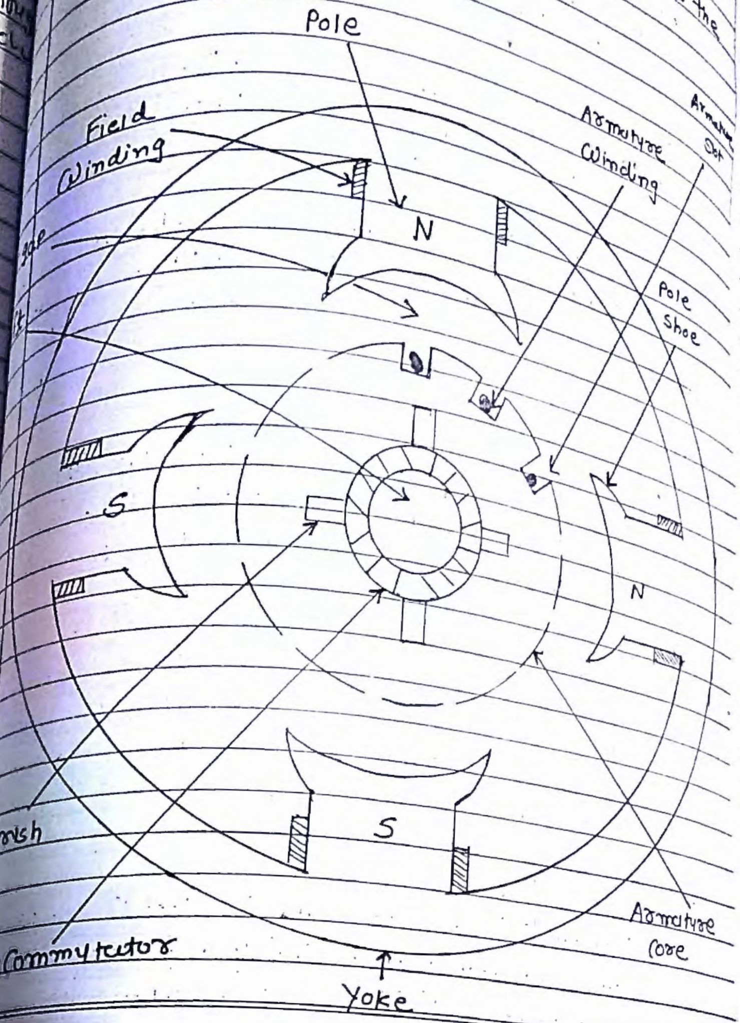


Fig. 1-Φ I.M

Q. Explain Construction & Working of D.C Motor. OR D.C Generator.

→ D.C motor and D.C generator has the same construction.



*** Pole**

→ Pole is made up of iron & function is to Produce Magnetic flux

*** Pole shoe**

→ Pole shoe is extended part of Pole & function is to provide uniform flux distribution.

*** Armature core**

→ Armature core is made up of iron & There are slots in periphery (OR) surface of core.

*** Armature Winding**

→ Armature winding (conductor) is made up of Copper and is connected to load through Commutator & brush. function is cut the magnetic flux & E.M.F Induced in it.

*** Field Winding**

→ Field winding is wound on pole. It is also known as Exciting winding. function is to magnetize the pole to produce flux.

*** Yoke**

→ Yoke is outer frame made of Silicon steel function is provide mechanical support to core & protection against mechanical damage.

*** Commutator**

→ Commutator is made up of copper segments. Mica insulation is provided between segments function is convert AC E.m.f to D.C E.m.f

BRUSH

Brushes are made up of Carbon. Function is to collect the Current from Commutator.

WORKING :-

→ When Current Carrying conductor is placed in magnetic field, conductor experiences mechanical force.

$$F = BIL \sin\theta$$

where B = Flux density wb/m^2

I = Current in conductor, A

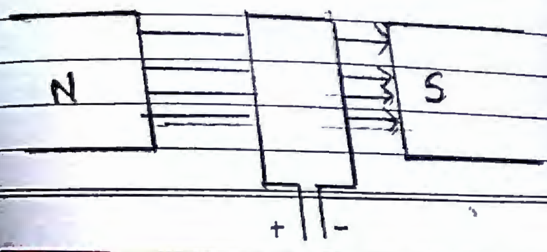
L = Length of conductor

θ = Angle between Magnetic field & Conductor

→ Force is Unidirectional hence armature rotates in one direction

→ The direction of rotation of armature is given by Fleming's Left hand Rule

→ In this way input Electrical power is converted into output mechanical power in D.C Motor.



Q) Explain Construction & working of Synchronous Generator OR Alternator.

→ Synchronus generator is machine which pro[duces] 3-ϕ a.c. power from the mechanical Energy.

→ Construction :-

→ There are two main ~~types~~ Parts
1) Stator
2) Rotor

★ Stator

→ In stator, Stator frame (outer cover) is made up of silicon steel or cast steel to reduce Hysteresis loss

→ Stator core is built up of thin lamination to reduce eddy current loss

→ The stator core has slots on its surface for holding armature conductors.

