CREDIT TO ASHISH JAIN

ELECTRICAL ENGINEERING

Units -

1) A.C. Circuits
2) D.C. Circuits
3) Magnetic Circuits
4) Transformers
5) Rotating Electrical Machines

Electricity

- Generation (G)
- Transmission (T_x)
- Distribution

11 kV, 3-ϕ (Phase)

Max^m

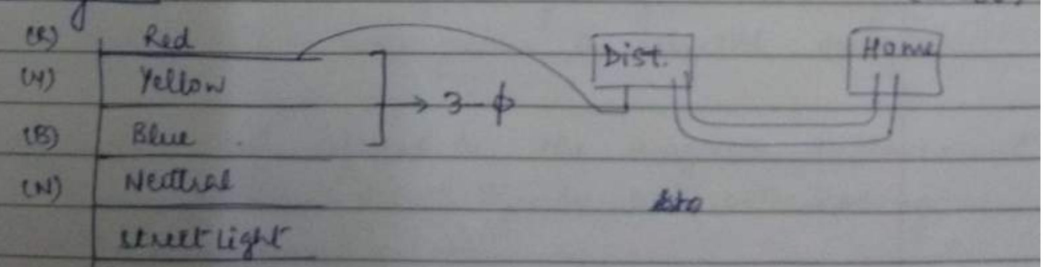
765 kV / 400 kV / 132 kV / 66 kV / 33 kV

$\longleftarrow T_x \longrightarrow$

33 kV / 11 kV / 440 V

$\longleftarrow$ Distribution $\longrightarrow$

5-Wire System:



Neutral $\rightarrow$ used for return path

Neutral & grounding (or Earthing) are different.

Resistor is a device & resistance is its property to oppose flow of charge.

Standard Rating -
230 V, 50 Hz, Single - Phase ($1-\phi$), A.C. supply

3-Pin
o → Earthing

o → Line
o → Neutral

Definitions - (Unit - 1)

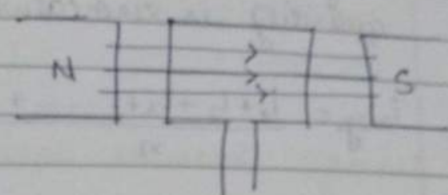
1) Current
2) Voltage
3) Electrical Power
4) Electrical Energy
5) Potential Difference
6) Potential
7) Charge
8) Resistance, Resistivity
9) Conductance
10) Conductivity
11) Permeability
12) Permittivity
13) Permeance
14) Ohm's Law
15) Series and parallel circuit
16) Current division and voltage division rule

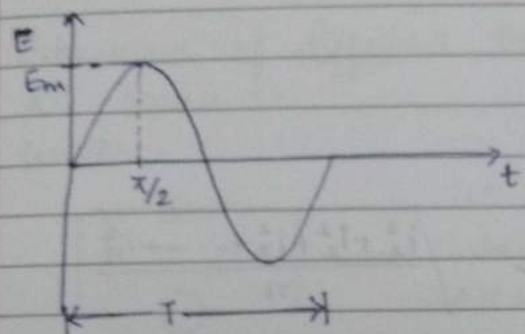
Unit - 1
A.C. Circuits

Generation of EMF-

$$e = -N\frac{d\phi}{dt} \quad \text{(Lenz's law)}$$

$$E = E_M \sin\omega t$$





T :- Time taken to complete one cycle
A :- Max^m value attained during cycle is amplitude
f :- No. of cycles produced in one second.

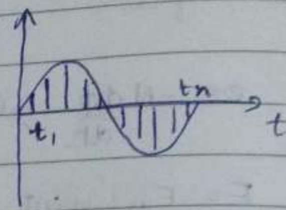
Phase & Phase difference:-
The phase of an alternating quantity at an instant is defined as the fractional part of a cycle through which the quantity has advanced from a selected origin.

Phase difference is defined as the angular displacement b/w maximum values (+/-) of the two alternating quantities having same frequency.

Peak Value:-
Maximum value attained by any alternating quantity during one complete cycle.
(Max^m value, Crest value)

Average Value :-

Arithmetic average of all the instantaneous values is over one complete cycle.



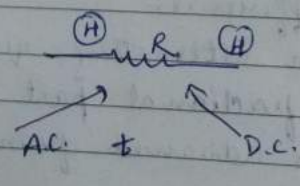
NOTE :- Avg. value of a sinusoidal quantity is zero (always).

$$i_{avg.} = \frac{i_1 + i_2 + i_3 + \cdots + i_n}{n}$$

RMS or Effective Value :-

Mathematically, $I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \cdots + i_n^2}{n}}$

The steady current which when flows through a resistor of ~~to~~ known resistance for a given time produces the same amount of heat as produced by A.C. quantities which when supply to the same resistor for the same time.



Form Factor -

It is the ratio of RMS value and avg. value.

$$F.F. = \frac{I_{rms}}{I_{avg}} \text{ or } \frac{E_{rms}}{E_{avg.}}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}, \quad I_{avg} = \frac{2I_m}{\pi}$$

$$FF = \frac{\cancel{I_m}}{\sqrt{2}} \times \frac{\pi}{2\cancel{I_m}} = \frac{\pi}{2\sqrt{2}} = 1.11$$

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– Form factor for a sinusoidal quantity is 1.11.

Peak Factor:-

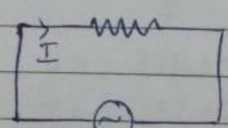
It is the ratio of maximum value to the RMS value.

$$P.F. = \frac{I_m}{I_{rms}} \text{ or } \frac{E_m}{E_{rms}}$$

$$P.F. = \sqrt{2} = 1.414$$

Behaviour of different Electrical elements against an A.C. Source :-

1) Resistor:-



$V = V_m \sin\omega t$

Let a purely resistive network, which is supplied by an alternating voltage $V = V_m \sin\omega t$.

