



## 1st year Electrical Engineering Notes

Basic Electrical Engineering (Dr. A.P.J. Abdul Kalam Technical University)



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# UNIT

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# D.C Circuit Analysis

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\* Notes \*

Ques. 1) Explain Active and passive element

Ans. 1) The element which supply energy to Network

are known as Active element

Ex. → Voltage source, current source etc.

The elements which dissipate or store energy

are known as passive element

Ex. → Resistor, Inductor and capacitor.

Ques. 2) Define unilateral and bilateral elements.

Ans. 2) Unilateral → The elements whose property depend upon the direction of current are known as Unilateral elements.

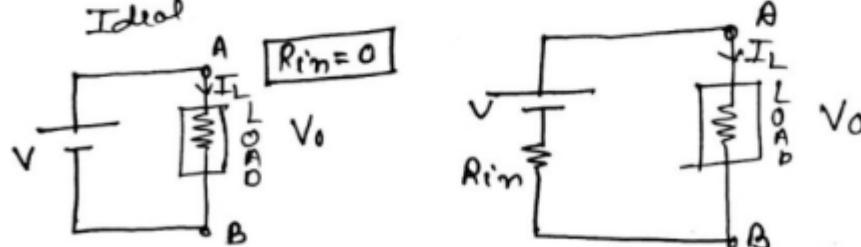
Ex. → Diode, Transistor, etc.

Bilateral → The elements whose properties do not depend upon the direction of current are known as bilateral elements.

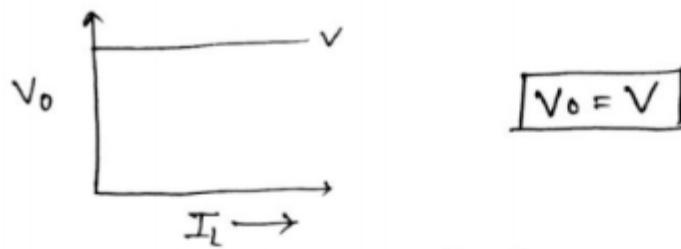
Ex. → Resistor, Inductor and Capacitor

Ques. 3) Explain Ideal and practical Voltage and Current Source

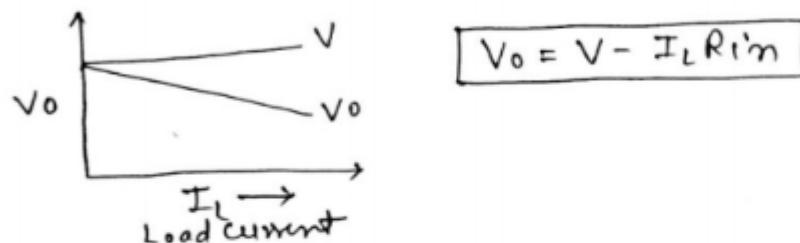
Ans. 3) Ideal & Practical Voltage Source



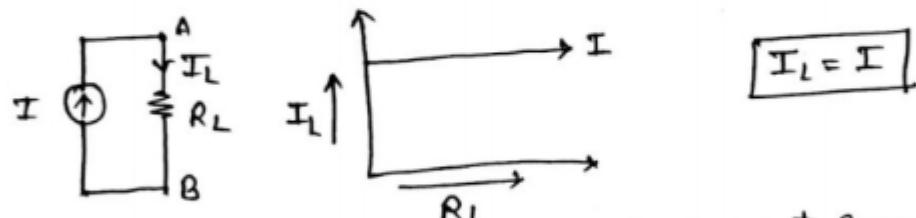
- \* The source which maintains a constant voltage across the load irrespective of the load current. is known as Ideal Voltage Source.



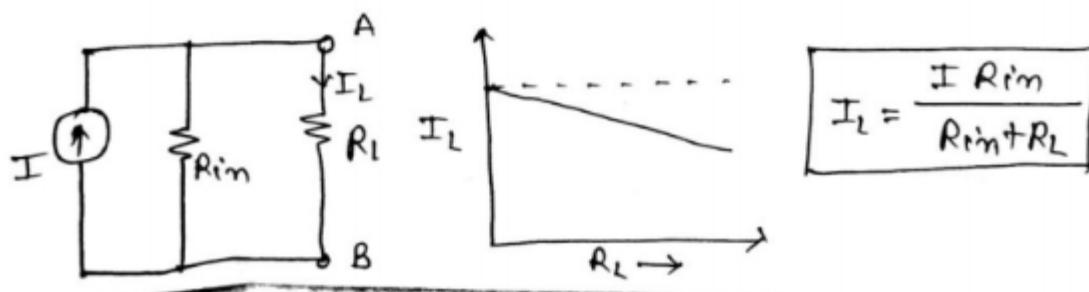
Practical Voltage Source  $\rightarrow$  the Source whose output terminal Voltage Decreases as we increase the load current i.e known as Practical Voltage Source



\* Ideal Current Source  $\rightarrow$  the Source which delivers Constant current to the load irrespective of the load resistance



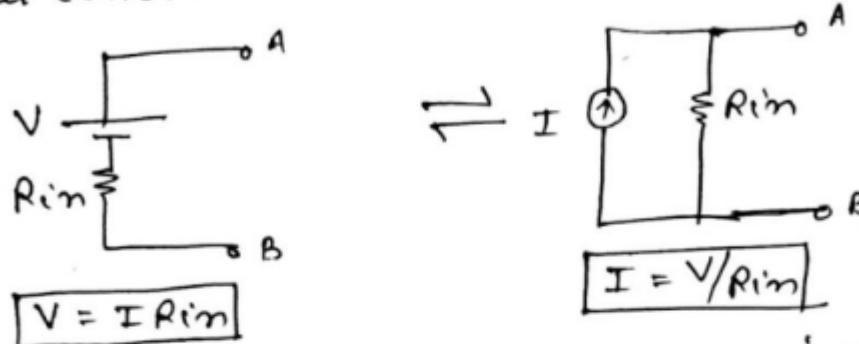
\* Internal Resistance of Ideal current source is  $\infty$   
 \* Practical Current Source  $\rightarrow$  The Source whose output current Decreases as we increase the Load Resistance i.e known as Practical Current Source



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Ques.3 What is Source Transformation?

Ans. → For the Simplification of Complex Network and Practical Voltage Source can be converted into a Practical Current Source and vice versa. This conversion is known as Source Transformation.



- \* for conversion Internal Resistance remains unchanged
- +  $I = V/R_{in}$  for Voltage to Current Source Conversion.
- +  $V = I R_{in}$  for Current to Voltage Source Conversion

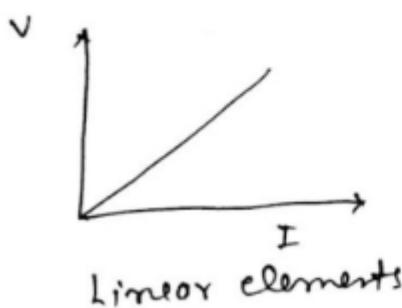
Ques.4 Explain Linear & Non-linear elements.

Ans. → The elements whose V-I characteristics is straight line are known as Linear elements.

Ex. → Resistor, Inductor & Capacitor

The elements whose V-I characteristics is other than straight line are known as Non-linear elements

Ex. → Diode



Non-linear elements



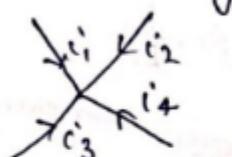
Ques-5 → Differentiate between Mesh & loop.

Ans. → Any closed path in a given network is known as loop.

The loop which does not contain any other loop within it is known as Mesh.

Ques-6 → What is KCL & KVL Explain their limitation?

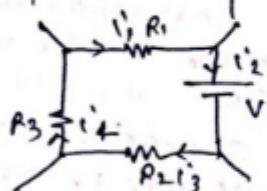
Ans. → (i) Kirchhoff's Current Law → (KCL) → according to KCL Algebraic sum of All the current entering or leaving at a node is equal to zero.



$$\sum I = 0$$

$$(i_1 + i_2 + i_3 + i_4 = 0)$$

(ii) Kirchhoff's Voltage Law (KVL) This law is applicable in a closed path (loop) according to the law algebraic sum of Voltage and Voltage drop in a closed path is equal to zero.



$$i_1 R_1 + V + i_3 R_2 + i_4 R_3 = 0$$

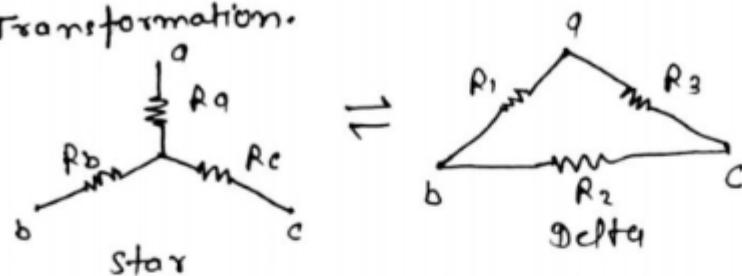
$$\sum V + \sum I_r \cdot R_i = 0$$

Limitations → (I) KCL & KVL both depend upon lumped element Model only.

(II) KCL, in its usual form is depend upon the assumption that current only flow in conductor.

Ques. 6 > Explain Star-Delta Transformation.

Ans. → For Solving the Complicated Circuits we have to Convert Star Network into Delta Network and vice-versa this Conversion is known as Star-Delta Transformation.



\* For conversion eq. resistance b/w any two terminal of given network must be same.

For star Network →

$$R_{ab} \text{ (eq. resistance b/w terminal } a-b) = R_a + R_b$$

$$R_{bc} \text{ (eq. resistance b/w terminal } b-c) = R_b + R_c$$

$$R_{ac} \text{ (eq. resistance b/w terminal } a-c) = R_a + R_c$$

For Delta Network →

$$R_{ab} \text{ (eq. resistance b/w terminal } a-b) = R_1 || (R_2 + R_3)$$

$$R_{bc} \text{ (eq. resistance b/w terminal } b-c) = R_2 || (R_1 + R_3)$$

$$R_{ac} \text{ (eq. resistance b/w terminal } a-c) = R_3 || (R_1 + R_2)$$

Now for conversion eq. resistance b/w given terminal of both the network must be same.

$$R_{a-b}(s) = R_{a-b}(D)$$

$$R_{b-c}(s) = R_{b-c}(D)$$

$$R_{a-c}(s) = R_{a-c}(D)$$

Now →

$$R_a + R_b = \frac{R_1(R_2 + R_3)}{R_1 + R_2 + R_3} \quad \text{--- (i)}$$

$$R_b + R_c = \frac{R_2(R_1 + R_3)}{R_1 + R_2 + R_3} \quad \text{--- (ii)}$$

$$R_a + R_c = \frac{R_3(R_1 + R_2)}{R_1 + R_2 + R_3} \quad \text{--- (iii)}$$

\* by Solving eq. (i) (ii) & (iii)

\* For Star to Delta  $\rightarrow$

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

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

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

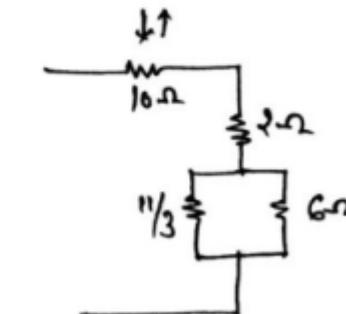
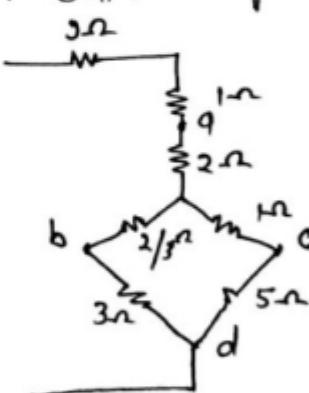
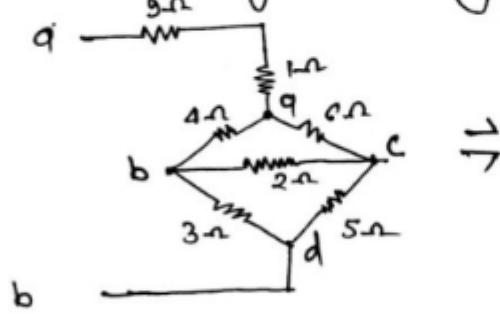
\* For Delta to Star  $\rightarrow$

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

$$R_b = \frac{R_2 R_1}{R_1 + R_2 + R_3}$$

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

Ques. → Solve the given circuit by star - Delta Transformation  $\rightarrow$



$$R_{ab} = 10.276 \Omega$$

ans

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Ques.7) Write the statement of following Theorem.

(i) Superposition Theorem (ii) Thevenin Theorem

(iii) Max Norton's Theorem

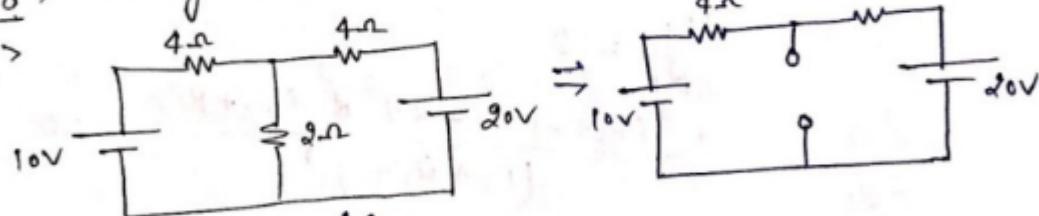
Ans.7 (i) Superposition Theorem) according to their Theorem in a linear resistive network containing two or more voltage sources the current through any element may be determined by adding together algebraically the current produced by each source acting alone, when all other sources are deactivated.

(ii) Thevenin's Theorem) According to their Theorem any complicated two terminal electrical network can be converted into a voltage source ( $V_T$ ) and resistance ( $R_T$ ) in series.

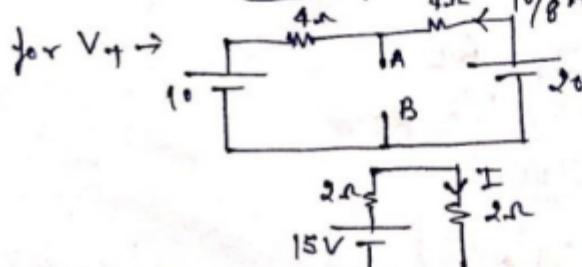
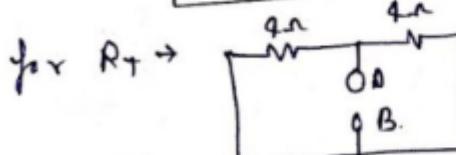
(iii) Norton's Theorem) According to their Theorem any complicated two terminal electrical network can be converted into a current source ( $I_S$ ) and resistance ( $R_N$ ) in parallel.

Ques.8) Using thevenin Theorem find current in  $2\Omega$ .

Ans.8 >



$$R_T = 2\Omega$$



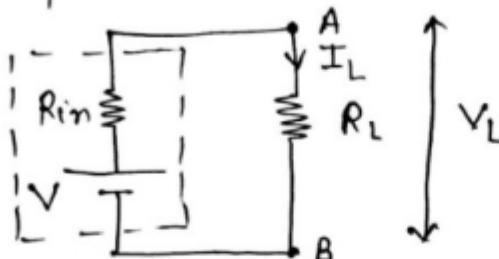
$$I = I_S / 4 \text{ A}$$

## Ques. 9 > State & Prove Max. Power Transfer Theorem

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Ans → "According To this Theorem Max. Power is Delivered to the load by a Voltage Source when Internal Resistance of Voltage Source becomes equal to Load Resistance"

Prove →



\* Current in load resistance is given by

$$I_L = \frac{V}{R_L + R_{in}}$$

Now Power Delivered to the load

$$P_L = I_L^2 R_L$$

$$P_L = \left( \frac{V}{R_L + R_{in}} \right)^2 R_L = \frac{V^2 R_L}{(R_L + R_{in})^2}$$

For Power to be maximum

$$\frac{dP_L}{dR_L} = 0$$

$$\frac{dP_L}{dR_L} = \frac{\frac{V^2 (R_L + R_{in})^2 - 2V^2 R_L (R_L + R_{in})}{(R_L + R_{in})^4}}{(R_L + R_{in})^4} = 0$$

$$\boxed{R_L = R_{in}}$$

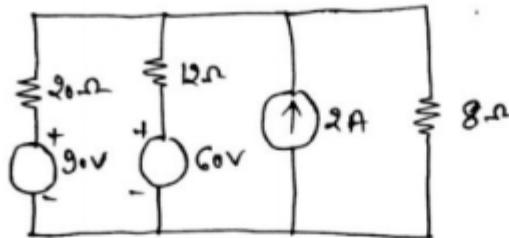
Value of Max. Power →

$$P_{L\max} = I_L^2 R_L \\ = \left( \frac{V}{2R_{in}} \right)^2 \cdot R_{in}$$

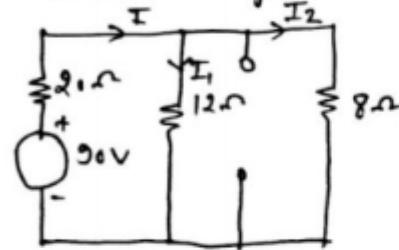
$$\boxed{P_{\max} = \frac{V^2}{4R_{in}}}$$

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Ques. 12 → Using Superposition Theorem find the current in  $2\Omega$  resistor.