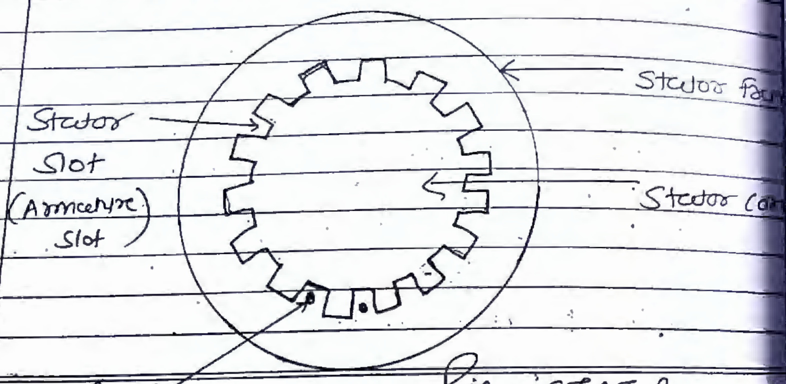


Fig:- STATOR

→ There are two type of Rotor

1) Salient pole type
(OR)
Projected pole type

2) Non Salient pole type
(OR)
Smooth cylindrical type

Salient pole type	Non Salient Pole
→ Poles are projecting	→ Poles are non projecting
→ Concentrated field winding is used	→ Distributed field winding is used
→ Separate damper winding is used to prevent hunting	→ separate damping winding is not required.
→ larger diameter and smaller axial length.	→ Smaller diameter and larger axial length.
→ preferred for low & medium speed of genrator (50 - 1000 rpm) driven by diesel engine & Hydro turbine.	→ High speed generat[or] (1500 - 3000 r.p.m) driven by steam turb[ine]

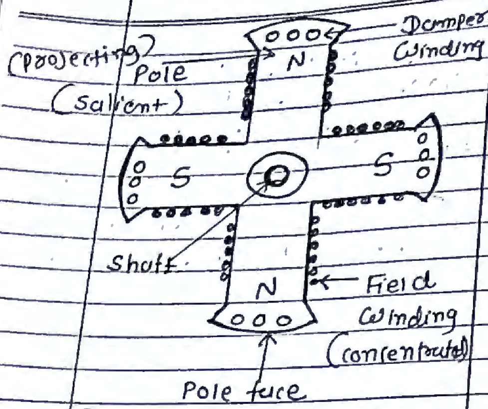


Fig:- Salient pole Rotor

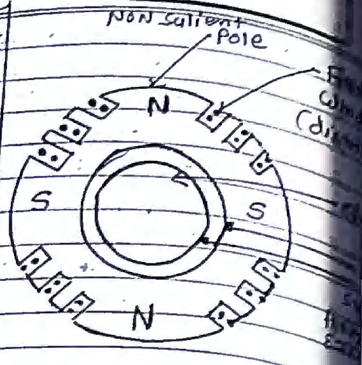


Fig:- Smooth cylindrical Rotor

* Working principle of synchronus generator (Alternator)

→ Generally stationary armature & rotating field type of Generator is used.

→ Rotor winding is energized by d.c exciter.

→ This causes alternate N and S poles to be developed on Rotor.

→ When the rotor is rotated in anticlockwise direction by prime movers stator conductors are cut by rotor pole flux.

→ As per faraday's law of Electro magnetic Induction e.m.f is induced in Stator.

→ This E.M.F is also alternating so current flows in one direction & then in other direction. The direction of E.M.F can be given by Fleming's right hand rule.

→ The induced voltage (E.M.F) depends on speed of rotor & d.c exciting current.

What is Earthing (Grounding)? Necessity of Earthing. List the types of Earthing. Explain any one Earthing (Plate Earthing OR Pipe Earthing)
(OR) Methods of Reducing Earth Resistance

Earthing : "Process of connecting the metalic part OR Non-current carrying part of Electrical Equipment to earth is called Earthing OR Grounding"

→ For the practical purpose potential of Earth is to be considered Zero.

→ Value of Earth resistence depends on following Factors

1) Material & size of Earth, wire & Electrode
2) Mositure & Temprature of soil
3) Depth of Earth Electrode (wire)

* Types of Earthing
(OR)
Methods of Reducing Earth Resistence

1) Pipe Earthing
2) Plate Earthing
3) Rod Earthing
4) Strip OR Wire Earthing
5) Water Earthing
6) Chemical Earthing

Necessity of Earthing :-

1) Protection against shock
2) Protection of Equipments
3) Maintain line voltage constant

PLATE Earthing :-

→ Earth connection is made using GI (Galvanised) plate (OR) copper plate

→ Dimensions of copper plate should not be less than 60 C.m × 60 C.m × 3.18 mm.
for GI plate 60 C.m × 60 C.m × 6.36 mm.

→ plate is buried in to the ground (Earth) not less than 3 m

→ Earth plate (Copper OR GI plate) is surrounded by char coal & salt layer for thickness of 15 Cm.
(Carbon)

→ Charcoal maintains mositure and enhence conductivity. Salts maintains the ions so helps in easily outflow of Earth fault current.