The instantaneous value of current flowing in the resistor, $I = \frac{V}{R}$ (By Ohm's Law)

$$I = \frac{V_m \sin\omega t}{R} \quad \text{— (1)}$$

For maximum value of current, $\omega t = 90°$ or $\sin\omega t = 1$

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

Put this value of I_m in eq^n (1)

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

From the eq^n's of V & I it is analysed that both are in same phase, hence for a purely resistive network current is always in phase with voltage.

Instantaneous Power, $P = V.I$

$$P = (V_m \sin\omega t)(I_m \sin\omega t)$$

$$P = \frac{V_m I_m}{2}(2\sin^2\omega t)$$

Inductive, cap

$$P = \frac{V_m I_m}{2}(1-\cos 2\omega t)$$

$$P = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}(1-\cos 2\omega t)$$

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

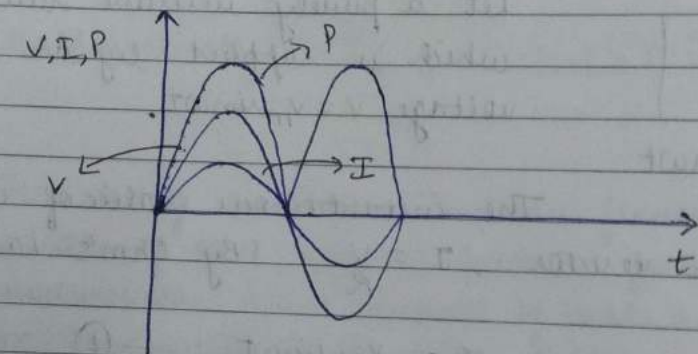
For avg. power over one complete cycle

$$P = V_{rms} I_{rms} - 0$$

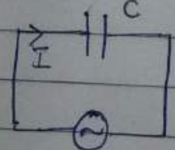
($\because$ for avg. $\cos 2\omega t = 0$)

$$\Rightarrow \boxed{P = V_{rms} I_{rms}}$$

or VI



2) capacitor:-



$V = V_m \sin\omega t$

$V = V_m \sin\omega t$

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Q-1) An A.C circuit consist of pure resistance of 10 ohms and is connected across a supply of 230 volts, 50Hz. Calculate -
RMS value (by default)
i) Current
ii) Power consumed
iii) Eq^n for voltage and current.

Sol:-

$I = \frac{V}{R} = \frac{230 \sin(2\pi \times 50 \times t)}{10} = 23 \sin(100\pi t)$

$V = 230\sqrt{2} \sin 100\pi t$

i) $I = \frac{V}{R} = \frac{230}{10} = 23A$

ii) $P = V_{rms} \cdot I_{rms}$

$= 230 \times 23 = 5290W$

$V = 325.27 \sin 100\pi t$

$I = 32.527 \sin 100\pi t$

Q-2) An inductive coil having negligible resistance & 0.1 Henry inductance is connected across 200V, 50Hz supply. Find i) inductive reactance ii) RMS value of current iii) Power iv) Eq^n for voltage & current

Sol:-

i) $X_L = \omega L = 2\pi f L = 2\pi \times 50 \times 0.1 = 10\pi$

ii) $I_{rms} =$

iii) Power = 0 (Avg. Power)

iv) $V = 200\sqrt{2} \sin 100\pi t = 282.84 \sin 100\pi t$

$I = \frac{282.84}{10\pi} \sin\left(100\pi t - \frac{\pi}{2}\right)$

$= 9 \sin\left(100\pi t - \frac{\pi}{2}\right)$

ii) $I = \frac{V}{X_L} = \frac{200}{31.4} = 6.37 A$

Q-3) A capacitor has a capacitance of 30μF. Find its
i) Capacitive reactance for frequencies of 25 & 50 Hz.
ii) In each case, find the current if the supply voltage is 440V.

Sol:-

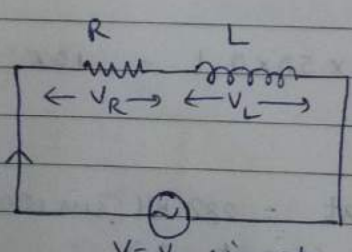
i)
$$X_C = \frac{1}{\omega C} = \frac{10^6}{2\pi \times 25 \times 30} = \frac{\overset{2}{\cancel{100}} \times 1000}{\cancel{50} \times 3 \times \pi}$$
$$= \frac{2000}{3\pi} = 212.21\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{10^6}{2\pi \times 50 \times 30} = \frac{1000}{3\pi} = 106.1\ \Omega$$

ii)
$$I = \frac{440}{212.21} = 2.07\ A$$
$$I = \frac{440}{106.1} = 4.14\ A$$

A.C. Series circuits:-

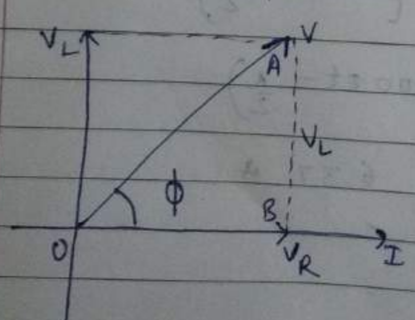
(I) R-L Combination (Circuit):-



$V_R = I \times R$

$V_L = I \times X_L$

(where $X_L = \omega L$)



In right angled Δ OAB

$$V = \sqrt{V_R^2 + V_L^2}$$
$$V = \sqrt{I^2R^2 + I^2X_L^2}$$
$$\boxed{V = I\sqrt{R^2 + X_L^2}}$$
$$\boxed{I = \frac{V}{\sqrt{R^2 + X_L^2}}}$$

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

Z = Impedence of R-L series circuit (Ω) $= \sqrt{R^2 + X_L^2}$

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

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

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

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

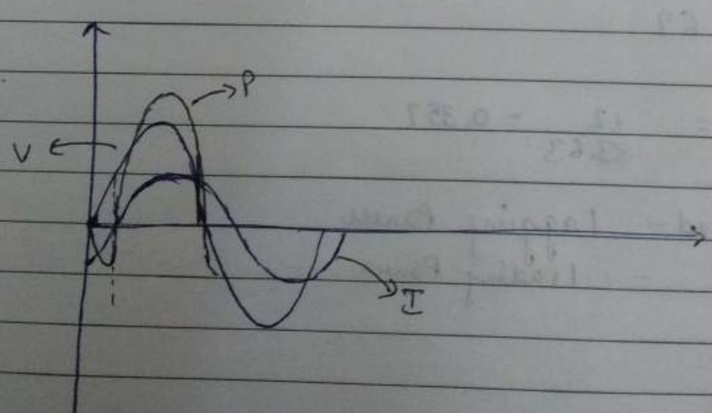
$$= \frac{V_m \cdot I_m}{2}\left[\cos\phi - \cos(2\omega t - \phi)\right]$$