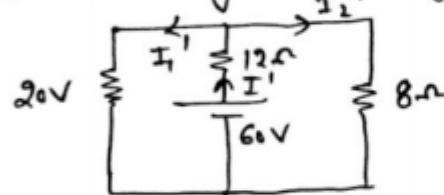


Ans. → First taking 90V Voltage Source →



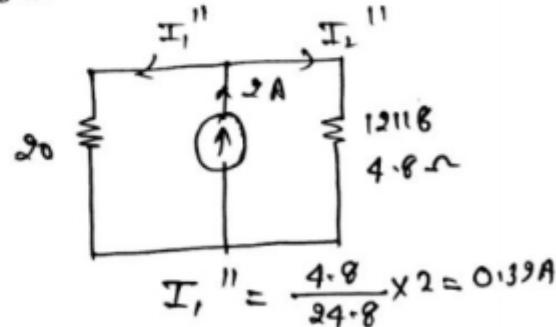
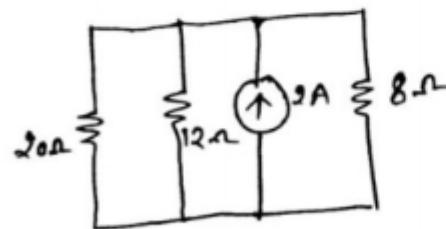
$$R = (12||8) + 2\Omega = \frac{96}{28} + 2\Omega = 24.8\Omega$$
$$I = \frac{90}{24.8} = 3.63 A$$

\* Now taking 60V Voltage Source →



$$R = (20||8) + 12 = \frac{160}{28} + 12 = 17.71\Omega$$
$$I' = \frac{60}{17.71} = 3.39 A$$
$$I_1' = \frac{8}{28} \times I' = 0.97 A$$

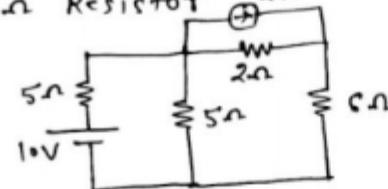
\* Now taking 2A Current Source



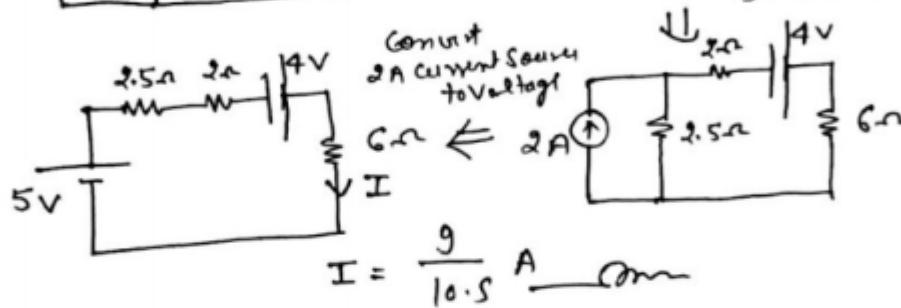
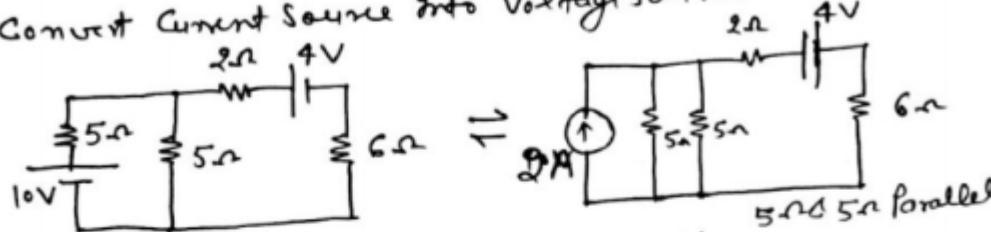
$$I_1'' = \frac{4.8}{24.8} \times 2 = 0.39 A$$

$$\text{total current in } 2\Omega = 3.63 - 0.97 - 0.39$$
$$= \underline{\underline{2.27 A}}$$

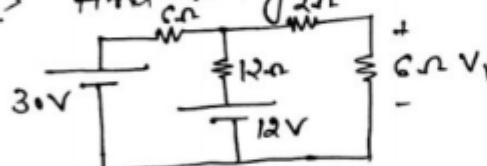
Ques.10 → Using Source Transformation find the current in  $6\Omega$  Resistor



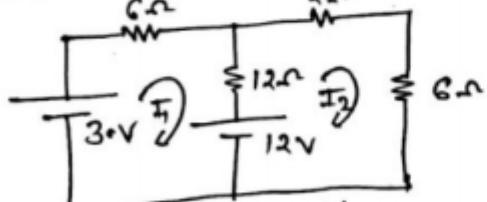
Ans. → Convert Current Source into Voltage Source



Ques.11 → Find Voltage across  $6\Omega$  resistor



Ans. → Solve the Circuit using Maxwell's theorem  
apply KVL in loop (i)



$$\text{Solve the eq. (i) & (ii)}$$

$$I_2 = \frac{12}{5} = 2.4 \text{ A}$$

$$6I_1 + 12(I_1 - I_2) + 12 - 30 = 0$$

$$3I_1 - 2I_2 = 3 \quad \text{---(i)}$$

apply KVL in loop (ii)

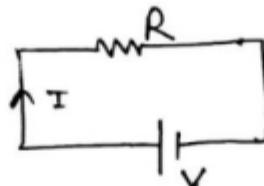
$$-12 + 12(I_2 - I_1) + 2I_2 + 6I_2 = 0$$

$$2I_1 - 3I_2 = -2 \quad \text{---(ii)}$$

$$\begin{aligned} \text{Voltage across } 6\Omega &= 2.4 \times 6 \\ &= 14.4 \text{ V} \quad \text{Ans.} \end{aligned}$$

Ques.12 > Explain R, L & C as a linear element.

Ans. > Resistor >



In case of Resistor ( $V = IR$ ) which is a linear relationship so Resistor is linear element.

Inductor & Capacitor both L & C voltage and current as function of time depend in a linear way on each other

Linearity means principle of superposition holds

$$f(ax+by) = af(x) + bf(y)$$

\* So In case of Inductor

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

+ capacitor

$$v = \frac{1}{c} \int r' dt$$


Integration & differentiation both follow principle of superposition.

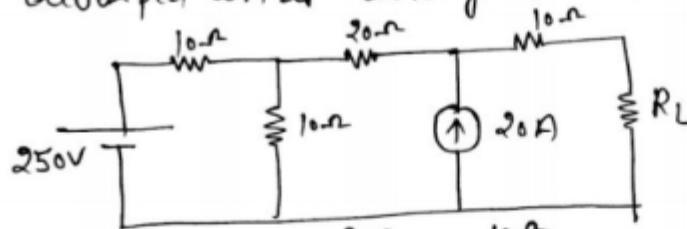
"So R, L, & C are be behave as a linear element."

$$V_1 + V_2 = L_1 \frac{di_1}{dt} + L_2 \frac{di_2}{dt}$$

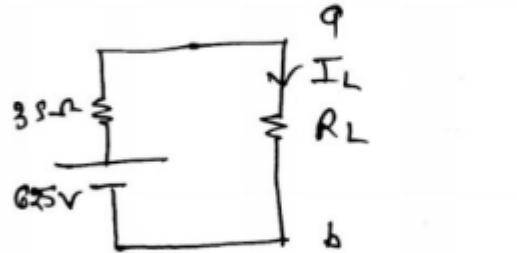
"Linear elements"

$$I_1 + I_2 = C_1 \frac{dV}{dt} + C_2 \frac{dV}{dt}$$

Ques.13) Find the Value of  $R_L$  so that Max. Power developed in it also find the Value of Max. Power



$$V_T = +40V + 295V = 335V$$

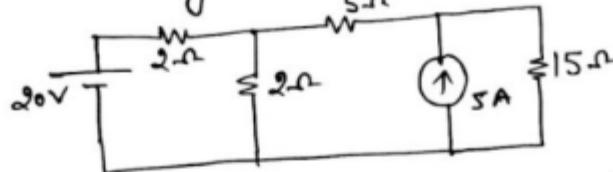


$$\text{for Max power } R_L = R_{\text{in}}$$
$$R_L = 35\Omega$$

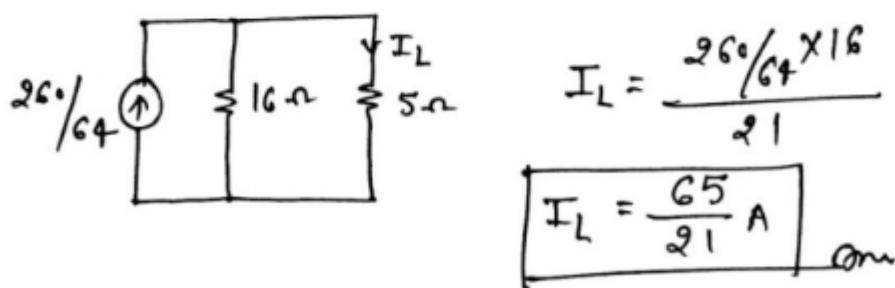
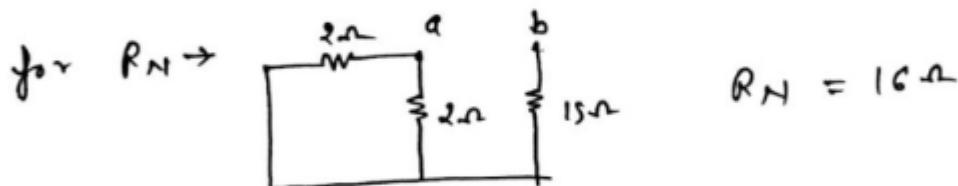
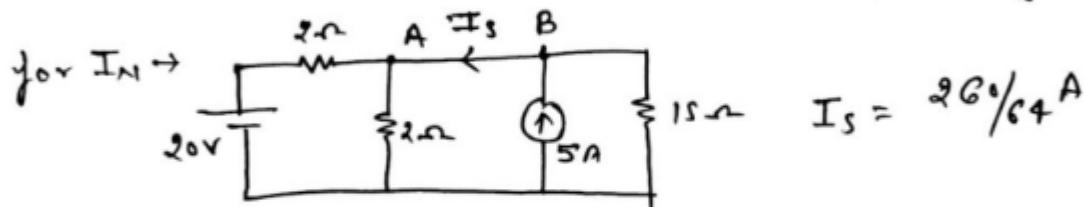
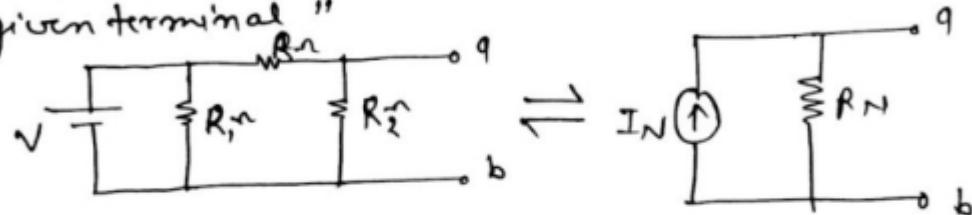
$$I_L = \frac{625}{70} = 8.926A$$

$$P_m = I_L^2 R_L = (8.926)^2 \cdot 35$$
$$P_m = 2788.58W$$

Ques.14> State Norton's Theorem. Then find current in  $5\Omega$  using Norton's Theorem.



Ans. > "According to this Theorem Any linear active, resistive, complicated Network can be converted into a equivalent circuit containing a current Source with Resistance in parallel b/w the given terminal"



# UNIT

# 2

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Ques.1 > For a given A.C. Voltage

$$V = 200\sqrt{2} \sin(100\pi t - 30^\circ)$$

- Find (i) Max value (ii) R.m.s Value (iii) Frequency (iv) Phase angle  
 (v) Average value (vi) Angular velocity (vii) Form Factor

Ans.1 >  $V = 200\sqrt{2} \sin(100\pi t - 30^\circ)$

general eq.  $V = V_m \sin(\omega t - \phi)$

on comparing  $\rightarrow V_m = 200\sqrt{2}$

$$\omega = 100\pi$$

$$\phi = 30^\circ$$

(i) Max Value  $V_m = 200\sqrt{2}$

(ii) R.m.s. Value  $V_{rms} = \frac{V_m}{\sqrt{2}} = 200$

(iii)  $\omega = 2\pi f = 100\pi$

$$f = 50 \text{ Hz.}$$

(iv)  $\phi = 30^\circ$  Phase angle  $= 30^\circ$

(v)  $V_{av} = \frac{2V_m}{\pi} = \frac{400\sqrt{2}}{\pi}$

(vi). angular velocity  $\Rightarrow \omega = 100\pi \text{ rad/sec.}$

(vii)

$$\begin{aligned} \text{Form Factor} &= \frac{V_{rms}}{V_{av}} \\ &= \frac{V_m/\sqrt{2}}{2V_m/\pi} \\ &= 1.11 \end{aligned}$$

Peak Factor = 1.414

Ques.2 > Explain form factor & Crest or Peak factor.

Ans.2 > (a) Form Factor  $\rightarrow$  The ratio of Effective or R.M.S Value

to Average Value is known as Form Factor

$$\text{Form Factor} = \frac{\text{R.M.S Value of A.C}}{\text{Average Value of A.C}}$$

(b) Peak Factor  $\rightarrow$  The ratio of Max. Value to R.M.S Value  
 is known as peak or crest Factor.

$$\text{Peak Factor} = \frac{\text{Maximum Value of A.C}}{\text{R.M.S Value of A.C.}}$$

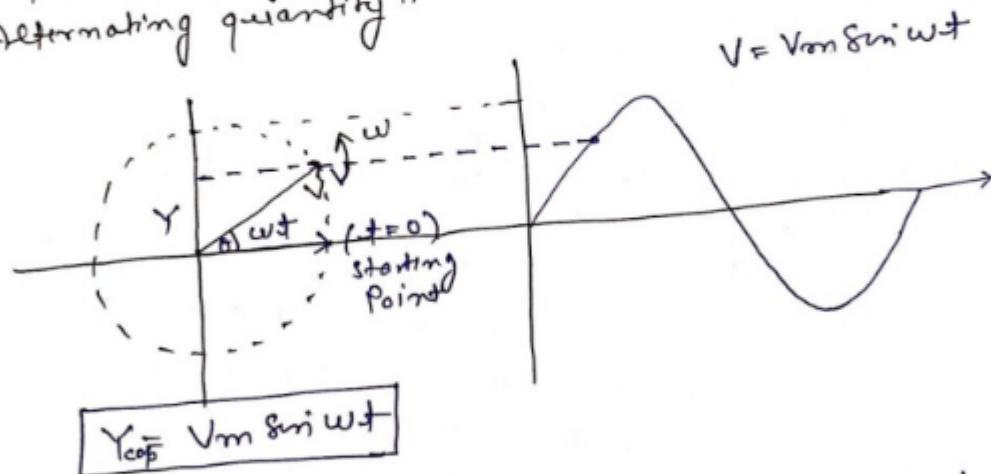
### Ques.3 > What is The Physical Significance of Phasor.