→ Water is poured for keeping the Earth's Electrode (plate) resistence value very low. Water is poured by funnel

→ Earth wire is securely bolted to plate (Copper Wire)

→ Cemenent chumber is built with cast iron cover for easy regular maintenance

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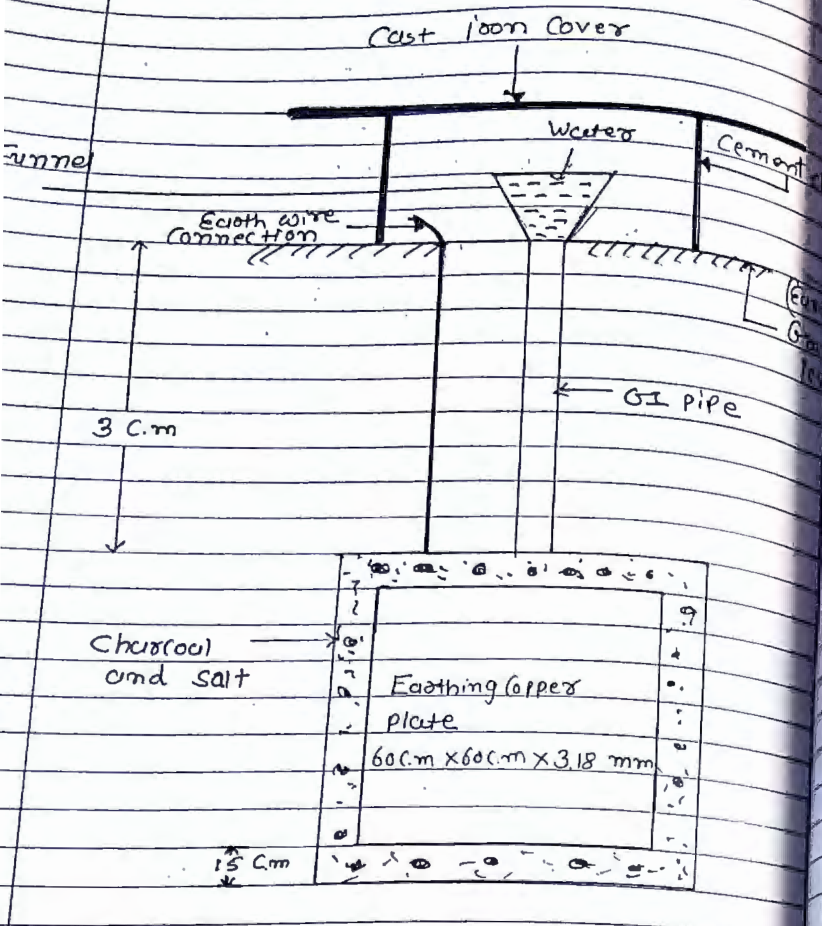
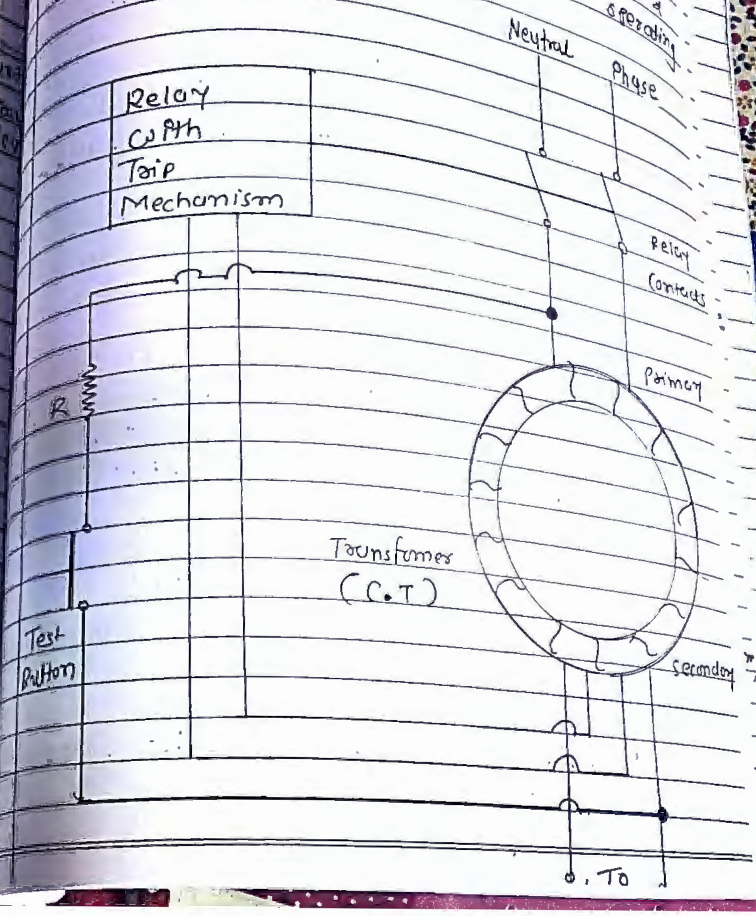


Figure: PLATE Earthing

Explain Working of ELCB (Earth Leakage Circuit Breaker).

ELCB consists of an operating coil (or) trip mechanism with Current transformer.

→ It operates if phase or Neutral wire is touched by current carrying object & current exceeds the rated operating current of ELCB.



→ Phase and Neutral wire connected to one winding of transformer through relay contacts.

→ second winding controls the trip mechanism.

→ Under the Normal conditions there is no leakage current so tripping is not energized. so the relay contacts are kept close using spring mechanism.