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

$$P_{avg.} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cdot \cos\phi - 0$$

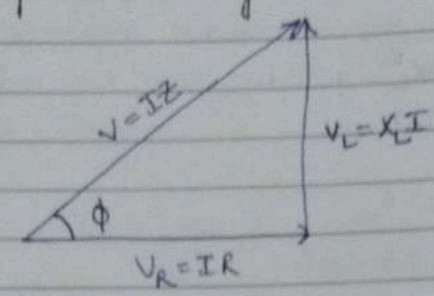
$$\boxed{P_{avg.} = V_{rms} I_{rms} \underbrace{\cos\phi}_{\text{Power Factor}}}$$

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



RC ckt, RLC ckt,

Impedence Triangle:-



Q-1) A coil having a resistance of 12 Ω and an inductance of 0.1 H is connected across 100V, 50Hz supply. Calculate
i) Reactance & Impedence of coil
ii) Current
iii) Phase difference b/w current & applied voltage
iv) Power Factor

Sol:-

i) $X_L = \omega L = 2\pi \times 0.1 \overset{\times 50}{=} \cancel{0.2\pi} = \cancel{0.628\ \Omega}\ 10\pi = 31.42$

$\cancel{Z = \sqrt{R^2 + X_L^2} = \sqrt{144 + 0.394} =}$

$Z = \sqrt{144 + 987.21} = 33.63\ \Omega$

ii) $I = \dfrac{100}{33.63} = 2.974\ A$

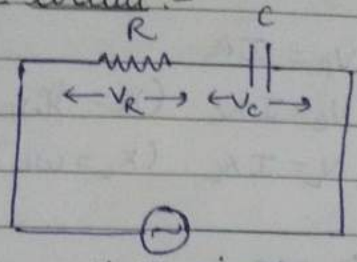
iii) $\tan\phi = \dfrac{31.42}{12} = 2.62$

$\phi = 69$

iv) $\cos\phi = \dfrac{R}{Z} = \dfrac{12}{33.63} = 0.357$

Inductive Load - Lagging Power
Capacitive - Leading Power

(II) R-C circuit :-

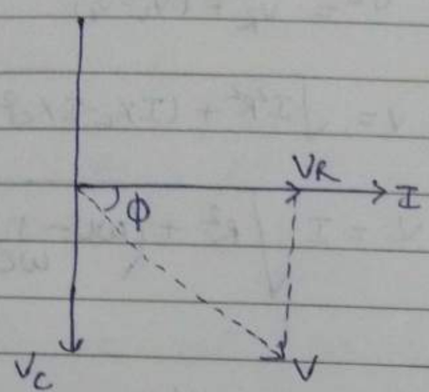


$V = V_m \sin\omega t$

$V_R = IR$

$V_L = I X_C$

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



$V^2 = V_R^2 + V_C^2$

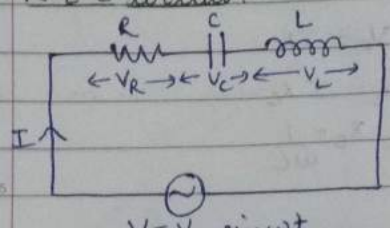
$V = I\sqrt{R^2 + \frac{1}{\omega C^2}}$

$I = \frac{V}{\sqrt{R^2 + \frac{1}{(\omega C)^2}}}$

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

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

(III) R-L-C circuit :-

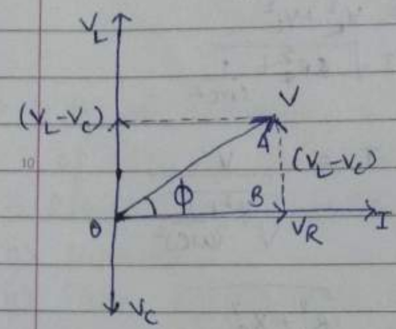


$V = V_m \sin\omega t$

$V_R = IR$

$V_C = IX_C \quad (X_C = 1/\omega C)$

$V_L = IX_L \quad (X_L = \omega L)$



In $\triangle OAB$,

$$V^2 = V_R^2 + (V_L - V_C)^2$$

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

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

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

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

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} = \frac{1}{R}\left(\omega L - \frac{1}{\omega C}\right)$$

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

$$P = V_{rms} I_{rms} \cos\phi$$

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

i) $X_L > X_C$ → Inductive ckt (lagging)

ii) $X_C > X_L$ → Capacitive ckt (Leading)

iii) $X_C = X_L$ → Resistive ckt

Q- A resistance of 15Ω & $C = 150\mu F$ are connected in series across 230V, 50Hz supply. Calculate:-

i) Z ii) I iii) $\cos\phi$ iv) ~~tan~~ ϕ v) Power consumed.

Sol:-

i) $Z = \sqrt{R^2 + X_c^2} = 25.99\Omega$

$X_c = \frac{1}{2\pi fC} = 21.23\Omega$

ii) $I = \frac{V}{Z} = \frac{230}{25.99} = 8.84A$

iii) $\cos\phi = \frac{R}{Z} = \frac{15}{25.99} = 0.577$ leading

iv) $\phi = \cos^{-1}(0.577) = 54.75°$

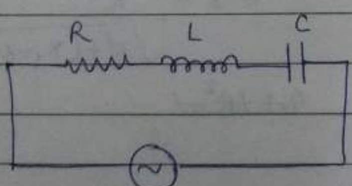
v) $P = VI\cos\phi$
$= 1174.9W$

Q- A coil of resistance 10Ω & inductance 0.1H is connected in series with a condenser of capacitance $150\mu F$ across 200V, 50Hz supply. Determine

i) Z ii) I iii) $\cos\phi$ iv) Voltage across coil

v) Voltage across condenser.