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Ans. > As we know Alternating quantities change its Magnitude and Direction Continuously so Mathematical analysis of A.C. is very complicated For Representing A.C. we use Phasor Method for Simplicity of Mathematical analysis

Phasor > Phasor is basically a Rotating line whose magnitude is equal to P.M.S value of alternating quantity and which is rotating in anticlockwise direction with angular velocity  $\omega$ .

" Y component of phasor gives the instantaneous Value of particular Alternating quantity, the starting Value of particular Alternating quantity, the starting point ( $t=0$ ) of phasor depends upon the equation of Alternating quantity "



- \* For Mathematical Analysis we represent phasor at ( $t=0$ ) only and then it is used for addition and subtraction of alternating quantities.

Ques 4 > Represent following Alternating quantities in phasor form then find the resultant of all.

$$V_1 = 100 \sin 500t$$

$$V_2 = 200 \sin(500t + 45^\circ)$$

$$V_3 = -50 \cos 500t$$

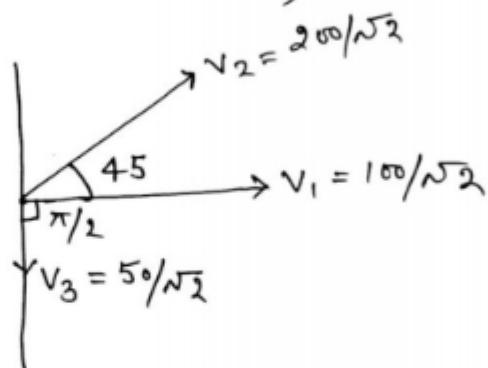
Ans. → For analysing all quantities must in phasor form

$$V_1 = 100 \sin 500t$$

$$V_2 = 200 \sin(500t + 45^\circ)$$

$$V_3 = 50 \sin(500t - \pi/2)$$

Phasor Representation >



Addition >

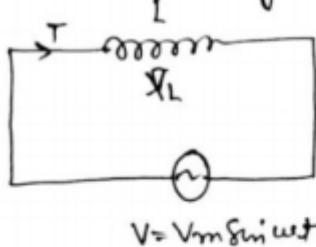
	$V_x$	$V_y$
$V_1$	$100/\cancel{\sqrt{2}}$	0
$V_2$	$100\sqrt{2}$	$141.42$
$V_3$	0	$-50$
$V_R$	$241.42$	$91.42$

$$V_R = \sqrt{V_x^2 + V_y^2} = V_{R\max} = 258.15 \text{ V}$$

$$\tan \phi = \frac{91.42}{241.42} \quad \phi =$$

Ques.5) Prove that in purely Inductive & Capacitive circuit  
Power Consumed is zero.

Ans. (i) Purely Inductive circuit  $\rightarrow$



When alternating current flows through the inductor an e.m.f. known as self induced e.m.f. is induced across the inductor and this induced e.m.f. opposes

the applied voltage and is given by

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

$$V = -e_L$$

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

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

Integrating both sides

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

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

$$I = \frac{V_m}{\omega L} \sin(\omega t - \pi/2)$$

$$I = I_m \sin(\omega t - \pi/2)$$

$$I_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L}$$

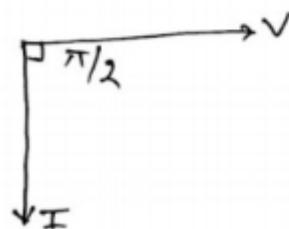
Now Instantaneous Power is

$$P_{in} = VI$$
$$= V_m \sin \omega t I_m \sin(\omega t - \pi/2)$$

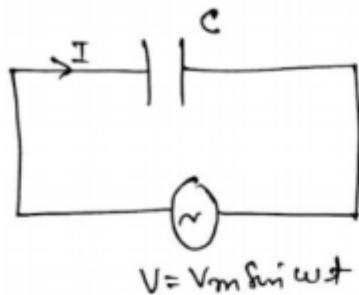
$$P_{in} = \frac{V_m I_m}{2} \sin 2\omega t$$

$$P_{av} = 0$$

because average value of  $\sin 2\omega t$  in half cycle is zero.



### iii) Purely Capacitive circuit



at particular time charge stored in capacitor is given by

$$Q = CV$$

$$Q = C V_m \sin \omega t$$

now

$$I = \frac{dQ}{dt}$$

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

$$I = V_m \omega C \sin(\omega t + \pi/2)$$

$$I = \frac{V_m}{1/X_C} \sin(\omega t + \pi/2) = \frac{V_m}{X_C} \sin(\omega t + \pi/2)$$

where  $X_C \rightarrow$  Capacitive reactance

\* Now instantaneous power across capacitor

$$P_{im} = VI$$

$$= V_m \sin \omega t \cdot I_m \sin(\omega t + \pi/2)$$

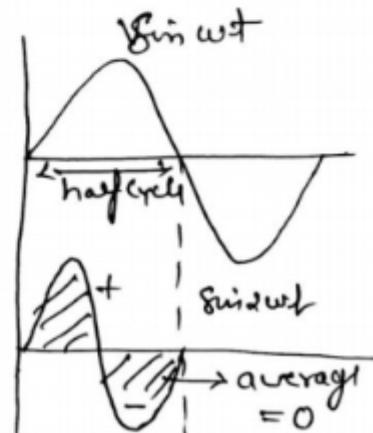
$$= \frac{V_m I_m}{2} \sin \omega t \cos \omega t$$

$$P_{im} = \frac{V_m I_m}{2} \sin 2\omega t$$

+ now average power  $\rightarrow$

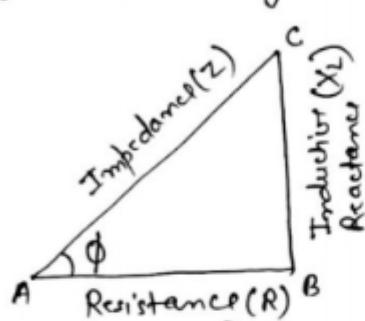
$$P_{av} = 0$$

because average value of  $\sin 2\omega t$  in half cycle is zero

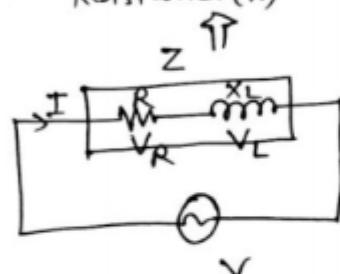


Ques. 6 → Explain Impedance Triangle with Suitable Diagram.

Ans. → When Resistance, Inductance and Impedance are Represented by Three Sides of Right-angle triangle such a Triangle is known as Impedance Triangle.



$$\left. \begin{array}{l} AB = \frac{VR}{I} = R \\ BC = \frac{VL}{I} = X_L \\ AC = \frac{V}{I} = Z \end{array} \right\}$$



\* the angle b/w AB & AC is known as phase angle

$$\text{Corr } \phi = R/Z$$

\* Corr  $\phi$  is the Power Factor of the Circuit.

Ques. 7 → Discuss about Apparent, True and Reactive Power.

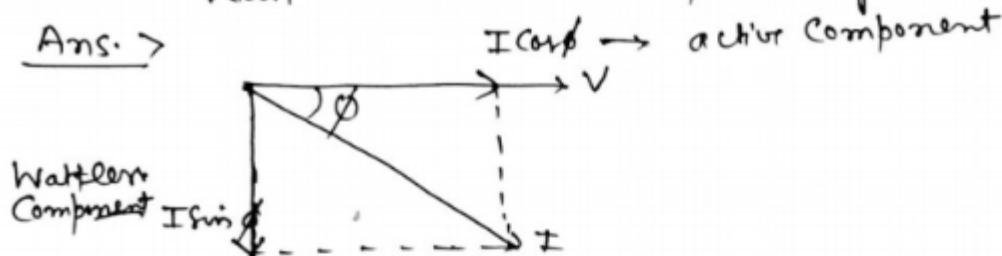
Ans. → (i) Apparent Power > The Product of r.m.s value of Voltage & current is known as Apparent Power.  $P_A = VI$  unit → V-A or KVA (Volt-Amperes)

(ii) True Power > When Apparent Power is multiplied by power factor then this product is known as True Power  $P_T = VI \text{Corr } \phi$  unit W or kW (Watt) or (kilowatt)

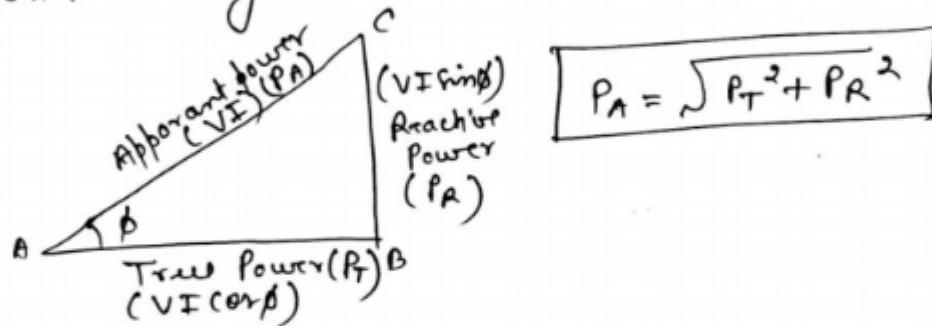
(iii) Reactive Power > The Product of apparent Power to the sine of angle b/w Voltage and current is known as Reactive Power.  $P_R = VI \sin \phi$  unit VA or KVAR ( Volt-Amper Reactive)

Ques 8 Explain Power Triangle the Discuss about Watt and Wattless Component of Current.

Ans. >



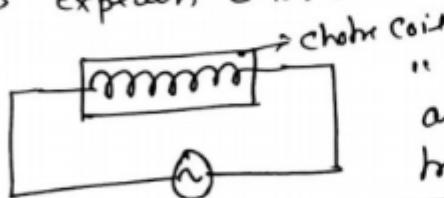
- \* The Component of current in phase with Voltage is known as active component or in Watt Component of current because it is Responsible for Power Consumption
- \* Wattless Component → The Component of current quadrature To Voltage is called Wattless Component it does not consume any power.



$$P_A = \sqrt{P_T^2 + P_R^2}$$

Ques 9 Explain choke coil then define quality factor.

Ans. >



"A coil having high Inductance and low resistance is known as choke coil"

$$\text{Power loss in choke coil} = \text{Iron-loss} + \text{Copper-loss}$$

Q Factor → Reciprocal of Power Factor is known as quality Factor

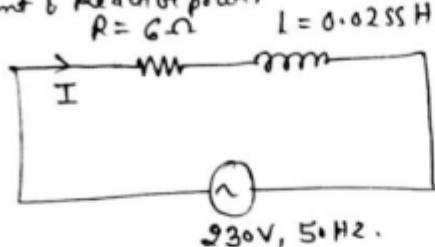
$$Q = 1/\cos\phi$$

"The quality factor of choke coil is very high" because  $\phi \rightarrow 90^\circ$

Ques. 9 → A coil having Resistance  $6\Omega$  and Inductance  $0.0255 \text{ H}$  is connected across  $230V, 50 \text{ Hz}$ .

A.C. Supply Calculate.

- (i) Impedance of coil (ii) Current in circuit (iii) Power factor  
(iv) Power Consumed (W) Instantaneous Value of Voltage & Current  
(v) Apparent & Reactive power



$$X_L = 2\pi f L$$
$$= 2\pi \times 50 \times 0.0255$$
$$= 8\Omega$$

(i)  $Z = \sqrt{R^2 + X_L^2} = \sqrt{6^2 + 8^2} = 10\Omega$

(ii)  $I = V/Z = \frac{230}{10} = 23 \text{ A}$

(iii)  $\cos\phi = R/Z = 0.6 \quad \phi = 53^\circ$

(iv)  $P = VI \cos\phi$   
 $= 230 \times 23 \times 0.6 = 3174 \text{ W}$

(v)

$V = 230\sqrt{2} \sin \omega t$

$I = 23\sqrt{2} \sin(\omega t - 53^\circ)$

(vi) Apparent & Reactive Power

$\Rightarrow$  Apparent  $P_A = VI$   
 $= 230 \times 23 = 5290 \text{ VA}$

5.290 KVA @m

$\Rightarrow$  Reactive power  $= VI \sin\phi$   
 $= 230 \times 23 \times 0.8$   
 $= 4232 \text{ VAR}$   
 $= \underline{4.232 \text{ KVAR}}$  @m.

Ques. 10 → The Instantaneous Value of Voltage and current in particular circuit is given by

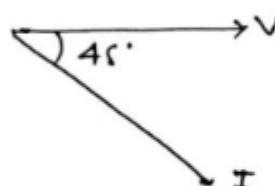
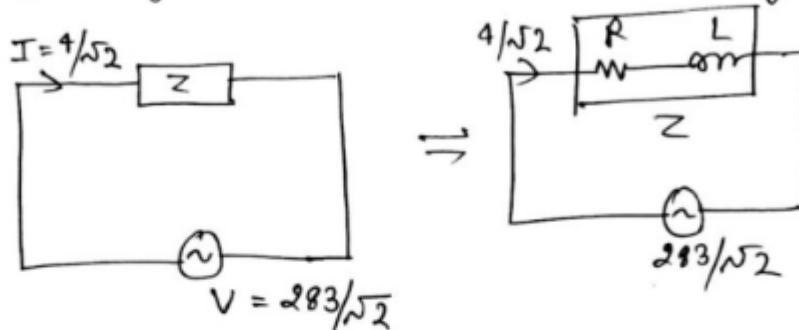
$$V = 283 \sin 314t$$

$$I = 4 \sin (314t - 45^\circ)$$

Find (i) Circuit elements & their value

(ii) Power factor and Power consumed by circuit.

Ans. 10



The current  $I$  lags behind the supply voltage by  $45^\circ$  so circuit contains  $R$  &  $L$

$$\text{now } Z = V/I = \frac{283/\sqrt{2}}{4/\sqrt{2}} = 70.75 \Omega \text{ on}$$

$$\cos \phi = R/Z \text{ so } R = Z \cos \phi \\ = 70.75 \cos 45 \\ = 50 \Omega$$

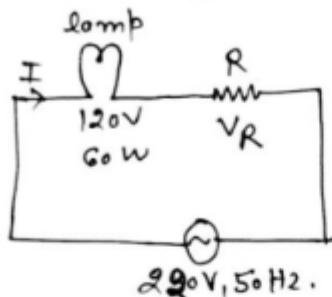
$$X_L = Z \sin \phi \\ = 50 \Omega \\ 2\pi f L = 50 \Omega \Rightarrow L = \frac{50}{2\pi f} = 0.159 \text{ H on}$$

$$(ii) \text{ Power Factor } \Rightarrow \cos \phi = \cos 45 = 0.707 \text{ (lagging)}$$

$$P = VI \cos \phi \\ = \frac{283}{\sqrt{2}} \times \frac{4}{\sqrt{2}} \times 0.707$$

Q.71 A, 60 W, 120V lamp connected across 220V, 50Hz A.C. Supply find the value of (i) Resistor (ii) Inductor connected in Series with the lamp so that lamp runs on correct voltage.

Ans. > (i)

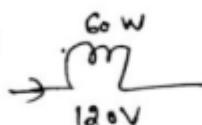


"Lamp to be considered as pure Resistor"

$$V_R + 120 = 220$$

$$V_R = 100 \text{ V}$$

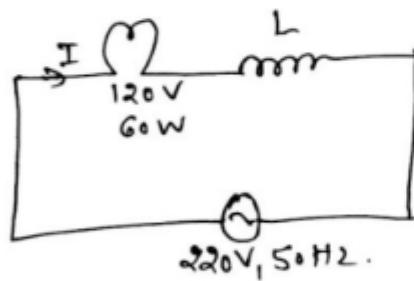
for lamp



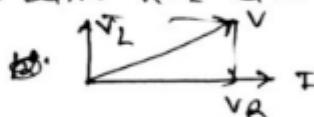
$$\begin{aligned} P &= VI \\ I &= 60/120 \\ &= 0.5 \text{ A} \end{aligned}$$

$$\begin{aligned} IR &= 100 \text{ V} \\ R &= 200 \Omega \end{aligned}$$

(ii) for Inductor  $\rightarrow$



\* If Inductor is connected in Series then it behaves as like R-L circuit



$$V_R^2 + V_L^2 = V$$

$$(120)^2 + (IX_L)^2 = 220$$

$$IX_L = 184.4$$

$$X_L = \frac{184.4}{0.5}$$

$$L = 1.174 \text{ H}$$

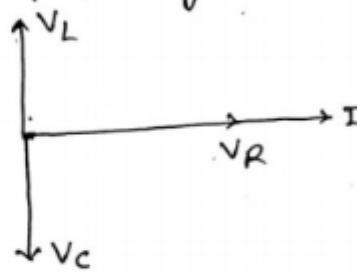
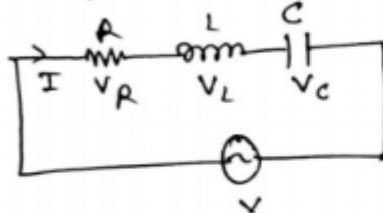
Ques.12) What is Resonance?