→ When Earth leakage occurs either the phase side or Neutral side of circuit, so currents are unbalanced.

→ Due to that Unbalanced current Relay operates the trip mechanism and its isolates supply from the load.

→ A Test button is included in ELCB for Testing trip mechanism. This test should be done periodically to ensure satisfactory working of ELCB.

→ ELCB senses small leakage current so we can avoid the injury & fire from the shocks.

→ This device also known as Residual Current Circuit Breaker (RCCB)

→ So ELCB (RCCB) operates with extremely small leakage currents in definite time which can't be sense by fuse and MCB.

→ So ELCB are used in Residential & Commercial premises.

Q. What is power Factor? Causes (Reasons) of low power Factor. Disadvantages of low Power Fa[ctor]. Methods of improving Power Factor.

ANS Power Factor :- Power Factor is the COSINE angle be[tween] Voltage and Current.

★ Causes (Reasons) of Low Power Factor :-

→ Most of AC Motors (1-ϕ & 3-ϕ A.C) have low lagging power factor around (0.2 to 0.3) light load. & at full load (0.8 to 0.9)

→ Arc lamps, Electrical discharge lamp have low power factor (0.6 to 0.7)

→ Industrial arc furnace has low power factor (0.5)

→ Load on power system is also varying d[uring] the day. At low load period in Transfo[rmer] Magnetizing Current is increased so the power factor is reduced.

★ Disadvantages of Low Power factor

Note → power consumed is depend on power fa[ctor]

for 1-ϕ A.C

$$P = VI\cos\phi$$

$$\cos\phi = \frac{P}{VI}$$

For 3-ϕ A.C

$$P = \sqrt{3}\, V_L I_L \cos\phi$$

$$\cos\phi = \frac{P}{\sqrt{3}\, V_L I_L}$$

$\cos\phi \propto \frac{1}{I}$

$\cos\phi \uparrow \Rightarrow I \downarrow$

$\cos\phi \downarrow \Rightarrow I \uparrow$

→ From the equation Power factor inversely proportional to load current

→ Greater conductor size is require as current is increase due to low power factor

→ Large copper loss (I^2R) due to large current reduce the efficiency

→ KVA Rating of Transformer

$$\cos\phi = \frac{\text{Active Power (kW)}}{\text{Apparent Power (KVA)}}$$

→ from the above equation KVA rating of transformer is increased lead to more capital cost

→ Poor Voltage Regulation due to low power factor there is Voltage drop in line leads to poor Voltage regulation.

★ Methods to improve the power Factor

→ A Majority of loads are inductive and take lagging currents. I_{Load} lags Voltage by ϕ.

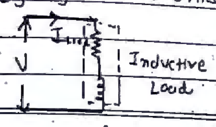


fig. circuit diagram

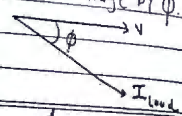


fig. Phasor (vo..)

'Note' $\cos\phi$ ⇒ $\cos 0 = 1$ ⇐ (ϕ ...
$\cos 45 = 0.707$ ⇐ (ϕ ...
$\cos 90 = 0$ ⇐ (ϕ ...

→ To improve the power factor, angle between voltage and current is to be decrease and become to zero for unity power factor.

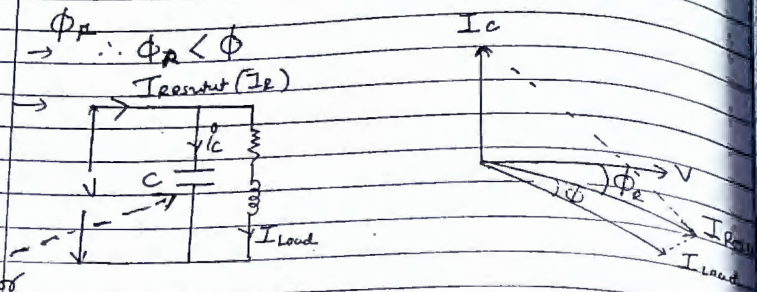
→ If capacitor is placed (connecte) in parallel then I_c is capacitor current (which is leading)

→ Now Resultant current (I_R) is vector sum of I_c & I_L.

→ Angle between $I_{resultant}$ & Voltage is ϕ_R

→ ∴ $\phi_R < \phi$

→



→ Methods to improve Power factor by following equipments

1) Static Capacitor
2) Synchronus Condenser
3) Phase advancer

What is wire? List types of wire?
Classification (Types) of Wiring
Comparision or Difference between Wiring Systems

"A single conductor is surrounded by insulation is known as wire"

→ function of wire is to carry current.
→ Gauge of wire measured by Gauge meter.