Sol:-



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

$= \sqrt{100 + \left(2\pi \times 50 \times 0.1 - \frac{10^6}{2\pi \times 50 \times 1}\right.}$

$= \sqrt{100 + \left(10\pi - \frac{10^6\ 1000}{1000 \times \pi \times 15}\right)^2}$

$= \sqrt{100 + (31.42 - 21.22)^2} = \sqrt{204.04} = 14.28\Omega$

ii) $I = \frac{V}{Z} = \frac{200}{14.28} = 14A$

iii) $\cos\phi = \frac{R}{Z} = \frac{10}{14.28} = 0.7$ lagging ($X_L > X_C$)

v) $V_C = X_C \times I = \frac{1}{\omega C} \times I = \frac{14 \times 10^6}{2\pi \times 50 \times 150} = \frac{14 \times 10^6}{1000 \times 15\pi}$

$= 297.08 \text{ V}$

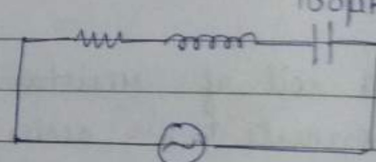
iv) $V_{coil} = \sqrt{R^2 + X_L^2} \times I = \sqrt{100 + 987.21} \times 14$

$= \sqrt{1087.21} \times 14$

$= 461.62 V$

Q.- A coil of power factor 0.8 is in series with a 100μF capacitor when connected to 50Hz supply, the voltage across capacitor is equal to voltage across coil. Find the values of resistance and inductance.

Sol:-



$\cos\phi = 0.8$, $f = 50Hz$

$V_C = V_{coil}$

$I \times X_C = I \times \sqrt{R^2 + X_L^2}$

$X_C^2 = R^2 + X_L^2$

$\frac{1}{\omega^2 C^2} = R^2 + \omega^2 L^2$

100×10^{-6} (10^{-4})

$\frac{10^8}{39.48} = R^2 + 39.48 L^2$

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

$0.8 = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

~~0.8 (R² + (~~

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Types of Power:-

1) Apparent Power-

Product of RMS value of applied voltage and circuit current. It is also called wattless or Ideal Power. It is represented by

$$S = V_{rms} \cdot I_{rms}$$
$$= (IZ) \cdot I$$

Unit:- VA (Volt Ampere)

→ It is calculated when power factor of the ckt. is unknown.

2) Active Power:-

It is the power which is actually dissipated in the ckt (especially resistance).

$$P = VI\cos\phi$$
$$= I^2R \text{ watts}$$

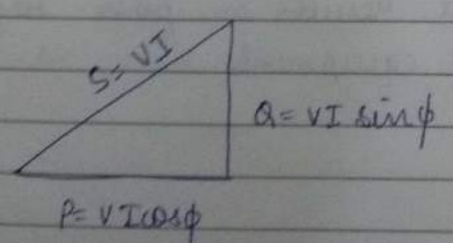
3) Reactive Power:-

It is the power developed in the reactance of the circuit. It is represented by

$$Q = VI\sin\phi$$
$$= I^2X_L$$

Unit:- VAR (Volt Ampere Reactive)

$\boxed{S = P + jQ}$ → Complex Form Notation



C → R. Power generator/Supplier
L → R. Power Absorber

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Power Factor:-
It is the cosine of angle b/w voltage and current or
It is the ratio of resistance and impedence of the circuit or
It is the ratio of Active Power to the Apparent Power

I) When $\phi = 0$:- $\cos\phi = 1$
Purely Resistive Network

II) When $\phi = 90°$:- $\cos\phi = 0$
The circuit may be inductive or capacitive.

III) When there is a combination of RC, RLC or RL, the power factor lies b/w 0 and 1.

Factors:-
By the relation $\frac{P}{VI} = \cos\phi$, for a fixed power at constant voltage I is inversely proportional to $\cos\phi$.
So, if the circuit power factor is low, circuit will draw heavy current from the mains which results in following disadvantages-

1) Greater conductor size
2) Poor Efficiency
3) Larger voltage drop and results in poor regulation
4) Larger $\underbrace{\text{KVA}}_{\downarrow}$ rating of equipments.

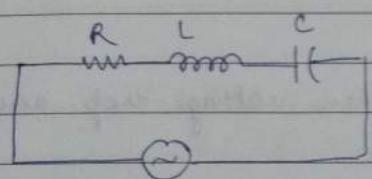
(Kilo Volt Amp.)

Resonance:-

Resonance in an AC circuit is a phenomena in which may be reactances or currents of inductive and capacitive loads would be equal.

~~Res~~ Resonance is of 2 types-
1) Series
2) Parallel

Series Resonance:-



In series RLC circuit, when circuit current is in phase with applied voltage then ckt is said to be in series resonance. Under this condition

$$\boxed{X_L = X_C}$$

or $X_L - X_C = 0$

then $\boxed{Z = R}$ (under this condition)

Under series resonance condition, as $Z = R$ the circuit will draw maximum current.

Resonant Frequency:-

$$X_L = 2\pi f L$$

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

Under series resonance, $X_L = X_C$

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

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

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Effect of Series Resonance-

1) At $X_L = X_C$, $Z = R$.
Network / circuit behaves as resistive network and Z of network will be minimum. As current drawn by the network will be max^m, it is sometimes called as Acceptor circuit.

2) As Z will be minimum, then ckt current will be maximum.

$$I_r = \frac{V}{Z} = \frac{V}{R}$$

3) Power taken by the network will also be max^m as current will be max^m.