Ans.) The Resonance is a phenomenon which takes place in the circuit containing two types of Energy storing element (like Inductor & Capacitor) such that Energy can interchange b/w them.

" At Resonance the Voltage & Current of R-L-C Ckt becomes in same phase "

Ques.13) Define Resonant frequency and Derive the expression for it (for Series R-L-C Ckt).

Ans.) The frequency at which Resonance takes place is known as Resonant frequency.



Resonance takes place when

$$V_L = V_C$$

$$IX_L = IX_C$$

$$X_L = X_C$$

$$2\pi f_r L = 1/2\pi f_r C$$

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

$$V_L = IX_L$$

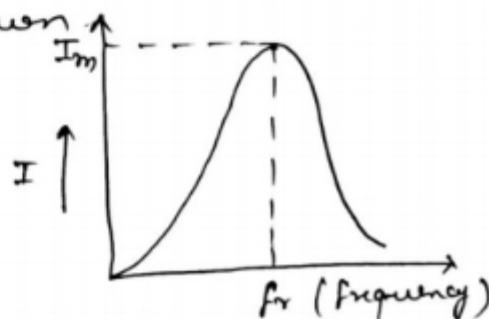
$$V_C = IX_C$$

$$V_R = IR$$

Ques.14) What is Resonance curve.

Ans.) The Curve Drawn b/w current & frequency for Series R-L-C Ckt is known as Resonant Curve

$f_r$  → frequency at which Voltage & current becomes in same phase.

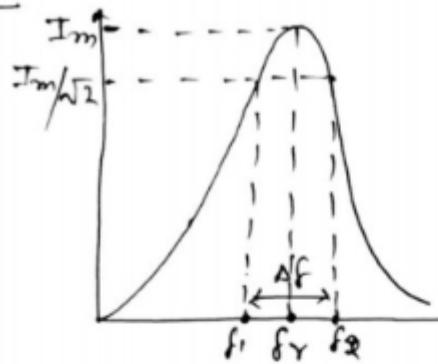


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Ques. 15 > Explain Selectivity & Bandwidth.

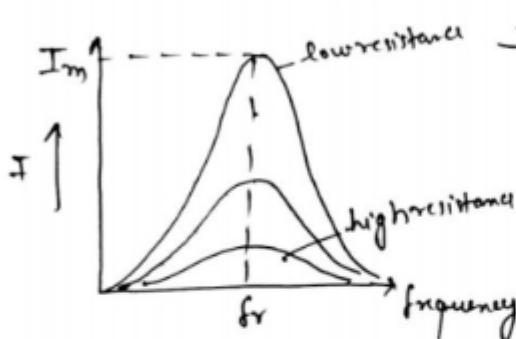
www.aktutor.in

Ans. >



Bandwidth → The band of frequencies either side of Resonance frequency where current becomes  $1/\sqrt{2}$  times maximum current.

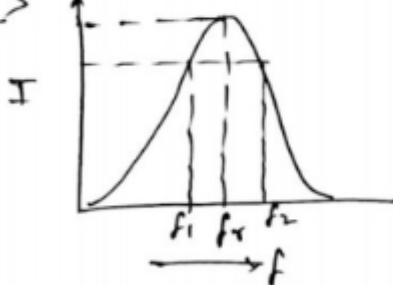
$$\boxed{\Delta f = f_2 - f_1} \text{ bandwidth}$$



Selectivity → If Resonant Curve is highly peaked then it is high Selective & if the curve is flat then it is low Selective. Selectivity depends upon Resistance of cht.

Ques. 16 > Derive the Expression for Bandwidth in Series R-L-C. cht >

Ans. >



$\omega_1, \omega_2$  Corresponding frequencies of point where current is  $I_m/\sqrt{2}$   
\* for maximum current  
+  $Z = R$   
+ if  $I = I_m/\sqrt{2} = \frac{V}{\sqrt{2}R}$   
means  $Z = \sqrt{2}R$

$$\text{Now } \rightarrow \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{2}R$$

$$X_L - X_C = \pm R$$

⇒ for lower cut off frequency  $\omega_1 \rightarrow$

$$\omega_{1,L} = 1/\omega_{1,C} = -R$$

$$\omega_{1,L}^2 C - L + R\omega_{1,C} = 0$$

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- Dividing whole eq. by LC

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

now  $\omega_1 = \frac{-R/L \pm \sqrt{(R/L)^2 + 1/LC}}{2}$

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

let  $R/2L = \alpha$        $\omega_r = 1/\sqrt{LC}$

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

$$\boxed{\omega_1 = -\alpha \pm \sqrt{\alpha^2 + \omega_r^2}}$$

Discarding negative frequency

$$\omega_1 = -\alpha + \sqrt{\alpha^2 + \omega_r^2}$$

\* for upper cut-off frequency  $\omega_2 \rightarrow$

$$X_L - X_C = +R$$

$$\omega_2 L - 1/\omega_2 C = R$$

$$\boxed{\omega_2 = +\alpha + \sqrt{\alpha^2 + \omega_r^2}}$$

now band width  $\omega_2 - \omega_1 = 2\alpha$

$$f_2 - f_1 = \frac{R}{2\pi L}$$

$$\boxed{Df = R/2\pi L}$$

also  $\omega_1 \omega_2 = \alpha^2 + \omega_r^2 - \alpha^2$

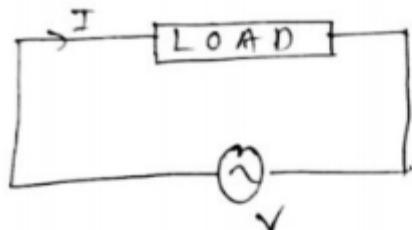
$$\omega_1 \omega_2 = \omega_r^2$$

$$\omega_1 \omega_2 = \omega_r^2$$

$$\boxed{f_1 f_2 = f_r^2}$$

Ques.17) Write Down Disadvantages of low power factor How can we Improve power factor.

Ans.7



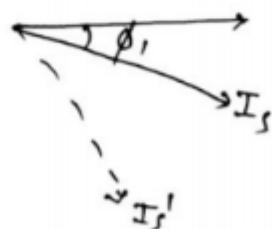
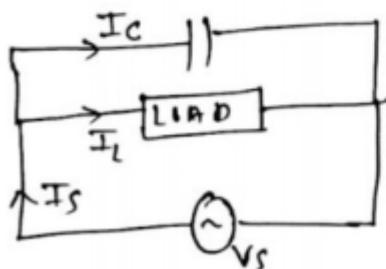
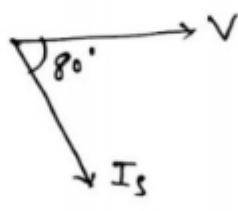
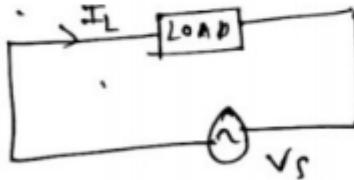
The Current for a Given load Supplied at Constant Voltage is given by

$$I = \frac{P}{V \cos \phi}$$

- if  $\cos \phi$  is low then current is high which result following Disadvantages →

- (i) Rating of generator's and Transformer's are proportional to their output current hence inversely proportional to power factor.
- (ii) The Conducting material required is proportional to current so large conducting material required for transmission of power at low power Factor.
- (iii) copper loss is proportional to current so low power factor result High Copper-loss ( $I^2 R$ ).

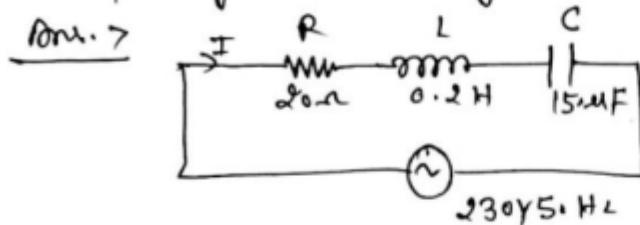
Power Factor Improvement → (i) by using capacitor with parallel to load  $\rightarrow$



- (ii) by using Induction motor with Phase advance.

Ques.18 A Series R-L-C Circuit consisting  $R = 20\Omega$ , Inductance  $0.2\text{H}$  and a Capacitance of  $150\mu\text{F}$  is connected across a  $230\text{V}, 50\text{Hz}$ . source. Calculate.

- Impedance
- The current
- Power Factor
- Resonant frequency
- Quality Factor.



$$X_L = 2\pi f L \\ = 2\pi \times 50 \times 0.2 \\ = 62.83\Omega$$

$$X_C = \frac{1}{2\pi f C} = 21.22\Omega$$

- Impedance  $Z = \sqrt{R^2 + (X_L - X_C)^2} \\ = \sqrt{(20)^2 + (62.83 - 21.22)^2} \\ Z = 46.167\Omega$

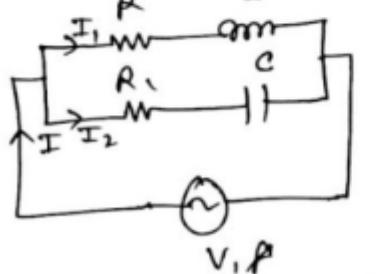
- Current  $I = V/Z = \frac{230}{46.167} = 4.98\text{A}$

- Power factor  $\text{Cos}\phi = P/Z = \frac{20}{46.167} = 0.4332$  lagging

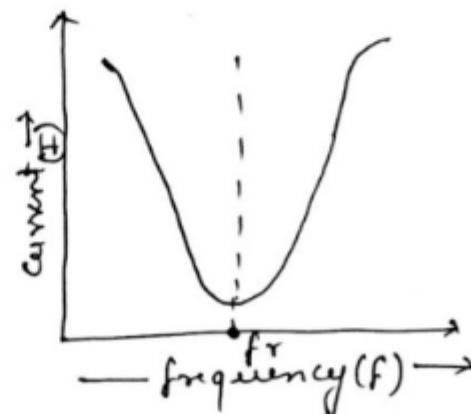
- Resonant Frequency  $f_r = \frac{1}{2\pi\sqrt{\frac{1}{LC}}} = 29.06\text{Hz}$

Ques.19 Drive the Expression for band width in Parallel R-L-C. circuit. (current resonance)

Ans.19



\* Current is minimum at Resonance.



in case of Parallel circuit at bandwidth frequency  
the net Susceptance  $B$  is equal to Conductance  $G$  so at  
frequency  $f_1$  the Net Susceptance

$$B_{L_1} - B_{C_1} = G$$

$$\text{at } f_2 \quad B_{C_2} - B_{L_2} = G$$

$$\text{Then } Y = \sqrt{G^2 + B^2} = \sqrt{2G}$$

$$\text{and } \phi = \tan^{-1} B/G = \tan^{-1} 1 = 45^\circ$$

Q Factor  $\Omega = \frac{\text{Circulating Current b/w } L \text{ & } C}{\text{Line current}}$

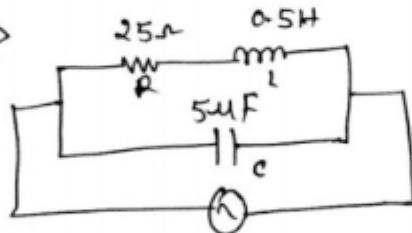
$$\text{now } I_C = 2\pi f_r C V$$

$$I = V/L/C R = VCR/L$$

$$\Omega = \frac{I_C}{I} = \frac{2\pi f_r L}{R} \quad \text{but } f_r = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

$$\boxed{\Omega = \frac{1}{R} \sqrt{\frac{L}{C}}} \quad \text{neglecting } R \text{ in } f_r$$

Ques 20



for the circuit find  
 (i) Resonant frequency  
 (ii) Impedance at Resonance  
 (iii) Bandwidth  
 (iv) Quality factor

$$(i) f_r = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} = 100.34 \text{ Hz.}$$

$$(ii) \text{ Impedance of cht at Resonance } Z = L/C R = 4000 \Omega$$

$$(iii) \Delta f = R/2\pi L = \frac{25}{2\pi \times 0.5} = 7.958 \text{ Hz.}$$

$$(iv) \text{ Quality Factor } Q = \frac{1}{R} \sqrt{\frac{1}{C}} = \frac{1}{25} \sqrt{\frac{0.5}{5 \times 10^{-6}}} = 12.65$$

# UNIT

3

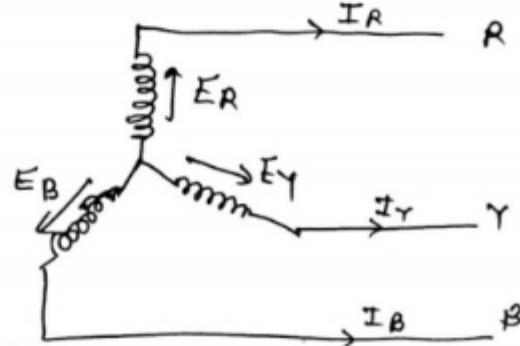
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Ques.1 > Write down Merits & Demerits of poly phase system over Single phase System.

- Ans.1 > (i) In a single phase system power delivered is pulsating even when Current and Voltage are in phase. the power is zero twice in a cycle. In case of heavy motor this causes vibration. this problem is resolved in three phase system.
- (ii) The rating of given machine increases with the increase in no of phases.
- (iii) Single phase Motor (Induction) has no starting torque but three phase induction motor has starting torque.
- (iv) Power factor of single phase motor is lower than that of poly phase motor of same rating.
- (v) Three phase system requires  $\frac{3}{4}$  th weight of copper of that required in single phase system to transmit the same amount of power at given voltage over same distance.
- (vi) Rotating magnetic field can be setup by poly phase system only.

Ques.2 > Prove that for a star connected system the line Voltage =  $\sqrt{3}$  Phase Voltage. ( $V_L = \sqrt{3} V_p$ ) .

Ans.2 >



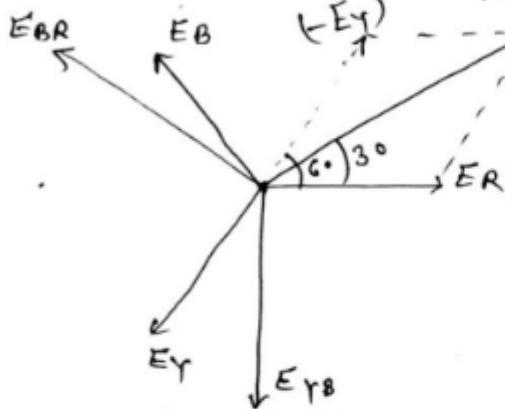
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\* Voltage b/w any two line is known as line voltage.

here the Phase Sequence is R, Y, B  
Line Voltages are  $E_{RY}$ ,  $E_{YB}$ ,  $E_{BR}$

now  $E_{RY} = E_R - E_Y$

$$= E_R + (-E_Y)$$



now from phasor Diagram

$$E_{RY} = \sqrt{E_R^2 + E_Y^2 + 2E_R E_Y \cos 60^\circ}$$

Let  $E_R = E_Y = E_B = \text{Phase Voltage}$   
( $E_p$ )

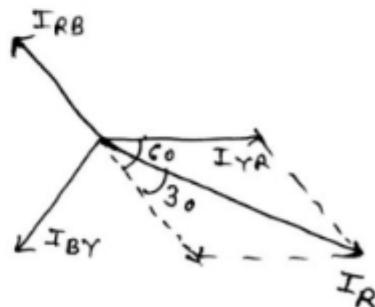
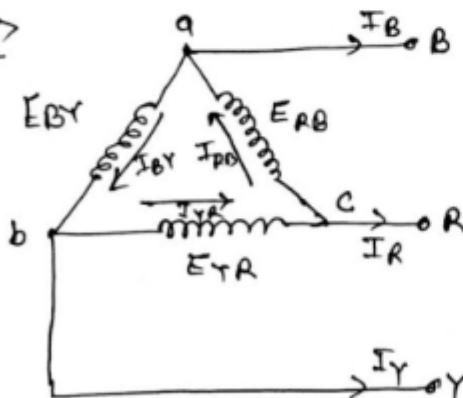
$$E_{RY} = E_L \text{ (Line Voltage)}$$

$$E_{RY} = \sqrt{E_p^2 + E_p^2 + 2E_p^2 \cos 60^\circ}$$

$$\boxed{E_L = \sqrt{3} E_p}$$

Ques. 3 For Delta Connected System Prove that  $I_L = \sqrt{3} I_p$ .