* Types of wire :-

1) V.I.R (Vulcanised Indian Rubber) wire
2) C.T.S (Cab Tyre Sheathed) OR T.R.S (Tough Rubber sheathed) wire
3) P.V.C (Poly Vinyl chloride) wire
4) Lead Alloy sheathed wire
5) Weather proof wire
6) Flexible wire

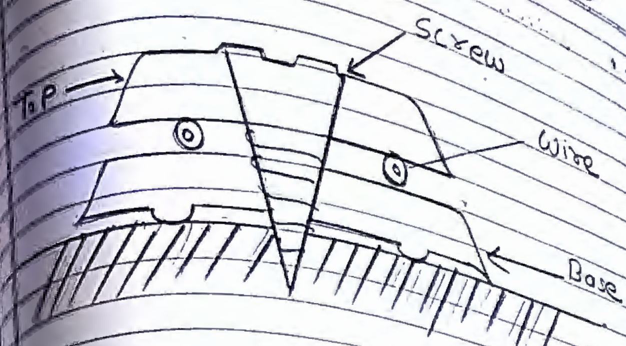
* Classification (Types) of Wiring :-

→ 1) Cleat wiring
→ 2) Casing & Capping (PVC type)
→ 3) Batten wiring
→ 4) Conduit wiring

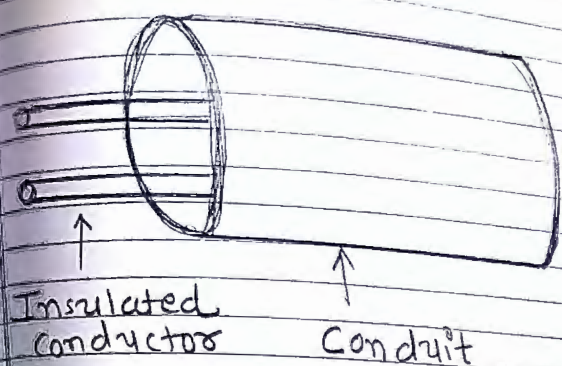
* Comparison between different wiring system

SR. NO	Particulars	Cleat wiring	Casing & Caping (PVC) wiring	Battern wiring	Conduit wiring
1	Life	Short	Moderately long	Fairly long	Very long
2	Cost	Less	Medium	Medium	Highest
3	Fire Protection	Nill	Good	Good	Nill
4	Mechanical Protection	None	Fair	None	Very goo
5	Protection From Moisture	No	Good	Less	Very goo
6	Flexibility	More	less	More	Very les
7	Maintenance	Easy	Moderate	Easy	Conduit w very diffi
8	Installation	Easy	difficult	Easy	very dificult
9	Type of Labour required	Semiskilled	Semi skilled	Semi skilled	Highly sk
10	Inspection	Easy	Easy	Easy	Difficult
11	Application	Social Function (Temporary)	Residential & Commercial	office building	Workshop, E Godowns, In

Cleat wiring



conduit wiring



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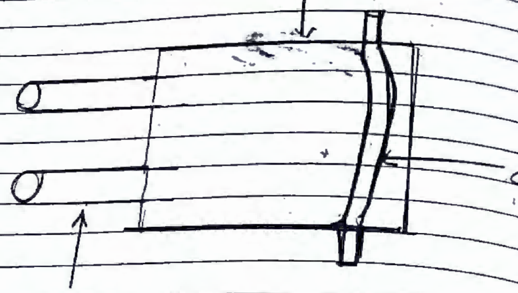
Batten Wiring



What is Cable? Give Classification of Cables? Explain General Construction of Cables.

"When two or more conductors covered with suitable insulation and surrounded by protecting cover is known as cable."

* Classification (Types) of Cables :-

1) Type of Conductor used
2) Type of Core used
3) According to insulation
4) According to Sheath
5) According to Armouring
6) According to Construction type.
7) According to use
8) According to Voltage level.

*1) Type of Conductor :-

→ Copper or Aluminium as conductor is use

*2) Type of Core :-

→ According to core 1 core, 2 core, 3 core, 3
4 core.

*3) According to Insulation :-

→ Rubber
→ PVC
→ Varnished
→ Paper
→ polythene
→ XLPE

*4) According to sheath :-

→ PVC sheathed
→ Lead sheathed
→ Lead-Alloy sheathed
→ Aluminium

*5) According to Armouring :-

→ Single layer steel wire
→ Double layer steel wire
→ Double layer steel tape

*6) According to construction :-

→ Belted cables
→ H-type cables
→ Oil filled cable
→ Gas filled cable
→ HSL type cable.

*7) According to use.

→ Power cables → To transmit Power
→ Control cables → To transmit control sign

*8) According to voltage level.

→ L.T (Low Tension cable) up to 1000 V
→ H.T (High Tension cable) up to 11,000 V
→ S.T (Super Tension cable) up to 33,000 V
→ E.H.T (Extra high tension cable) up to 66000
→ E.S.V (Extra super tension voltage) up to 1320
→ U.H.V (ultra high voltage) beyond 132000

CONSTRUCTION OF CABLE :-

The Main part of cables or There are six layers of cables: 1) Core 2) Insulation 3) Metalic Sheath 4) Bedding 5) Armouring 6) Serving

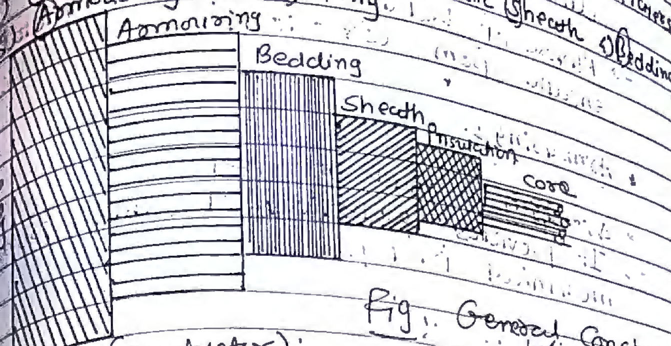


Fig: General Construction of Cable.