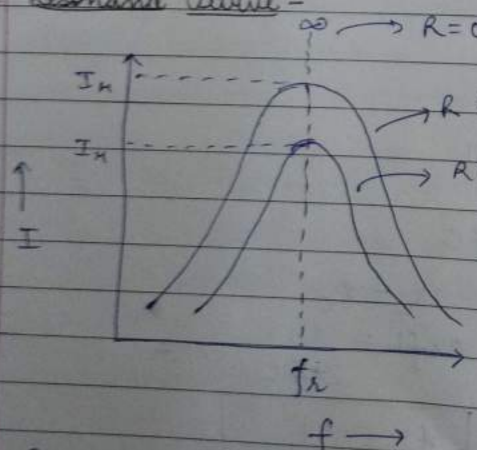
$$P_r = I_r^2 R$$

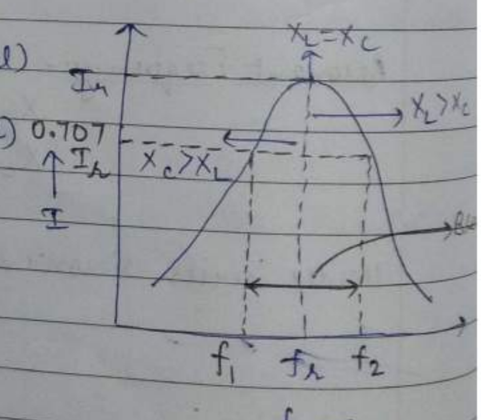
4) As current will be max^m, then voltage drop across L & C will also be maximum.

Applications -

1) Radio & TV receiver.
2) Tuning circuits.

Resonance Curve -





B.W. → Bandwidth

Bandwidth :-

The range of frequencies over which circuit current is equal to or more than 70.7% of maximum current is known as bandwidth.

$$B.W. = f_2 - f_1$$

f_1: Lower cut-off frequency

f_2: upper cut-off frequency

Q-factor:-

The factor by which the potential difference across R L or C rises to that of applied voltage is called Q-factor

$$Q\text{-factor} = \frac{V_L \text{ or } V_C}{\text{Applied voltage}}$$

$$V_L = IX_L \quad , V_c = IX_c$$

$$V = IZ = IR$$

$$Q\text{-factor} = \frac{IX_L}{IR} = \frac{X_L}{R}$$

(Quality Factor)

$$X_L = \omega_r L$$

$$= 2\pi f_r L$$

$$= 2\pi \times \frac{1}{2\pi\sqrt{LC}} \times L = \frac{L}{\sqrt{LC}}$$

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

Q-1) A choke coil is connected in series with a 200μF capacitor with a constant supply voltage of 250V. The current drawn by the network is 50A. when the supply frequency is 100Hz, determine:

max^m current → so cond^n

i) R & L of ~~induc~~ choke coil

Sol:-

$C = 100\mu F$, $I = 50A$, $V = 250V$, $f = 100Hz$

$I =$

$$50 = \frac{250}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$I_r = \frac{V}{R}$$

$$R = \frac{V}{I_r} = \frac{250}{50} = 5\Omega$$

$$X_L = X_C$$

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

100×10^{-6}
10^{-4}

|12.66

$$L = \frac{1}{4\pi^2 f^2 C} = \frac{10^4}{4\pi^2 \times 10^4 \times 10^{-8}}$$

ii) Voltage across capacitor

$$V_c = I_r X_c$$
$$= 50 \times \frac{1}{2\pi \times 100 \times 10^{-4}}$$
$$= \frac{10^4}{4\pi}$$

|397.88

iii) Q-factor

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

Q-2) A choke coil having an inductance of 50mH and resistance of 10Ω is connected in series with a $25\mu F$ capacitor across 200V ac supply. Calculate i) resonant freq. ii) current at resonance iii) Q-factor.

Sol:-

i) $$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{50 \times 10^{-3} \times 25 \times 10^{-6}}} = \frac{1}{2\pi\sqrt{5 \times 25 \times 10^{-8}}}$$

$$= \frac{10^4\ 1000}{10\pi\sqrt{5}}$$

$$= 142.35\ Hz$$

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ii) $I_L = \frac{200}{10} = 20A$

iii) $Q\text{-factor} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{10}\sqrt{\frac{50\times10^{-3}}{25\times10^{-6}\,10^{-3}}} = \frac{1}{10}\sqrt{\frac{5\times10^{2}}{25}} = \frac{1}{10}\sqrt{20}$

$= 0.4472$

Q-3) An AC varies sinusoidal with a frequency of 50Hz has an rms value of 20A. Write down the eq^n for instantaneous value and find the value of current at

i) ~~0.025~~ 0.0025 seconds

ii) 0.0125 seconds after passing through max^m ⊕ve value.

Sol^n: iii)

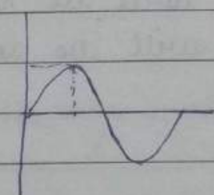
$f = 50HZ, \quad I = 20A$

$I = 20\sqrt{2}\sin[\omega t \cancel{\pm\phi}] = 28.28\sin\omega t \quad \frac{1}{50}$

$\omega = 2\pi f = 100\pi$

$I = 20\sqrt{2}\sin[\omega t \cancel{\pm\phi}]$

i) ~~$20\sqrt{2}\sin(100\pi\times\pi\times0.0025$~~



~~$20\sqrt{2}\sin[\omega t\ \frac{\pi}{2}\ \pm\omega t(\frac{\pi}{2}+\omega t)]$~~

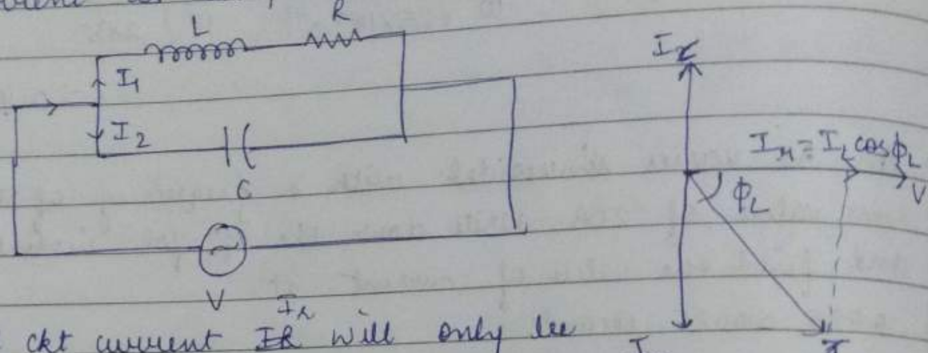
$I = 28.28\sin(100\pi t)$

$I = 28.28\cos(100\pi t)$

$I = 28.28\cos(100\pi\times0.0025)$

Parallel Resonance

An AC circuit containing an inductor and capacitor in parallel then circuit is said to be in || resonance, when ckt current is in phase with applied voltage



The ckt current I_R will only be in phase with supply voltage when $I_C = I_L\sin\phi_L$.