Ans. 3



from the figure we can say

line Voltage = Phase Voltage

$$\boxed{E_L = E_p}$$

$$I_R = I_{YR} - I_{RB}$$

$$I_R = I_{YR} + (-I_{RB})$$

the angle b/w  $I_{YR}$  &  $-I_{RB}$  is  $60^\circ$

$$\text{So } I_R = \sqrt{I_{YR}^2 + I_{RB}^2 + 2I_{YR}I_{RB} \cos 60^\circ}$$

$$\text{Now } I_{YR} = I_{RB} = I_p (\text{Phase Voltage})$$

$$I_R = \sqrt{I_p^2 + I_p^2 + 2I_p^2 \cos 60^\circ}$$

$$I_R = \sqrt{3} I_p$$

$$I_L = \sqrt{3} I_p$$

Ques. 4 A balanced Delta connected load of  $(12 + j9) \Omega$ /

phase is connected to 3phase 400V supply find

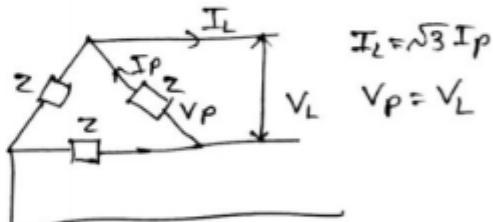
(i) Line current (ii) Power factor (iii) Power consumed (iv) Reactive power

$$\text{Ans. } R = 12 \Omega \quad X_L = 9 \Omega$$

$$Z = \sqrt{R^2 + X_L^2} \\ = 15 \Omega$$

$$\text{Corr} \phi = R/Z = 12/15$$

$$\phi = 36.87^\circ$$



$$(i) \text{ Phase current } I_p = \frac{V_p}{Z} = \frac{400}{15} = 26.67 \text{ A}$$

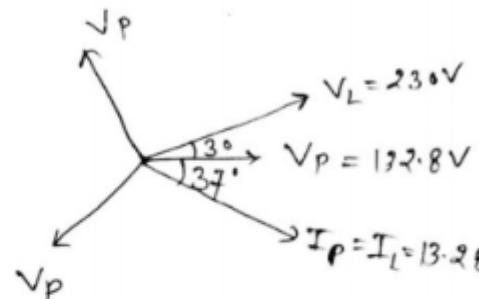
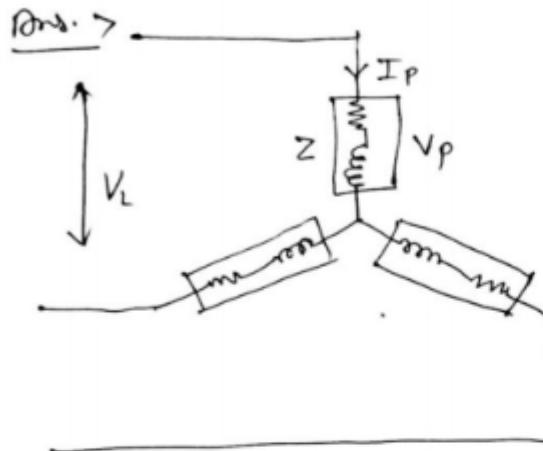
$$I_L = \sqrt{3} I_p \quad I_L = 46.2 \text{ A}$$

$$(ii) \text{ Corr} \phi = 12/15 = 0.8 \text{ (lagging)}$$

$$(iii) P = 3 V_p I_p \text{ Corr} \phi = 3 \times 400 \times 26.67 \times 0.8 = 25600 \text{ W}$$

$$(iv) P_R = 3 V_p I_p \sin \phi = 3 \times 400 \times 26.67 \times 0.6 = 19200 \text{ W}$$

Ques-5) A balanced star connected load of  $(8+j6)\text{-}\Omega$  per phase is connected to 3 phase, 230V, 50Hz. Supply. Find the line current, power factor, Volt amper reactive. Draw the phasor diagram for ch.



now given  $\rightarrow V_L = 230\text{V}$        $Z = \sqrt{8^2 + 6^2} = 10\text{-}\Omega$   
 $Z = 8+j6\text{-}\Omega$        $V_P = V_L/\sqrt{3} = 132.8\text{V}$

now       $I_P = \frac{V_P}{Z} = \frac{132.8}{10} = 13.28\text{A}$

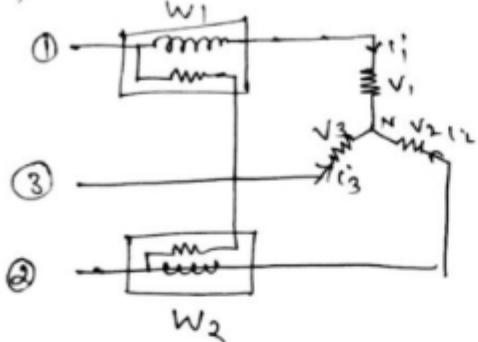
- (i)  $I_L = I_P = 13.28\text{A}$
- (ii)  $\cos\phi = R/Z = 0.8$  and  $\phi = 36.87$
- (iii)  $P = 3V_P I_P \cos\phi = 3 \times 132.8 \times 13.28 \times 0.8 = 4.232\text{kW}$
- (iv)  $P_F = 3V_P I_P \sin\phi = 3 \times 132.8 \times 13.28 \times 0.6 = 3.179\text{kvar}$

Ques-6) A 3 phase balanced load draws 10kW power from a 400V, 3phase, supply at 0.8 lagging power factor. determine (i) line current (ii)

Ans.)  $P = 10\text{kW}$      $V_L = 400\text{V}$      $\cos\phi = 0.8$   
 $P = 3V_P I_P \cos\phi = \sqrt{3} V_L I_L \cos\phi$   
 $I_L = 18.04\text{A}$  Ans.

Ques.7 Prove that Power can be measured by two wattmeter method for Star & Delta Connected System.

(i) Star Connected System>



Total Power which is given by

$$P = V_1 i_1 + V_2 i_2 + V_3 i_3 \quad \text{--- (i)}$$

apply KCL at node N

$$i_1 + i_2 + i_3 = 0$$

$$i_3 = -(i_1 + i_2)$$

Put the value of  $i_3$  in eq. (i)

$$P = V_1 i_1 + V_2 i_2 - V_3 (i_1 + i_2)$$

$$P = i_1 (V_1 - V_3) + i_2 (V_2 - V_3) \quad \text{--- (ii)}$$

\* Now for Wattmeter reading.

(W<sub>1</sub>) → the current coil having current  $i_1$  & Potential coil voltage is  $V_{13} = (V_1 - V_3)$  So Wattmeter reading is

$$W_1 = i_1 (V_1 - V_3)$$

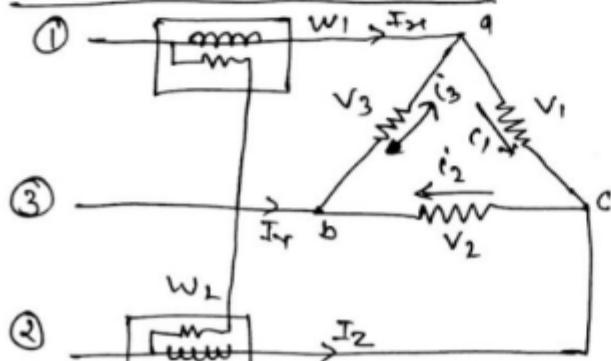
Similarly  $W_2 = i_2 (V_2 - V_3)$

by eq. (ii) total Power is now

$$P = W_1 + W_2$$

∴ total Power can be measured by two wattmeter Method

(ii) Delta Connected System>



Total Power in Delta Connected System is

$$P = V_1 i_1 + V_2 i_2 + V_3 i_3 \quad \text{--- (i)}$$

apply KV L in loop abcba

$$V_1 + V_2 + V_3 = 0$$

$$V_1 = -(V_2 + V_3)$$

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Put the Value of  $V_1$  in eq.(1)

$$P = V_1 i_1 + V_2 i_2 + V_3 i_3$$

$$= -(V_1 + V_3)i_1 + V_2 i_2 + V_3 i_3$$

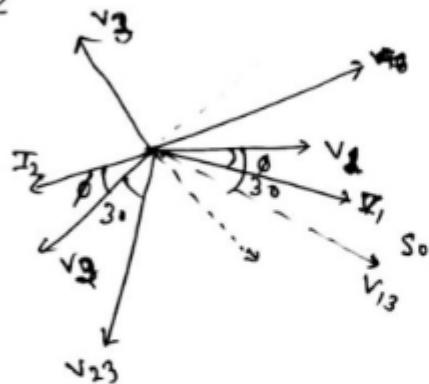
$$P = -V_3(i_1 - i_3) + V_2(i_2 - i_1)$$

Comparing with wattmeter reading  $\rightarrow$

$$P = W_1 + W_2$$

Ques. 8 Derive the Expression for power Factor by wattmeter reading.

Ans. 8



Wattmeter readings are

$$W_1 = i_1(V_1 - V_3)$$

$$W_2 = i_2(V_2 - V_3)$$

$$\text{for Inductive load} \rightarrow W_1 = V_L I_L \cos(30^\circ - \phi)$$

$$W_2 = V_L I_L \cos(30^\circ + \phi)$$

$$\text{now } W_1 + W_2 = V_L I_L \cos(30^\circ - \phi) + V_L I_L \cos(30^\circ + \phi)$$
$$= \sqrt{3} V_L I_L \cos \phi$$

$$W_1 - W_2 = V_L I_L \cos(30^\circ - \phi) - V_L I_L \cos(30^\circ + \phi)$$
$$= V_L I_L [2 \sin 30^\circ \sin \phi]$$
$$= V_L I_L \sin \phi$$

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{1}{\sqrt{3}} \tan \phi$$

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

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

Ques.1 > Explain Different type of Magnetic Material

Ans.1 > Magnetic Materials are basically three types

(i) Paramagnetic Material

(II) Diamagnetic Material

(III) Ferromagnetic Material

(i) Paramagnetic Materials > The materials which are not strongly attracted by a magnet are known as paramagnetic material.

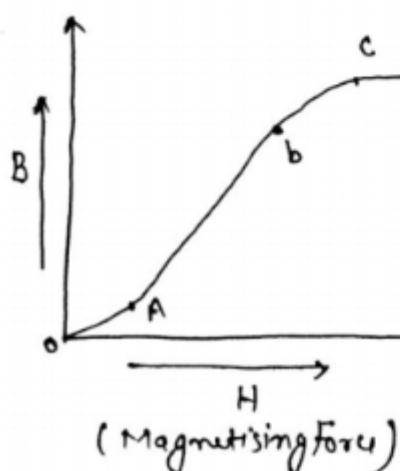
Ex. + aluminium, platinum, magnesium.

(II) Diamagnetic Materials > The materials which are repelled by a magnet such as zinc, mercury, lead are known as diamagnetic materials.

(III) Ferromagnetic Materials > The material which are strongly attracted by a magnet such as Iron, steel, Nickel are known as ferromagnetic materials.

Ques.2 > Explain B-H curve in detail >

Ans.2 > The Curve Drawn b/w Induction density B and Magnetising Force H is known as B-H curve or magnetising curve.



- \* in region OA increase in flux density is very small
- \* in region ab flux density is directly proportional to Magnetising force
- \* in Region bc again increase in flux density is very small.
- + beyond c there is no change in flux density on increasing the magnetising force this Region is known as Magnetic Saturation.

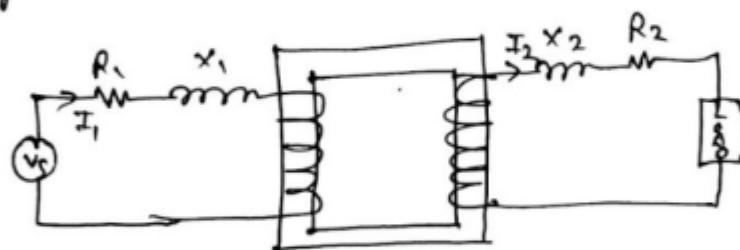
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Ques.3 > Explain Ideal & Practical Transformer.

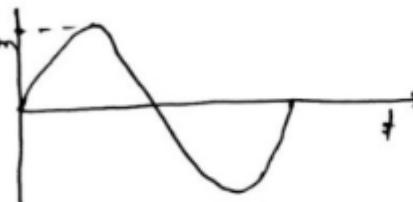
Ans.1 > For a Ideal Transformer we take following assumption's →

- (i) No winding resistance → The primary & Secondary winding's have no resistance.
- (ii) No magnetic leakage → There is No leakage flux all the flux setup is confined to the core.
- (iii) No Iron loss → There is no hysteresis and eddy current loss
- (iv) Zero magnetising current → The core has infinite permeability and zero reluctance.

Practical Transformer > The Transformer which Not follow the assumption of ideal Transformer is known as practical Transformer



Ques.4 > Write down E.m.f. Equation of transformer

Ans.2 >  + let flux associated with the core is

$$\phi = \phi_m \sin \omega t$$

+  $N_1$  &  $N_2$  no of turn in primary and secondary winding.

\* Now Induced e.m.f in Primary winding

$$e_1 = -N_1 \frac{d\phi}{dt} = -N_1 \omega \phi_m \cos \omega t \\ = N_1 \omega \phi_m \sin(\omega t - \pi/2)$$

Similarly

$$\begin{aligned}\mathcal{E}_2 &= -N_2 \frac{d\phi}{dt} \\ &= -N_2 \frac{d}{dt} (\Phi_m \sin \omega t) \\ &= N_2 \omega \Phi_m \sin(\omega t - \pi/2)\end{aligned}$$

Now ~~corr.~~ value of induced e.m.f.

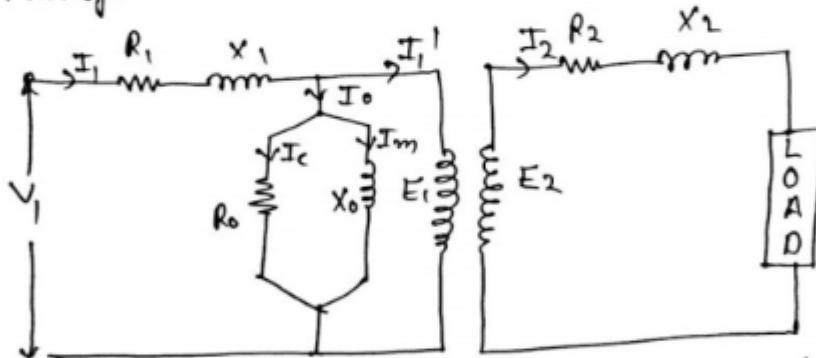
$$\begin{aligned}\mathcal{E}_1 &= \frac{N_1 \Phi_m \omega}{\sqrt{2}} \\ &= \frac{N_1 \Phi_m 2\pi f}{\sqrt{2}}\end{aligned}$$

$$\boxed{\mathcal{E}_1 = 4.44 f \Phi_m N_1 \text{ Volt}}$$

$$\boxed{\mathcal{E}_2 = 4.44 f \Phi_m N_2 \text{ Volt}}$$

Ques 5 > Draw and Explain Equivalent circuit of Transformer.

Ans. >



Equivalent ckt of any device can be quite helpful in predetermination of the behaviour of the device under various condition of operation.

$R_1, X_1 \rightarrow$  Primary Resistance and Reactance

$R_2, X_2 \rightarrow$  Secondary Resistance and Reactance.