* Core (conductor) :-
→ Core (conductor) is made up of copper or Aluminium
→ Core may be 1 core, 2 core, 3 core, 4 core
→ function of core is to carry the current.
→ 3 1/2 core or 4 core is used for 3-ϕ A.C with Neutral system

* Insulation :-

→ To withstand against high voltage (pressure)
→ Various type of insulation like paper, rubber, PVC etc.

* Sheath :-

→ Sheath is made of Aluminium or Lead or Metal
→ It restricts mositure to reach the insulation.

* Bedding :-

→ Bedding is made up of fibrous material like Jute or hessian tape.
→ Purpose of bedding is to protect metallic sheath from corrosion.

* Armouring :-

→ Armouring is made of steel
→ It provides protection of cable from mechanical injury.

* Serving :-

→ Serving is the last layer of cable, above the armouring.
→ It is made of jute cloth which protects armouring from atmospheric condition.

What is cell & types of cell? Explain Types of Grouping of cells?
(OR)
Explain Series and parallel grouping of cells
Explain Mixed grouping of cells.

Cell :- Device which convert chemical Energy into Electrical Energy.

Types of cell

- Primary Cell
- Secondary cell

Primary :-
→ Cell in which Reversible process (Electrical to Chemical) is not possible is called Primary Cell.
→ It can supply the current only until Electrode is dissolved. It is non-Rechargeable
e.g. Danial cell, Lech-lanche, dry cell, Zinc-Carbon, Mercury,

Secondary :-
→ Cell in which chemical to electrical & Reversible process (Electrical to chemical) is possible is called secondary cell.
e.g. Lead-acid, lithium-ion, Nickel-cadmium Cadmium-alkaline.
→ Due to rechargeable property it is widely used.

There are three types of grouping

1) Series Grouping
2) Parallel Grouping
3) Mixed grouping (Combination of series & Parallel)

- **Series Grouping** :–

→ Series Grouping is used where higher amount of voltage OR desirable Voltage is required

→ When two or More cells are connected such that negative terminal of one cell to the positive terminal of other cell then it is called Series grouping as shown in fig.

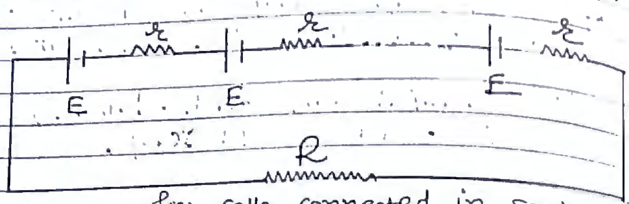


fig.- cells connected in series

Therefore,

∴ Total voltage = $n \times E$ Volt

Total Internal resistance = $n \times r$ Ω

Total Resistance = $R + (n \times r)$ Ω

Total Current (I) = $\frac{nE}{R + (n \times r)}$ Amp

Mixed Grouping (Series-Parallel Grouping)

→ Few cells are connected in series and these branches are connected in parallel then it is called series-parallel grouping OR Mixed grouping

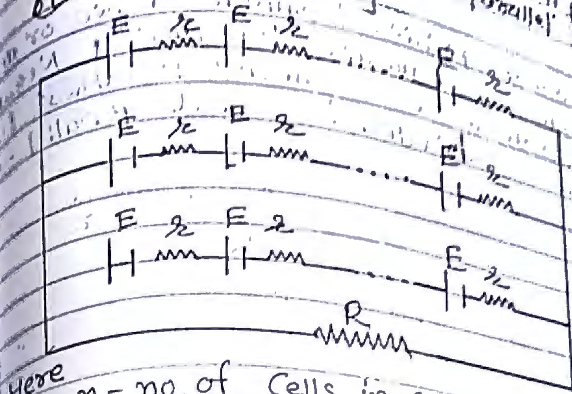


fig.- Mixed grouping

Here
n = no. of cells in series
m = no. of branches in parallel
r = internal resistance of each cell
E = E.M.F (Voltage) of cell

→ So Voltage of one branch = nE

→ So Total internal resistance of one branch = nr

→ Total resistance of all cell = $\frac{nr}{m}$

→ Total Resistance of circuit = $R + \frac{nr}{m}$

→ Total current $I = \frac{nE}{\left(R + \frac{nr}{m}\right)} = \frac{nmE}{mR + nr}$

Q. What is Battery? Types of Battery & Explain Lead - Acid Battery
OR
Charging & discharging of Lead - Acid Battery
OR
Explain Construction & Working of Lead - Acid Battery

* **Battery** :- "When two or more cells are connected together is called Battery"

* **Types of Batteries** :-

1) Lead - Acid Battery
2) Nickel - Iron Battery
3) Nickel - Cadmium alkaline
4) Lithium - ion Battery
5) Nickel - Metal Hydride

* **Construction of Lead - Acid Battery** :-

→ Battery consists of following parts
1) Anode (Positive)
2) Cathode (Negative)
3) Electrolyte
4) Container

→ Anode (Positive) Plates made of (PbO_2) Lead peroxide & Colour of it is brown

→ Negative (cathode) plates made of (Pb) spongy Lead & colour is gray

→ Positive & negative plates are arranged in group

→ Electrolyte used is dilute Sulphuric acid (H_2SO_4). Both plates (Anode & cathode) are immersed in Electrolyte. Specific gravity about 1.28 in dilute form.