Since, at resonance, the reactive component of current is suppressed, hence current drawn by the network will be minimum. Due to this, value of impedance will be very high.

$$I_C = I_L \sin\phi_L$$

$$\cancel{X_C \times I = X_L \times I \sin\phi_L}$$

$$I_L = \frac{V}{Z_L} = \frac{V}{\sqrt{X_L^2+R^2}}$$

$$I_C = \frac{V}{X_C} = \frac{V}{1/\omega C} = V\omega C$$

$$\sin\phi_L = \frac{X_L}{Z_L}$$

$$\cancel{V}\cancel{\omega}C = \frac{\cancel{V}}{\sqrt{X_L^2+R^2}} \times \frac{\cancel{\omega} L}{\sqrt{X_L^2+R^2}}$$

$$C(X_L^2+R^2) = L$$

$$\frac{V}{Z_L} = \frac{V}{X_C} = \frac{V}{Z_L} \times \frac{X_L}{Z_L}$$

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

$$\frac{\omega L}{\omega C} = Z_L^2$$

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

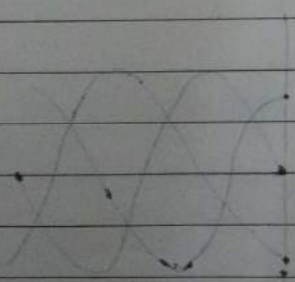
$$\frac{L}{C} = R^2 + \omega^2 L^2 = R^2 + 4\pi^2 f_r^2 L^2$$

$$\sqrt{\frac{L}{C} - R^2} = 2\pi f_r L$$

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

Effects of Parallel Resonance-

1) Circuit impedance is pure resistive because $Z_R = \frac{L}{CR}$, which doesn't contain any frequency term.
2) The value of Z_R is very high because ratio of $\frac{L}{C}$ is very high
3) The value of current $I = \frac{V}{Z_R}$ is very low, because Z is very high.
4) The current flowing through capacitor and coil is much greater than line current because the impedence of each branch is quite low than the circuit impedence Z.
5) Since, current drawn by ckt will be very low, it will ~~the~~ treated as rejector circuit.



Q-1) In an A.C. circuit the voltage across & current through the circuit are given by $V = 250\sin(314t-10)$, $I = 10\sin(314t-50)$. Find impedence, resistance & reactance.

Sol:-

$$Z = \frac{V_{rms}}{I_{rms}} = \cancel{250}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{250}{\sqrt{2}}\angle 10 \;,\; I_{rms} = \frac{10}{\sqrt{2}}\angle 50$$

$$Z = \cancel{25\,\Omega} \quad Z = \frac{V_{rms}}{I_{rms}} = \frac{(250/\sqrt{2})\angle 10}{(10/\sqrt{2})\angle 50}$$

$$= 25\angle -60\ \Omega$$

$$= 12.5 - 21.65i$$

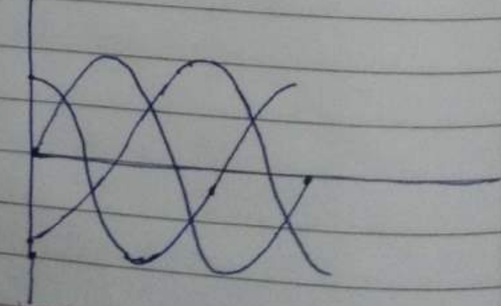
$$Z = R - jX_c$$
$$R = 12.5\,\Omega$$
$$X_c = 21.65\,\Omega$$

Poly-Phase A.C. Circuits :-

Advantages of 3-Phase over Single Phase :-

1) Constant Power.
2) Higher Rating.
3) 3- Power transmission is Economical in 3-Phase.

$$\left.\begin{aligned} e_R\ E_R &= E_m\sin(\omega t) \\ e_y &= E_m\sin(\omega t-120) \\ e_b &= E_m\sin(\omega t-240) \end{aligned}\right] \longrightarrow \text{Phase Sequence}$$



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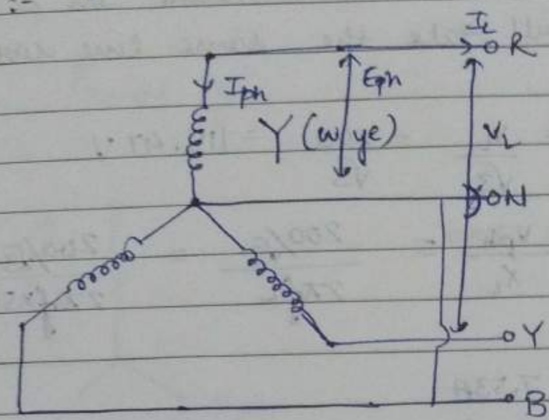
Inter-connection of three phases:-

(i) Star or Y-connection (Wye) and (ii) Delta or Mesh Connection

Star :-

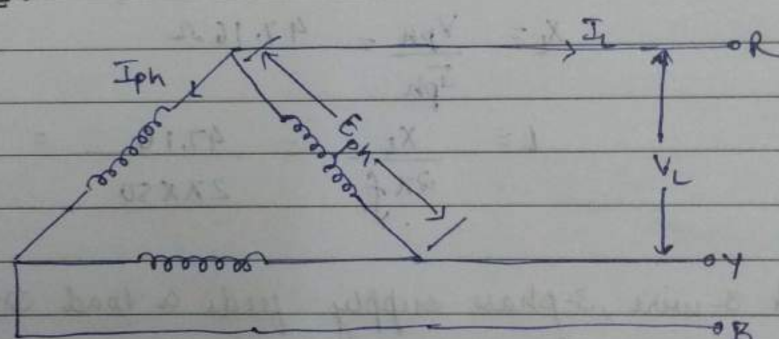


* Relation b/w Voltages & Current:-

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

and $I_L = I_{ph}$

Delta or Mesh :-



* Relation b/w Voltages & Current:-

$$V_L = V_{ph}$$

and $I_L = I_{ph} \cdot \sqrt{3}$

✓

Q-1) Three inductive coils each of inductance 50 mH are conne[cted] in star to a 3-phase 200V, 50Hz supply. Calculate the inductance of each coil when connected in Δ to the same supply & will take the same line current.