$I_1, I_2 \rightarrow$  Primary & Secondary current

$R_o, X_o \rightarrow$  No-load Parameter of Transformer

$I_0 \rightarrow$  No-load current

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$I_1'$  → Counter balancing current which neutralizes the flux produced by secondary current.

$$I_1 = I_0 + I_1'$$

$$N_1 I_1 = N_2 I_2$$

Ques 6 → Explain Different types of losses present in Transformer.

Ans. → There are two types of losses present in Transformer

(i) Copper loss

(ii) Iron loss

Copper-loss → Copper loss is basically due to Resistance and it takes place in primary & secondary winding.

$$P_c = I_1^2 R_1 + I_2^2 R_2$$

Iron-loss → Iron loss is also two types.

(i) Hysteresis loss

(ii) Eddy current loss.

(i) Hysteresis loss → When alternating flux setup in the core the Hysteresis loop is traced out and area under Hysteresis loop represent Hysteresis loss. and it is given by

$$P_h = \eta (B_{max})^n f V \text{ Joule}$$

where  $\eta$  → Hysteresis coefficient

$B_{max}$  → Max. flux density

$f$  → Supply frequency

$V$  → Volume of core.

(ii) Eddy current loss → When Variable flux setup in the core the flux linkage with iron core is change due to which a current in

Induced in the core thus current is known as Eddy Current and result heating due to which is known as Eddy current loss. And is given by

$$P_e = K_c (B_{max})^2 f^2 t^2 v \text{ Watt}$$

Ques. 7 → What is the efficiency of Transformer. Derive the expression for Max. efficiency.

Ans. 7 → The efficiency of any machine is given by

$$\eta = \frac{\text{output}}{\text{Input}} = \frac{\text{output}}{\text{output} + \text{losses}}$$

for a fixed Input Voltage Iron-loss is constant but Copper loss is dependent upon Load current

$$\eta = \frac{\text{output}}{\text{output} + \text{Copper loss} + \text{Iron loss}}$$

let  $P_o \rightarrow$  output Power at full load

$P_i \rightarrow$  Iron loss

$P_c \rightarrow$  copper loss at full load

then efficiency at  $\alpha$ -load where  $\alpha$  is fraction of full load  $\rightarrow$

$$\eta = \frac{\alpha P_o}{\alpha P_o + P_i + \alpha^2 P_c}$$

for max. efficiency

$$\frac{d\eta}{d\alpha} = 0 \text{ now } \frac{d\eta}{d\alpha} = \frac{(\alpha P_o + \alpha^2 P_c + P_i)P_o - \alpha P_o(1+2\alpha P_i)}{(\alpha P_o + P_i + \alpha^2 P_c)^2}$$

$$P_i - \alpha^2 P_c = 0$$

$$\boxed{\alpha = \sqrt{\frac{P_i}{P_c}}}$$

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Ques. 8 → In a 25 kVA 2000V/200V Transformer The Iron and Copper losses are 400W and 400W respectively calculate the efficiency at half load 0.8 Power Factor lagging, also determine max. efficiency and corresponding load.

Ans. 8 →  $P_C = 400 \text{ W} = 0.4 \text{ kW}$   
 $P_I = 400 \text{ W}$

$$P_o = \frac{1}{2} \times V \times I \times \cos \phi$$

$$= \frac{1}{2} \times 25 \times 0.8$$

$$= 10 \text{ kW}$$

\* Copper loss at half load =  $(\frac{1}{2})^2 \times 400 = 0.1 \text{ kW}$

\* Efficiency at half load →

$$\eta = \frac{10}{10 + 0.1 + 0.2} \times 100 = 97.08\%$$

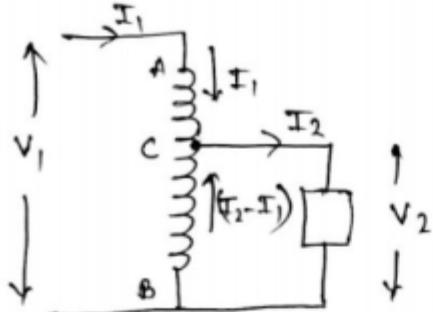
\* For max. efficiency  $\omega = \sqrt{\frac{P_I}{P_C}} \Rightarrow$

$$\text{Corresponding load} = 25 \times \sqrt{\frac{P_I}{P_C}} = 17.68 \text{ kVA}$$

$$\text{So max. efficiency} = \frac{17.68}{17.68 + 0.2 + 0.2} = 97.788\%$$

Ques. 9 → What is Auto Transformer. How Conducting Material Saved in Auto Transformer.

Ans. 9 → The Auto Transformer has same principal as like conventional two winding transformer the only difference is that in auto transformer primary and secondary windings are Interrelated.



$$\frac{V_2}{V_1} = \frac{E_{BC}}{E_{AB}} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$$

Conducting Material  $\rightarrow$  Conducting Material required is  
Directly proportional to cross sectional  
area and length of conductor so.

Conducting Material in ordinary Transformer

$$C_o \propto (N_1 I_1 + N_2 I_2)$$

$$C_o \propto 2N_1 I_1 \text{ because } N_1 I_1 = N_2 I_2$$

In auto Transformer

$$C_A \propto I_1 (N_1 - N_2) + N_2 (I_2 - I_1)$$

$$C_A \propto 2(N_1 - N_2) I_1$$

now

$$\frac{C_A}{C_o} = \frac{2(N_1 - N_2) I_1}{2 N_1 I_1} = 1 - \frac{N_2}{N_1} = 1 - K$$

$C_A = C_o(1-K)$

conducting Material saved.

$$\begin{aligned} C_o - C_A &= C_o - C_o(1-K) \\ &= C_o K \end{aligned}$$

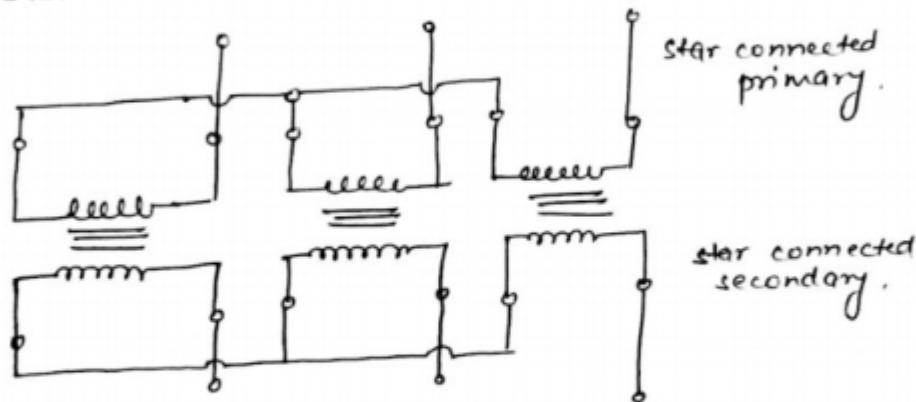
$\text{Saving} = K \times \text{Conducting Material in Ordinary}$

Ques.10 Explain Different type of Three phase Transformer Inter Connection.

Ans. The winding of Three phase Transformer are either Connected in Star or Delta. According To Primary & Secondary Winding Inter Connection there are four Method of Interconnection.

- (i) Y-Y (Star-Star) Connection
- (ii) Δ-Δ (Delta-Delta) Connection
- (iii) Y-Δ (Star-Delta) Connection
- (iv) Δ-Y (Delta-Star) Connection

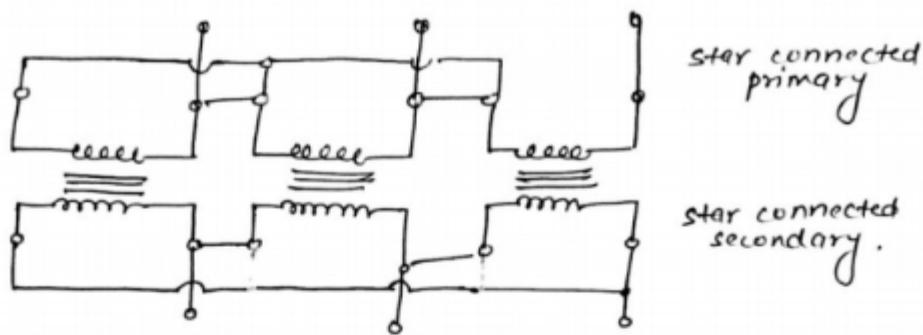
(i). Y-Y (Star-Star) Connection:



It gives line voltage  $\sqrt{3}$  times phase voltage. It is economical for small rating, high voltage transformers as the number of turns per phase and the amount of insulation required is less.

$$\text{Voltage ratio} = \frac{V_{L2}}{V_{L1}} = \frac{\sqrt{3} V_{P2}}{\sqrt{3} V_{P1}} = \frac{N_2}{N_1}$$

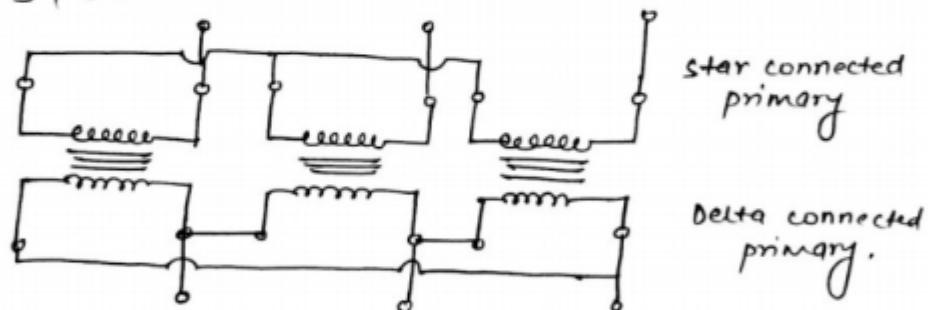
$$\text{Current ratio} = \frac{I_{L2}}{I_{L1}} = \frac{I_{P2}}{I_{P1}} = \frac{N_1}{N_2}$$



This arrangement is generally used in systems which carry large currents on low voltages. The conductor is required of smaller cross section as the phase current is  $\frac{1}{\sqrt{3}}$  times the line current.

$$\text{Voltage ratio} = \frac{V_{L2}}{V_{L1}} = \frac{V_{P2}}{V_{P1}} = \frac{N_2}{N_1}$$

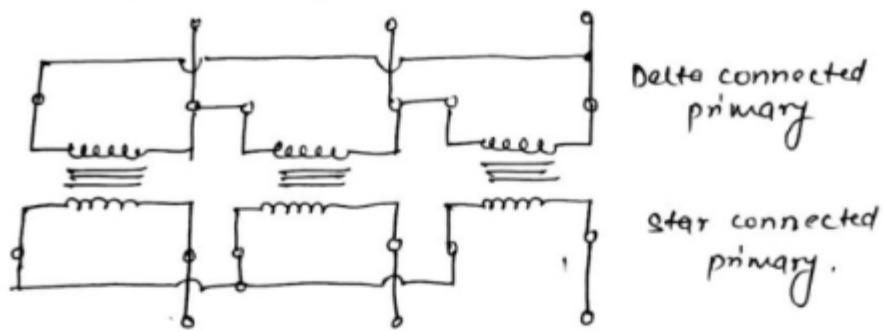
$$\text{Current ratio} = \frac{I_{L2}}{I_{L1}} = \frac{\sqrt{3} I_{P2}}{\sqrt{3} I_{P1}} = \frac{N_1}{N_2}$$

(iii).  $Y-\Delta$  (star-Delta Connection):

Such connections are used principally where the voltage is to be stepped down. The neutral of the primary winding is earthed.

$$\text{Voltage ratio} = \frac{V_{L2}}{V_{L1}} = \frac{V_{P2}}{\sqrt{3} V_{P1}} = \frac{1}{\sqrt{3}} \frac{N_2}{N_1}$$

$$\text{Current ratio} = \frac{I_{L2}}{I_{L1}} = \frac{\sqrt{3} I_{P2}}{I_{P1}} = \sqrt{3} \frac{N_1}{N_2}$$



Such connections are used where it is necessary to step up the voltage.

$$\text{Voltage ratio} = \frac{V_{L2}}{V_{L1}} = \frac{\sqrt{3} V_{P_L}}{V_{P_1}} = \sqrt{3} \frac{N_2}{N_1}$$

$$\text{Current ratio} = \frac{I_{L2}}{I_{L1}} = \frac{I_{P2}}{\sqrt{3} I_{P1}} = \frac{N_1}{\sqrt{3} N_2}$$

# UNIT

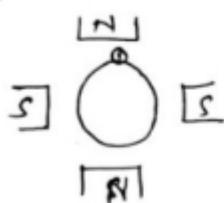
# 4

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< UNIT- 4 >  
< Electrical Machine >

Ques. 1 > Drive the Expression for e.m.f equation of D.C. Generator.

Ans. 1 >



Let  $\phi$  → flux per pole

$N$  → Speed of ~~motor~~ Generator in R.P.M.

$Z$  → Total no of Conductor

$P$  → no of Pole of Generator

\* Flux cut by 1 Conductor in one revolution =  $P\phi$

\* Flux cut by conductor in one second =  $P\phi \times N/60$

" now flux cut by conductor in one second is actually a average value of induced e.m.f. because

$$e = \frac{d\phi}{dt} \text{ so average value is } e = \frac{\Delta\phi}{\Delta t}$$

+ average value of induced e.m.f per conductor =  $P\phi \times N/60$

now no. of conductor in series is given by

$$Z^* = \frac{Z}{A} \text{ where } A \rightarrow \text{no of parallel Path}$$

+ Total Induced e.m.f. is given by  $E = \phi P \times N/60 \times Z^*$

$$E = \frac{\phi Z N P}{60 A}$$

$A = 2$  for wave winding

$A = P$  for slot winding

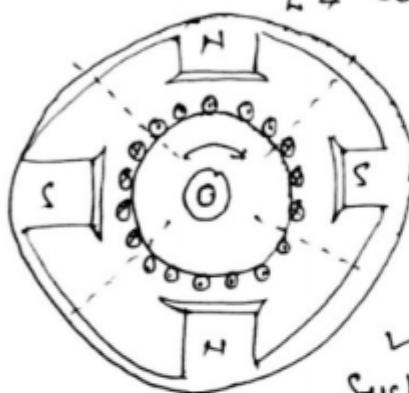
Ques 2 > Explain working principle of D.C. Motor >

Ans. > D.C. Motor is based on the Principle that when a current carrying conductor placed in a magnetic field force is experienced by the conductor and magnitude of force is given by  $F = B I L$

where  $B \rightarrow$  magnetic field strength

$I \rightarrow$  Current in Conductor

$L \rightarrow$  length of Conductor



+ When Motor is connected to D.C. Supply ~~as~~ Current starts to flow in Rotor Conductor through Commutator & Commutator Perform following Part.

~ "if convert D.C. current into A.C. Such that Conductor under different pole have current in opposite direction. So by Fleming's left hand rule ~~Force~~ in all Conductor must in same direction and unidirectional Torque is produced and motor start to run in particular direction"

~ also when particular Conductor comes influence of one pole to another pole the direction of current in it is reversed and Motor continues to run in particular direction.

Ques 3 > What is back e.m.f.?

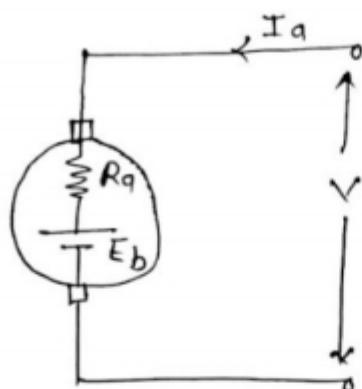
Ans. > When Rotor Conductor continues to run due to Motor action flux linkage with the conductor is change so e.m.f. is induced in the conductor as like generator. this Induced e.m.f. oppose the supply Voltage and is known as back e.m.f.

$$E_b = \frac{\phi Z N P}{60 A}$$

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Ques.4 > What is the Physical Significance of back e.m.f.

Ans. >



$$E_b = \frac{\phi Z N P}{60 A}$$

$$V = E_b + I_a R_a$$

$$I_a = \frac{V - E_b}{R_a}$$

\* Without back e.m.f. the speed of D.C. motor is undefined because there is no opposing factor to Supply.