→ Container is made of plastic or ceramic, so that no action take place on container.

Working (charging & discharging) :-

Discharging :-

→ When full charged battery is connected to an External load circuit, it starts delivering current to load.

→ During Discharging process direction of current from positive (Anode) terminal to Negative (Cathode) terminal in External load circuit and from cathode to anode through Electrolyte inside battery

→ Current passing through H_2SO_4 Electrolyte decomposes H_2SO_4 in positive ($2H^+$) and Negative (SO_4^-) ions

→ At Cathode
→ SO_4 reacts with Negative (cathode) plates
$Pb + SO_4 \rightarrow PbSO_4$

$PbSO_4$ is lead sulphate

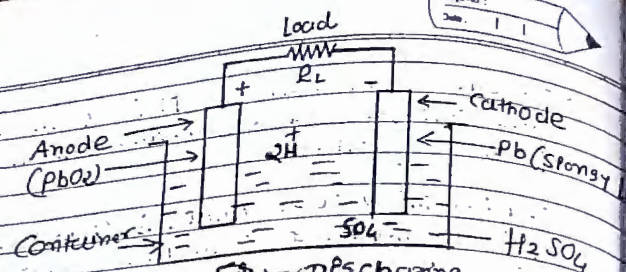


Fig:- Discharging

→ At Anode

→ hydrogen gas (H_2) reacts with Anode

$$PbO_2 + H_2 \rightarrow PbO + H_2O$$

→ This further reacts with H_2SO_4

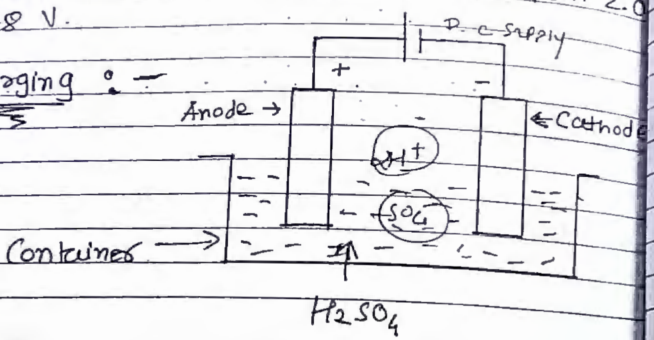
$$PbO + H_2SO_4 \rightarrow PbSO_4 + H_2O$$

→ During load condition, discharging take place & Chemical energy stored in battery is converted in to Electrical Energy.

→ By this process Both Electrodes converted in whitish colour.

→ Due to formation of water H_2SO_4 diluted specific gravity reduced from 1.28 to 1.. & terminal voltage get reduced from 2.0 to 1.8 V.

• Charging :-



→ To charge the battery, it is connected with d.c voltage source having higher than Battery voltage.

→ During this process Anode is connected (+ve) terminals & Cathode is connected with (-) Negative terminal. By this (+ve) ions (H_2) move towards Cathode & sulphate ion (SO_4^-) towards anode.

→ At Anode :-

$$PbSO_4 + SO_4 + 2H_2O \Rightarrow PbO_2 + 2H_2SO_4$$

At Cathode :-

$$PbSO_4 + H_2 \Rightarrow Pb + H_2SO_4$$

→ During Charging of battery both the plates regain their composition.

→ Water is consumed & H_2SO_4 is formed.

→ Specific gravity of acid increased from 1.15 to 1.28

→ Voltage is increased from 1.8 V to 2.0 V

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Q Explain characteristic (Electrical) of Battery (Lead-Acid Battery) OR Any Battery?

OR

Explain Watt hour Efficiency, Ampere-hour efficiency, Voltage & Current Capacity and the CCA of Battery (Accumulator)

ANS * Watt-hours Efficiency (Energy Efficiency) :-

" Ratio of Watt-hour required during discharging to Watt-hour required during charging "

Watt-hour Efficiency (η_{Wh})

$$\eta_{Wh} = \frac{\text{Watt hour (Energy) required during discharging}}{\text{Watt hour (Energy) required during charging}}$$

-> Practically Watt-hour OR Energy efficiency η_{Wh} is about 75% to 85%.

* Ampere-hour Efficiency (η_{Ah}) :-

" Ratio of Ampere-hour during discharging to Ampere hour require during charging "

Ampere-hour Efficiency (η_{Ah})

$$\eta_{Ah} = \frac{\text{Ampere hour during discharge}}{\text{Ampere hour during Charging}} \times 100$$

-> Another name of Ampere hour Efficiency is " Quantity "

-> η_{Ah} is about 90% to 95%.

Voltage :-

-> Average E.M.F of cell is about 2.0 V

-> E.M.F of cell changes with change in specific gravity, temperature & time.

-> While charging the Battery or cell, source Voltage must be higher than Battery E.M.F

Current :-

-> Current capacity is also known as Battery capacity, it is also expressed in Ampere-hour

-> Take an Example, 10 Ampere-hours means One Ampere current drawn (flow) for 10 hurs.