Sol:-

Star:-

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{200}{\sqrt{3}} = 115.47\ V$$

$$I_{ph} = \frac{V_{ph}}{X_L} = \frac{200/\sqrt{3}}{2\pi f L} = \frac{200/\sqrt{3} \times 10^3}{2\pi f \times 50 \times 50}$$

$$I_L = I_{ph} = 7.53A$$

Delta:-

$$I_{ph} = \frac{I_L}{\sqrt{3}} = 4.24A$$

$$V_{ph} = V_L = 200V$$

(given)

$$X_L = \frac{V_{ph}}{I_{ph}} = 47.16\,\Omega$$

$$L = \frac{X_L}{2\pi f} = \frac{47.16}{2\pi \times 50} = 0.15H$$

Q-2) A 3-wire, 3-phase supply feeds a load consisting of 3 e[qual] resistors. By how much is the load reduced if one of the resistors be removed, when the load is in

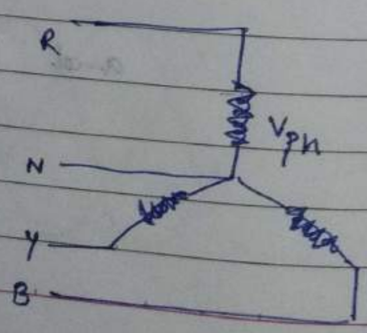
i) star

ii) Delta

Sol:-

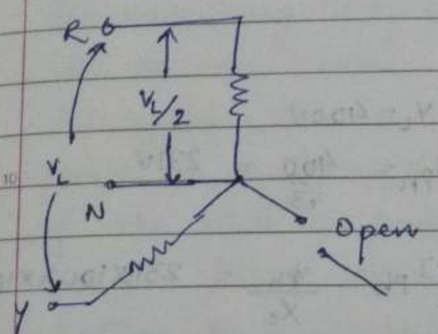
i) $P = \frac{(V_{ph})^2}{R}$ in one phase

$$P_{3-\phi} = \frac{3(V_{ph})^2}{R}$$



$$P_{3-\phi} = \frac{3\left(\frac{V_L}{\sqrt{3}}\right)^2}{R}$$

$$P_{3-\phi} = \frac{V_L^2}{R}$$



$$\text{Total Power} = \frac{2\left(\frac{V_L}{2}\right)^2}{R} = \frac{V_L^2}{2R} = P_{3\text{-}}$$

$$\% P_{red^n} = \frac{\left(\frac{V_L^2}{R} - \frac{V_L^2}{2R}\right)}{\frac{V_L^2}{R}} \times 100 = 50\%$$

ii) 33.33% → Ans

Q-3) 3 - 20μF capacitors are star connected across a 400V, 50Hz 3-phase 3-wire supply.

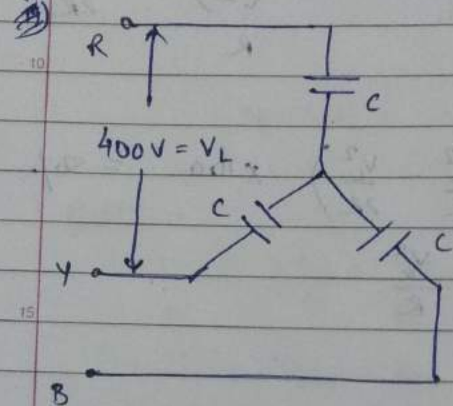
i) Calculate the current in each line.

ii) If one of the capacitor is open circuited, find line current & p.d. across each of the two capacitors.

iii) If one of the capacitor is short circuited then calculate the line current.

Sol:-

i)



i) $V_L = 400V$

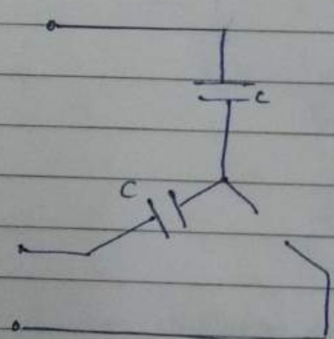
$$V_{ph} = \frac{400}{\sqrt{3}} = 231V$$

$$I_{ph} = \frac{V_{ph}}{X_c} = 231 \times 100\pi \times 10^{-6} \times 20$$

$= 1.45A$

$I_L = I_{ph} = 1.45A$

ii)



$$\text{Total capacitance} = \frac{20 \times 20}{20+20}$$

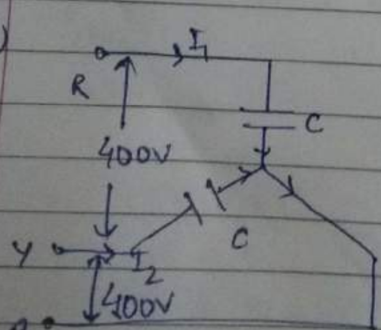
$= 10\mu F$

$$X_c = \frac{1}{2\pi f C} = \frac{10^6}{100\pi \times 10}$$

$= 318.3\Omega$

$$I_L = \frac{V_L}{X_c} = \frac{\cancel{231}\ 400}{318.3} = 1.256\,A$$

iii)



$$X_c = \frac{1}{2\pi f c} = \frac{10^6}{2\pi \times 50 \times 20} = 159.15\Omega$$

$$I_1 = \frac{V_L}{X_c} = \frac{400}{159.15} = 2.5A$$

$$I_2 = \frac{V_L}{X_c} = \frac{400}{159.15} = 2.5A$$

$I_3 = I_1 + I_2$ (vector sum of I_1 & I_2)