\* Also back e.m.f. is responsible for producing Variable Torque in motor according to applied load. So motor becomes self regulating.

+ as the load is increases Motor reduces its speed so that  $E_b$  decreases and Torque increases.

Ques.5 > Drive the Torque equation of D.C. Motor.

Ans. > Let Motor is running with Speed  $N$  R.P.M. and Producing a Torque of  $T$  then

$$\begin{aligned} \text{Power developed in Motor} &= T \omega \\ &= T \frac{2\pi N}{60} \text{ Watt} \end{aligned}$$

Now this Mechanical Power is equivalent to electrical Power in armature ( $E_b I_a$ )

So

$$T \times \frac{2\pi N}{60} = E_b I_a$$

$$T = \frac{E_b I_a \times 60}{2\pi N} \quad \rightarrow (i)$$

$$\text{now } E_b = \frac{\phi Z N P}{60 A}$$

Putting the Value of  $E_b$  in eq. (i)

$$T = 0.159 \phi Z P \frac{I_q}{A} \text{ Newton-metre}$$

$$T \propto \phi I_q$$

Ques. 6 > A 4 pole lap wound armature has 144 slots with two coil sides per slot each coil having two turns if flux per pole is 20 mWb and speed of armature is 720 RPM find Induced Voltage.

Ans. >  $Z = \text{total slots} \times \text{no of coil sides per slot} \times \text{no of turns in each coil}$

$$= 144 \times 2 \times 2$$

$$Z = 576$$

$$E = \frac{\phi Z N P}{60 A} = \frac{20 \times 10^{-3} W_b \times 576 \times 720 \times 4}{60 \times 4}$$

$$E = 138.24 V$$

Ques. 7 > What is slip. Drive the expression for Rotor frequency in term of supply Frequency.

Ans. > The difference between Stator Field and Rotor Speed is known as slip and denoted by  $s$

$$S = \frac{N_s - N}{N_s}$$

\* It is expressed as fraction of Synchronous speed.

\* When Rotor is stationary the Supply frequency and Rotor Frequency is same.

$$f = \frac{N_s P}{120 f}$$

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but when Rotor start rotating in the direction of Field Relative speed b/w Rotor & Stator Decrease so frequency also decrease

$$f' = \frac{(N_s - N) P}{120 f}$$

$$= \frac{N_s - N}{N_s} \times \frac{N_s P}{120 f}$$

$$f' = S \times f$$

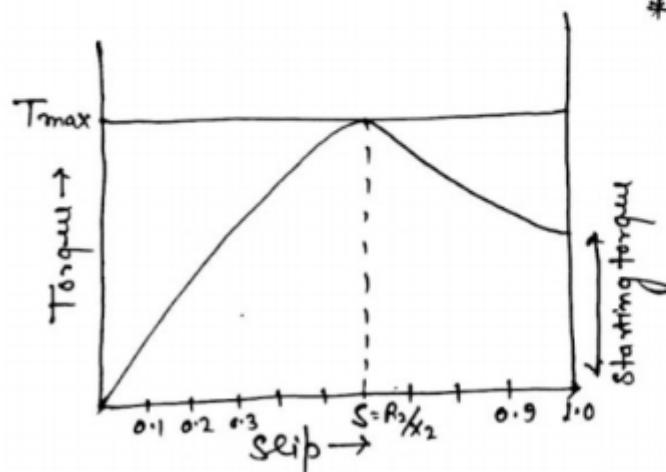
$$\boxed{f' = SF}$$

$$\boxed{S = \frac{N_s - N}{N_s}}$$

Ques. 8 > "Explain Torque vs. Slip characteristics of three phase induction motor."

Ans. > as we know Torque of Three phase induction motor is given by

$$T = \frac{KS R_2 E_2^2}{R_2^2 + S^2 X_2^2}$$



\* for starting torque very small  $S$ , we can neglect the  $S^2$  term and

$$\boxed{T \propto S}$$

and curve is straight line  
on increasing the slip  
Torque is also increase  
upto its become maximum  
at  $\boxed{S = R_2/X_2}$

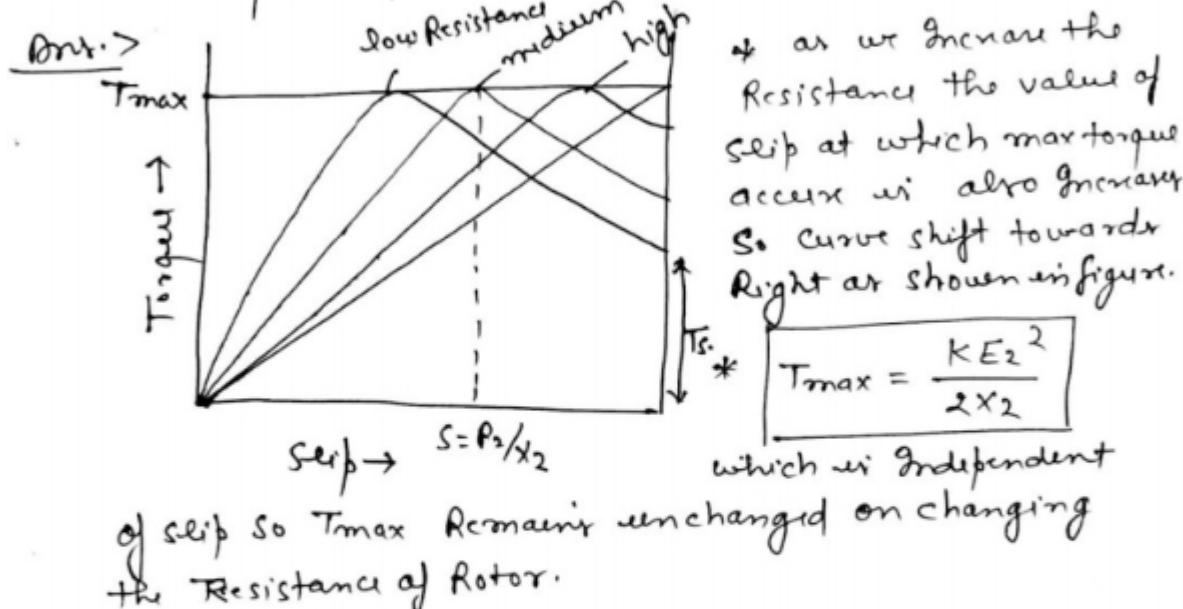
\* after max. torque if we further increase the slip now  
slip is sufficient so we cannot neglect the  $S^2$  term and

$$\boxed{T \propto 1/S}$$

Now Increasing slip further Torque start decreasing and curve is rectangular hyperbola.

\* If we further increase the slip Motor eventually stop and at this point Torque is equal to starting Torque.

Ques.9 Explain the effect of Rotor Resistance on Torque slip characteristics.



Ques.10 A 3phase 4-pole 5Hz. Induction motor is running at 1455 r.p.m. find the slip.

Ans.10  $N_s = 120f/p = \frac{120 \times 50}{4} = 1500 \text{ r.p.m.}$

actual speed  $n = 1455$

$$\text{Slip (s)} = \frac{N_s - n}{N_s} = \frac{1500 - 1455}{1500} = .03$$

$$.s = .03 \times 100$$

$$\boxed{.s = 3\%}$$

Ques 11 > A 3-pole, 4-Pole Induction motor connected to 3φ, 400V, 50 Hz. ac. Supply. Calculate.

- (i) Synchronous speed
- (ii) Rotor speed at 4% slip
- (iii) Rotor frequency when rotor speed is 600 r.p.m.
- (iv) Rotor induced e.m.f. when Rotor to stator turn ratio is 2:1 and stator is star connected and rotor speed is 600 r.p.m.

Ans > (i)  $N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ r.p.m.}$

(ii)  $\frac{N_s - N}{N_s} \times 100 = 4$   
 $\frac{1500 - N}{1500} = 0.04 \Rightarrow N = 1440 \text{ r.p.m.}$

(iii)  $N = 600 \quad S = \frac{1500 - 600}{1500} = 0.6$

$$f' = Sf = 50 \times 0.6 = 3 \text{ Hz.}$$

(iv)  $V_1 = \frac{400}{\sqrt{3}} \quad \frac{V_2}{V_1} = \frac{2}{1} \quad V_2 = \frac{800}{\sqrt{3}}$

$$V_2' = SV_2$$

for  $N = 600$

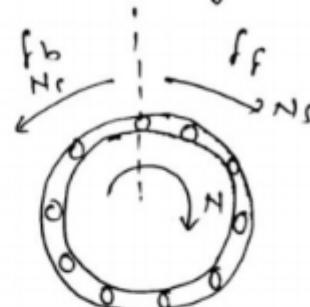
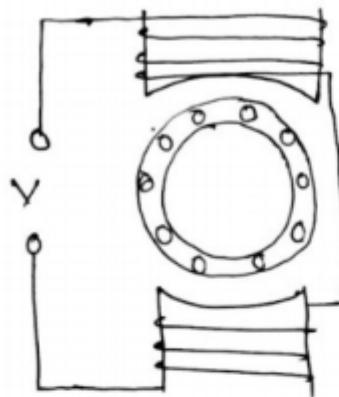
$$S = 0.6$$

$$V_2' = SV_2 \\ = 0.6 \times 800 / \sqrt{3}$$

$$\boxed{V_2' = 48 / \sqrt{3} \text{ V}} \text{ Ans.}$$

Ques. 12 > Explain operating principle of Single phase Induction Motor. also explain why it is not self-starting.

Ans. > The operation of Single phase Induction motor can be explained by "Double revolving field" theory.



Double revolving field theory

- \* When we give Single phase Supply to Motor pulsating Magnetic field is produced this pulsating magnetic field can be resolved into two Rotating Magnetic field of half its amplitude and Rotating in opposite direction with synchronous speed.
- \* When Rotor is stationary both field produce equal and opposite Torque so Net torque is zero and motor is not self starting.
- \* Now if we rotate rotor in particular lets in forward direction with speed  $N$  such that  $N \approx N_s$ 
  - ↳ Slip due to forward field  $S_f = \frac{N_s - N}{N_s} = S$
  - ↳ Slip due to backward field  $S_b = \frac{N_s - (-N)}{N_s} = \frac{2N_s - (N_s + N)}{N_s}$
  - $S_b = 2 - S$
- \* Now because  $2 - S \gg S$   
So current in conductor due to backward field is very high so magnetic field produced in rotor conductor due to backward field is also high and it completely finish the backward field due to which only forward

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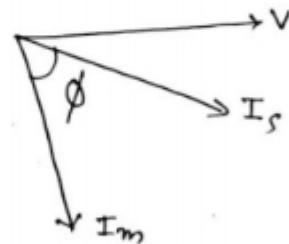
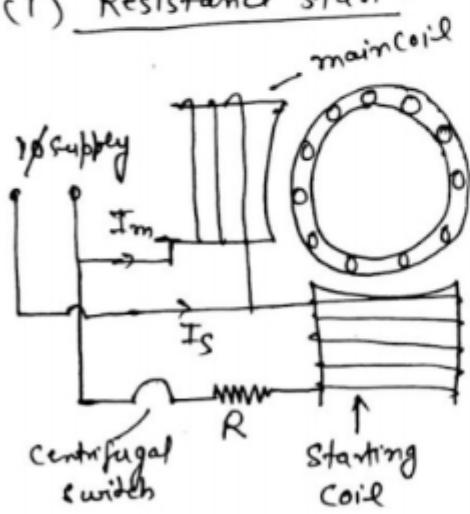
field remains and motor behave as like Three phase Induction motor and continue to run in forward direction.

Ques. 13 > Explain starting method of single phase Induction Motor. why it is not self starting.

Ans. > as we know there is No Torque in single phase Induction motor at starting due to pulsating field. So we produce Rotating Magnetic field at starting with the help of Auxiliary coil and at motor attain sufficient speed for proper operation we remove auxiliary coil with the help of Centrifugal switch. In starting method we try to develop phase difference b/w main coil and auxiliary coil near about ( $90^\circ - 50^\circ$ )

- (i) Resistance start Single phase Induction motor
- (ii) Capacitor start Single phase Induction motor
- (iii) Capacitor start Capacitor run Single phase Induction motor
- (iv) permanent capacitor Single phase Induction motor

(i) Resistance Start >



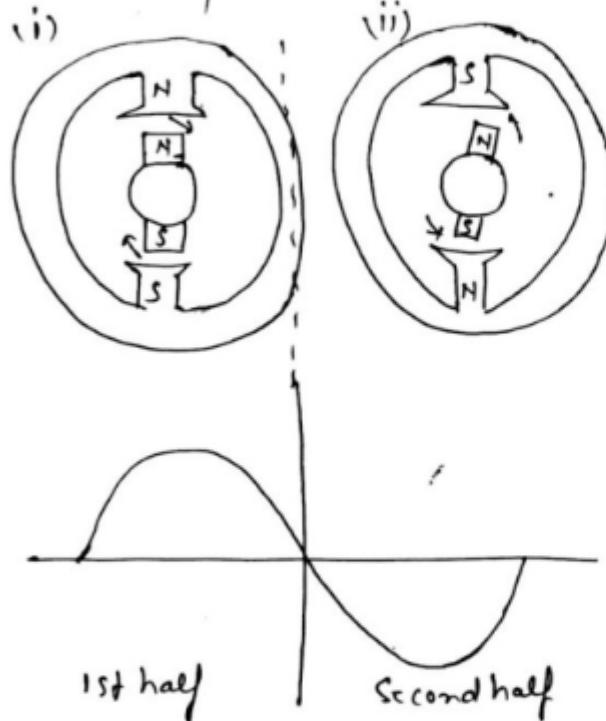
+ "Due to heavy resistor in starting coil a phase difference is developed b/w main coil and auxiliary coil which is not  $90^\circ$  but sufficient to develop a magnetic field (Rotating) which is capable for starting the low power Single phase Induction motor."

Magnetic field (Rotating) which is capable for starting the low power Single phase Induction motor."

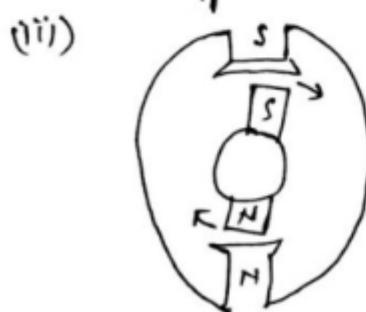
Ques.14 > Explain operating Principle of Synchronous Motor.  
the Draw V-curve. Why it is not self starting.

Ans. > Let Consider 3 $\phi$  2 pole Synchronous Machine  
in Three phase Synchronous Motor Stator windings  
are Connected to 3 $\phi$  A.C. Supply by Rotor windings are  
Connected to D.C. Supply.

- So Rotor pole Remains unchanged due to D.C. Supply.
- Stator pole change after each half cycle or half  
Time period N pole becomes S & S pole becomes N pole.



and motor Does not rotate in any direction and it is  
not Self starting.

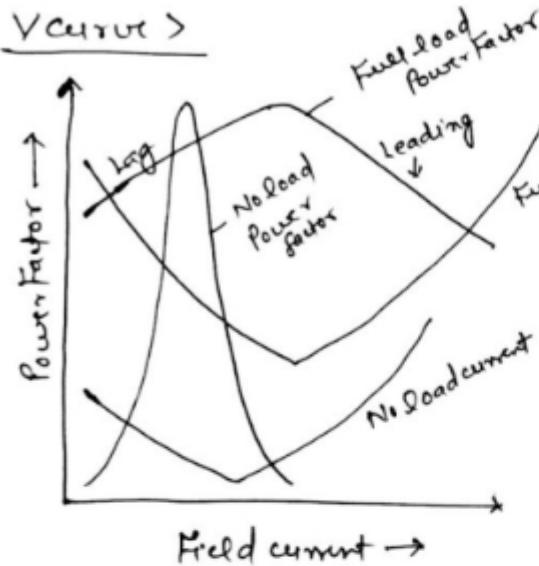


Now if Rotate the Rotor with speed  
So that in half time Period air comes  
in influence of one stator pole to adjacent  
stator pole and Now the Torque is  
Same as like figure (i) unidirectional  
Torque is produced and Motor start  
to Rotate in clockwise Direction.