-> Current depends on size of Electrodes & space between plate (Electrodes)

* CCA (Cold Cranking Ampere) :-

-> This rating is applicable to cell 12 Volt Batteries irrespective of their size.

-> Battery discharge or provides Ampere ~~that~~ at $-18°C$

Q. Comparision between Fuse and MCB

Fuse	MCB
→ Fuse wire melts on excessive current flows	→ It operates to cut off circuit even on very small overload cur[rent]
→ The fuse wire may not be available of demand of rating	→ MCB (Miniature circuit Breaker) available in standard rating.
→ It melts on 50 to 100% Overload	→ It operates on 50% to 100% of over load.
→ It is very dangerous and Risky to rewire fuse at night.	→ It is very easy to operate it.
→ It is cheapest source of protection	→ Intial cost is more
→ It is require skillfull person to Rewire the fuse	→ It is does not require skillful person to operate MCB.
→ Fuse board is very large compare to MCB for same rating so it looks is moderate.	→ MCB is compact so lookwise it looks elegant.

~~Energy~~ ... calculation

A consumer uses 10 kw geezer, 6kw furnace & five 100 w bulbs for 15hrs. How many units of Electrical Energy have been used also find total cost of Energy consumption take cost per unit is 2.5 Rs

Load 1 → 10 kw geezer

Load-2 → 6 kw Electric furnace

Load-3 → 100 w bulb × 5 = 500 Watt = 0.5 kw

Total load = 10kw + 6kw + 0.5 kw = 16.5 kw

Time taken = 15 hurs

Energy Consumed = Power × time

= 16.5 kw × 15 = 247.5 k[wh]

→ We know that

1 Unit = 1 kwh

so total Unit is 247.5 Unit.

→ Cost is 2.5 Rs per Unit

then

total cost is = 247.5 × 2.5

= 618.75 Rs

Q. Explain or Enlist or Describe the Saftey Precautions for Electrical saftey or Handling Electrical appliances (Equipments)

ANS → Following are the Saftey precaution

→ Always wear rubber shoes when working with Electrical appliances.

→ Do not charge battery in a dark room.

→ always follow the Manufacturer's Instruction

→ Replace or Repair damaged wire.

→ keep Electrical equipments away from the

→ Do not overload the outlets

→ Shut off the power supply when you don't want to operate appliances for longer time.

→ Do not use flammable liquids.

→ always use proper Protection like ELCB, MCB, fuse, etc.

→ Do the Maintaines of Equipment when it is needed.

→ Do not touch overhead lines unless you sure that it is dead and properly Earthed.

Q6 Calculate Ah efficiency and Wh efficiency of cell having 20 hrs charge rate of 10A and delivering 5A for 36 hrs on discharge with mean terminal voltage of 1.96 V. The terminal voltage on charge has a mean value 2.35 V

→ Charging current (I_c) = 10 A
→ Charging time (t_c) = 20 hrs
→ Charging Voltage (V_c) = 2.35 V

→ Discharging current (I_d) = 5 A
→ Discharging time (t_d) = 36 hrs
→ Discharging Voltage (V_d) = 1.96 V

⇒ $Ah\ charge = I_c t_c = 10 \times 20 = 200\ Ah$
⇒ $Ah\ discharge = I_d t_d = 5 \times 36 = 180\ Ah$

⇒ $Ah\ efficiency = \frac{Ah\ discharge}{Ah\ charge} \times 100$

$= \frac{180}{200} \times 100 = 90\%$

Ah efficiency is 90%

$\boxed{\eta_{Ah} = 90\%}$

Wh efficiency $= Ah\ efficiency \times \frac{V_d}{V_c}$

$= 90 \times \frac{1.96}{2.35}$

Wh efficiency = 75% ⇒ $\boxed{\eta_{wh} = 75\%}$

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Ex. A discharged battery is put on charge at 5A for 3.5 hrs. At the End of this time it is disconnected and discharged through Resistance R ohms. If the duration of discharge period is 6 hr and terminal voltage remain constant at 12 V. Determine the value of R. The Ah efficiency is 85

ANS $I_c = 5A$, $t_d = 6$ hrs
$t_c = 3.5$ hrs $V = 12V$
$\eta Ah = 85\%$

→ Ah charge $= 5 \times 3.5 = 17.5$ Ah

→ Ah discharge = Ah charge × Ah Efficiency
$= 17.5 \times 0.85$
$= 14.875$ Ah

→ Discharge current $I_d = \frac{V}{R}$
$= \frac{12}{R}$

Ah discharge $= I_d \times t_d$

$14.875 = \frac{12}{R} \times 6$

$R = \frac{12 \times 6}{14.875}$

$\boxed{R = 4.84\,\Omega}$

6 similar cells are connected in series and supply current to load Resistance of $6\,\Omega$. The E.M.F of Each cell is 2 Volt and internal resistence of Each cell is $0.2\,\Omega$. Calculate i) Total internal resistence
ii) Current supplied
iii) Terminal voltage

i) Total internal resistence $= nr$
$= 6 \times 0.2$
$= 1.2\,\Omega$

ii) Total Voltage $= nE$
$= 6 \times 2$
$= 12$ V

iii) Current supplied $I = \frac{nE}{R + nr}$

$= \frac{12}{6 + 1.2}$

$= 1.667$ A.

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