- + let Condition (i) where  
North pole of stator repel  
North pole of Rotor So  
Torque is developed in  
clock wise direction and  
motor try to rotate in this  
direction.
- + but after half time period  
Stator North pole becomes  
South by Rotor Pole  
remain unchanged and  
Stator South pole attract the  
Rotor North pole hence  
Torque produced in anti  
clockwise direction
- + hence Torque is pulsating

So Required speed is calculated by →  

$$N_S = \frac{120f}{P}$$
 known as Synchronous speed



\* The Variation between current and Power Factor of a Synchronous Motor with Variation of Field current is Represented by curve these curve are known as V-Curve

Ques. 15 > Explain application of D.C. Motor.

Ans. -> (i) D.C. Series Motor > It is Variable speed motor and develops very high Torque at low speed. It has very high starting Torque therefore used in hoist, crane, Trolley cars, Conveyors, electric locomotive, elevator, etc.

(ii) D.C. Shunt Motor > It is Constant speed Motor and has medium starting Torque and therefore used for Constant speed applications like centrifugal pump, reciprocating pump, Fan, blowers, conveyor, woodworking machines, Machine tools, etc.

(iii) Compound Wound Motor's > Rarely used due to poor Torque characteristics. It is basically used in machine which is subjected to sudden application of heavy load like rolling mill, Punching & Shearing Machines, lifts, mini hoists etc.

Ques. 16) Explain application of Single phase Induction Motor and Three phase Synchronous Motor.

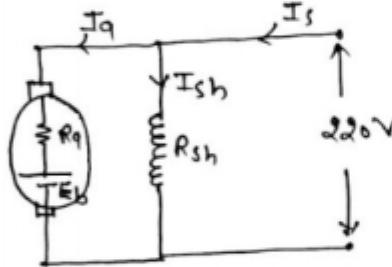
Ans.) (i) Three phase Synchronous Motor  $\rightarrow$  It is Constant Speed Motor hence used in -

- ✓ Power houses and substations for improving the Power Factor
- ✓ Regulate the Voltage at the end of Transmission line
- ✓ Fans, blowers, dc generator, line shafts, Constant speed application.

(ii) Single phase Induction Motor  $\rightarrow$  low load application like, home appliances like fan, washing machine, mixer, juicer, etc.

Ques. 17) A 220V D.C. Shunt Motor have 4 pole and take a line current of 3A at no-load while running at 1500 r.p.m. determine the Speed when motor take line current of 50A, armature field and armature resistances are  $400\Omega$  and  $0.2\Omega$  respectively.

Ans.)



$$\text{Case (i)} \rightarrow I_s = I_a + I_{sh}$$

$$I_{sh} = \frac{220}{400} = 0.55A$$

$$I_{a_0} = 3 - 0.55 = 2.45A$$

$$E_b = V - I_{a_0} R_q \\ = 220 - (2.45 \times 0.2)$$

$$E_{b_0} = 219.51V$$

$$\text{Case (ii)} \quad I_s = 50A$$

$$I_{a_1} = 50 - 0.55 = 49.45A$$

$$E_{b_1} = 210.11V = V - I_{a_1} R_q = 220 - (49.45 \times 0.2) \\ = 210.11V$$

$$\therefore N_f = N_0 \times \frac{E_{b_1}}{E_{b_0}} = 1500 \times \frac{210.11}{219.51} = 1436 \text{ r.p.m}$$

# UNIT

# 5

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### **1. Explain different types of wires and cables?**

According to types of insulation, the cables are of the following types:

i. Vulcanized Indian Rubber (VIR) Cables:

VIR cable consists of either tinned copper conductor covered with a layer of vulcanized Indian rubber insulation. Over the rubber insulation cotton tape sheathed covering is provided with moisture resistant compound bitumen wax or some other insulating material for making the cables moisture proof. The thickness of rubber insulation depends upon the voltage grade for which the cable is required. The copper conductor is tinned to provide protection against corrosion due to presence of traces of sulphur, zinc oxide and other mineral ingredients in the VIR.

ii. Tough Rubber Sheathed (TRS) or Cab Tyre Sheathed (CTS) Cables:

These cables are available in 250/440 volt and 650/1, 100 volt grades and used in CTS (or TRS) wiring. TRS cable is nothing but a vulcanized rubber insulated conductor with an outer protective covering of tough rubber, which provides additional insulation and protection against wear and tear. These cables are waterproof, hence can be used in wet conditions. These cables are available as single core, circular twin core, circular three core, flat three core, twin or three core with an earth continuity conductor (ECC). The cores are insulated from each other and covered with a common sheathing.

iii. Lead Sheathed Cables:

These cables are available in 240/415 volt grade. The lead sheathed cable is a vulcanized rubber insulated conductor covered with a continuous sheath of lead. The lead sheath provides very good protection against the absorption of moisture and sufficient protection against mechanical injury and so can be used without casing or conduit system. It is available as a single core, flat twin core, flat three core and flat twin or three core with an earth continuity conductor.

iv. Polyvinyl Chloride (PVC) Insulated Cables:

These cables are available in 250/440 volt and 650/ 1,100 volt grades and are used in casing-capping, batten and conduit wiring system. In this type of cable conductor is insulated with PVC insulation. Since PVC is harder than rubber, PVC cable does not require cotton taping and braiding over it for mechanical and moisture protection.

v. Weather Proof Cables:

These cables are used for outdoor wiring and for power supply or industrial supply. These cables are either PVC insulated or vulcanized rubber insulated conductors being suitably taped (only in case of vulcanized rubber insulated cable) braided and then compounded with weather resisting material. These cables are available in 240/415 volt and 650/1,100 volt grades.

vi. Flexible Cords and Cables:

The flexible cords consist of wires silk/cotton/plastic covered. Plastic cover is popular as it is available in different pleasing colours. Flexible cords have tinned copper conductors. Flexibility and strength is obtained by using conductors having larger number of strands. These wires or cables are used as connecting wires for such purposes as from ceiling rose

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to lamp holder, socket outlet to portable apparatus such as radios, fans, lamps, heaters etc. The flexibility of such wires facilitates in handling the appliances and prevents the wires from breakage. These must not be used in fixed wiring.

#### vii. XLPE Cables:

PVC and XLPE cables are built of insulation made of polymers. Polymers are substances consisting of long macromolecules built up of small molecules or groups of molecules as repeated units. These are divided into homopolymers and copolymers. Homopolymers are built by reactions of identical monomers. Copolymers are built up of at least two different kinds of monomers.

The mechanical properties of the polymers e.g. tensile strength, elongation elasticity and resistance against cold depend upon chemical structure. Their resistance against external chemical influences, acids, bases or oils together with their electrical and thermal characteristics are the decisive factors for the usefulness of cables insulated and sheathed with these materials.

## **2. What is need of earthing. Explain different types of earthing method.**

Earthing means connections of the neutral point of a supply system or the non-current carrying parts of electrical apparatus, such as metallic framework, metallic covering of cables, earth terminal of socket outlet, stay wires etc., to the general mass of earth in such a manner that at all times an immediate discharge of electrical energy takes place without danger.

Earthing is provided

1. to ensure that no current carrying conductor rises to a potential with respect to general mass of earth than its designed insulation.
2. to avoid electric shock to the human beings, and
3. to avoid risk of fire due to earth leakage current through unwanted path.

The various methods of earthing are

#### i. Strip or Wire Earthing:

In this system of earthing, strip electrodes of cross section not less than 25 mm<sup>2</sup> if of copper and 25 mm x 4 mm if of galvanised iron or steel are buried in horizontal trenches of minimum depth 0.5 metre. If round conductors are used, their cross-sectional area shall not be smaller than 3.0mm<sup>2</sup> if of copper and 6mm<sup>2</sup> if of galvanised iron or steel. The length of buried conductor shall be sufficient to give the required earth resistance. It shall, however be not less than 15 metres. The electrodes shall be as widely distributed as possible preferably in a single straight or circular trench or in a number of trenches radiating from a point. If conditions require use of more than one strip, they shall be laid either in parallel trenches or in radial trenches.

This type of earthing is used at places which have rocky soil earth bed because at such places excavation work of plate earthing is difficult.

#### ii. Rod Earthing:

In this system of earthing, 12.5 mm diameter solid rods of copper or 16 mm diameter solid rods of galvanised iron or steel or hollow section 25 mm GI pipes of length not less than 2.5 metres are driven vertically into the earth either manually or by pneumatic hammer. In

order to increase the embedded length of electrodes under the ground, which is sometimes necessary to reduce the earth resistance to desired value, more than one rod sections are hammered one above the other.

This system of earthing is suitable for areas which are sandy in character. This system of earthing is very cheap as no excavation work is involved.

### iii. Pipe Earthing:

This is the most common and best system of earthing as compared to other systems suitable for the same earth and moisture conditions.

In this method of earthing, a galvanised steel and perforated pipe of approved length and diameter is placed upright in a permanently wet soil.

The size of the pipe depends upon the current to be carried and type of soil. Usually the pipe used for this purpose is of diameter 40 mm and 2.5 metres in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends upon the moisture of the ground. The pipe is placed at a depth of 3.75 metres (minimum). The pipe is provided with a tapered casting at the lower end in Order to facilitate the driving. The pipe at the bottom is surrounded by broken pieces of coke or charcoal for a distance of about 15 cm around the pipe. Generally alternate layers of coke and salt are used to increase the effective area of the earth and to decrease the earth resistance respectively. Another pipe of 19 mm diameter and minimum length 1.25 metres is connected at the top of GI pipe through reducing socket.

### iv. Plate Earthing:

This is another common system of earthing. In plate earthing an earthing plate either of copper of dimensions 60 cm X 60 cm X 3 mm or of galvanised iron of dimensions 60 cm X 60 cm X 6 mm is buried into the ground with its face vertical at a depth of not less than 3 metres from ground level.

## 3. What is the effect of electric shock on human body?

Bruner (1967) states that the threshold of perception of electric shock is about 1 mA. At this level a tingling sensation is felt by the subject when there is a contact with an electrified object through intact skin. With the increase in magnitude of ac. the sensation of tingling gives way to contraction of muscles. The muscular contractions increase as the current is increased and finally a value of current is reached at which the subject cannot release his grip on the current carrying conductor. The maximum current at which the subject is still capable of releasing a conductor by using muscles directly stimulated by the current is called "let go current". The value of this current is significant because an individual can withstand, without serious after effects, repeated exposures to his 'let go current' for at least the time required for him to release the conductor. Also currents slightly in excess of 'let go current' would not permit the individual to release his grip from the conductor supplying current.

Based on the experiments conducted on males and females, it is generally accepted that the safe 'let go current' could be taken approximately 9 mA and 6 mA for men and women respectively.

At current levels higher than the 'let go current' the subject loses ability to control his muscle actions and he is unable to release his grip on the electrical conductor. Such currents are very painful and hard to bear. This type of accident is called 'hold-on-type' accident, and is

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caused by currents in the range 20-100 mA. These currents may also cause physical injury due to powerful contraction of the skeletal muscles. However, the heart and respiratory function usually continue because of uniform spread of current through the trunk of the body.

If current contacts contact skin and passed through the trunk, at about 100 mA and above, there is a likelihood of pulling the heart into ventricular fibrillation. In this condition, the rhythmic action of the heart ceases, pumping action stops and the pulse disappears. Ventricular fibrillation is a serious cardiac emergency because once it starts, it practically never stops spontaneously. It proves fatal unless corrected within minutes, since the brain begins to die 2 to 4 minutes after it is robbed of its supply of oxygenated blood.

At very high currents of the order of 6A and above, there is a danger of temporary respiratory paralysis and also of serious burns. However, if the shock duration is of only a very few seconds, there is a possibility of heart reverting to the normal rhythmic action.

The threshold of perception depends largely on the current density in the body tissues. It may vary widely depending upon the size of the current contact. At very small point contact, it is probable that even 0.3 mA current may be felt whereas a current in excess of perhaps 1 mA may not produce sensation if the contacts are somewhat larger. Similarly, depending on the size of contact, the threshold of pain may also be considerably above 1 mA, probably 10 mA if the contacts are large enough.

Besides the magnitude of current, the current duration and the relationship of current flow resistance are also important. Duration of less than 10 ms typically does not produce fibrillation whereas duration of 0.1 s or longer does. It has been found experimentally that the safe value of current in amperes (rms) which a human body can tolerate is given as

$$I = \frac{0.165}{\sqrt{t}} \text{ for } t < 3s \text{ and } I = 9mA \text{ for } t > 3s$$

where t is the time duration in seconds of the flow of current.

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Ans. In an electric power system switch gear is the combination of electrical disconnect switcher, fuse or circuit breaker used to control, protect and isolate electrical equipment. Following component are used to perform above mentioned function.

(i) Fuse → Simplest and cheapest Device for break the electrical connection under overload or short circuit protection.

The action of Fuse is based on flow of current through fuse wire if current exceed beyond limit then heat developed in wire which is more than melting point of wire so Fuse break the electrical connection. There are following types:

- (i) Round type (ii) Kit Kat type fuse (iii) Cartridge type
- (iv) HRC (v) Semiconductor Fuse unit.

(ii) Miniature Circuit Breaker (MCB) > It is used to protect wiring installations and sophisticated equipment against overcurrent and short circuit faults. The operation is based on bimetallic strip which deflects when heated by over current flowing through it hence releases the electrical connection. MCB are available with different current rating 5A to 160A.

(iii) Earth Leakage Circuit Breaker [ELCB] > It is device that provide protection against earth leakage. There are of two types:

- (i) Current operated earth leakage circuit breaker
- (ii) Voltage operated earth leakage circuit breaker

✓ Current operated ELCB is used when the product

of the operating current in ampere and the earth loop Impedance in ohms does not exceed 40.  $I_m Z_s \leq 40$

- \* Voltage operated ELCB is used when earth-loop Impedance exceeds the value applicable to fuse or other circuit breaker.

(iv) Molded Case Circuit Breaker (MCCB) > It is used to wide range of Voltage and frequency and have current rating upto 2500 A also trip setting is adjustable, also MCCB is larger than MCB. operating principle is based on bimetallic strip contact which expand and contracts in response to change in temp.

Ques. 3 > What is the difference b/w MCCB & MCB

MCB

- (i) Current rating up to 160A
- (ii) Size is small
- (iii) Trip setting is not adjustable
- (iv) Range of frequencies are narrow

MCCB

- (i) Current rating up to 2500 Amper
- (ii) Size is large in compare to MCB
- (iii) Tripping current is adjustable
- (iv) Range of Frequencies are wide.

Ques. 5) Explain ampere hour and watt-hour efficiency.

Ans. 5(i)) Ampere-hour efficiency  $\rightarrow$  ratio of Ampere hour of discharge to ampere hour of charge.

$$\eta_{A-h} = \frac{I_d T_d}{I_c T_c} \times 100$$

(ii) watt-hour efficiency  $\rightarrow$  Ratio of energy delivered in watt-hour during Discharge to energy consumed during charging.

$$\eta_{W-h} = \frac{V_d I_d T_d}{V_c I_c T_c} \times 100$$

$V_d$   $\rightarrow$  Discharge Voltage

$V_c$   $\rightarrow$  Charging Voltage

$T_d$   $\rightarrow$  Discharge time

$T_c$   $\rightarrow$  Charging time

$I_d$   $\rightarrow$  Discharge current

$I_c$   $\rightarrow$  Charging current

Ques. 6) A battery has taken charging current of 5.2 A for 24 hours at a voltage of 2.25 V while discharging it gave a current of 4.5 A for 24 hours at an average voltage of 1.85 V calculate ampere-hour and watt-hour efficiency.

Ans. 6) Given  $\rightarrow$

$$I_c = 5.2 \text{ A}$$

$$I_d = 4.5 \text{ A}$$

$$V_c = 2.25 \text{ V}$$

$$V_d = 1.85 \text{ V}$$

$$T_c = 24 \text{ hours}$$

$$T_d = 24 \text{ hours}$$

$$\text{now } \eta_{A-h} = \frac{T_d I_d}{I_c T_c} \times 100 = \frac{4.5 \times 24}{5.2 \times 24} \times 100 = \underline{\underline{86.54\%}}$$

$$\eta_{W-h} = \frac{V_d I_d T_d}{V_c I_c T_c} \times 100 = \frac{4.5 \times 1.85 \times 24}{5.2 \times 2.25 \times 24} \times 100 = \underline{\underline{71.15\%}}$$