$= 2 \times 2.5 \times \cos 30°$

$= 5 \times \frac{\sqrt{3}}{2} = 4.33\ A$

Power Measurement in Three-Phase Circuits:-

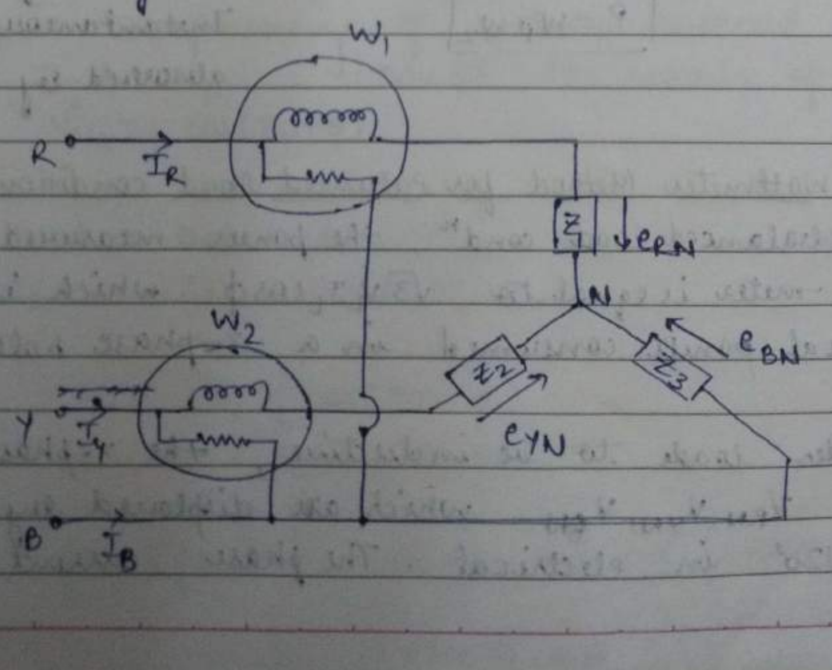
For measuring poly-phase power, we use Blondel's Theorem. Acc. to this theorem, when power is supplied by K-wire A.C. system, the no. of watt meters required to measure the power is one less than the no. of wires (i.e. K-1) regardless of the load is unbalanced or balanced.

Hence, we require 3 watt meter for 3-phase, 4-wire system and 2-watt meters for 3-phase, 3-wire system.

Two-Watt Meter Method:-

This method is used to measure power in a 3-phase 3-wire star or delta connected balanced or unbalanced load.

In this method, sum of power measured by 2-watt metres i.e. $W_1 + W_2$ = The total power (instantaneous) absorbed by 3 loads Z_1, Z_2 and Z_3.



Consider Star Connection

Instantaneous current through current coil of W_1

$$= I_R$$

Instantaneous p.d across potential coil of W_1

$$e_{RN} - e_{BN}$$

Instantaneous power measured by W_1

$$W_1 = (e_{RN} - e_{BN}) I_R$$

Similarly for watt meter 2 :

Instantaneous current through current coil of $W_2 = I_Y$

Instantaneous p.d. across potential coil of W_2

$$e_{YN} - e_{BN}$$

Instantaneous power measured by W_2

$$W_2 = I_Y (e_{YN} - e_{BN})$$

Now,

$$W_1 + W_2 = I_R(e_{RN} - e_{BN}) + I_Y(e_{YN} - e_{BN})$$

$$= I_R e_{RN} + I_Y e_{YN} - e_{BN}(I_R + I_Y)$$

$$= \underbrace{I_R e_{RN} + I_Y e_{YN} + I_B e_{BN}}_{\text{Instantaneous power absorbed by loads}} \quad [\because I_R + I_Y + I_B = 0]$$

$$\boxed{P = W_1 + W_2}$$

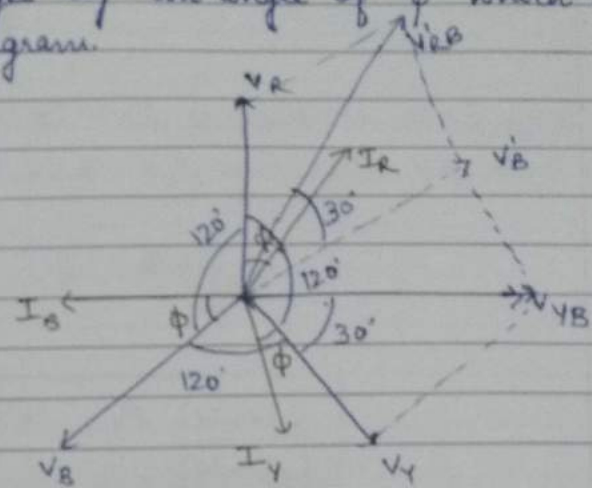
*** Two Wattmeter Method for Balanced load condition-

For balanced load cond^n, the power measured by two watt-meter is equal to $\sqrt{3} V_L I_L \cos\phi$ which is the actual power consumed in a 3-phase balanced load

Consider loads to be inductive, the 3-phase voltages are- V_{RN}, V_{YN}, V_{BN} which are displaced by an angle of 120° in electrical. The phase current lag behind

Pg.-703 Table wattmeter reading variation with φ.

their respective voltages by an angle of ϕ which is shown in phasor diagram.



Current through watt meter $W_1 = I_R$

P.d. across voltage coil of $W_1 \Rightarrow V_{RB} = V_R - V_B$

V_{RB} is compounding of V_R & V_B with a phasor diff. of $(30° - \phi)$ b/w V_{RB} & I_R.

Reading of watt meter 1 $\Rightarrow W_1 = V_{RB} I_R \cos(30-\phi)$

Similarly for watt meter 2 ⇒

Current through watt meter $W_2 = I_Y$

P.d. across voltage coil of $W_2 \Rightarrow V_{YB} = V_Y - V_B$

V_{YB} is compounding of V_Y & V_B reversed and angle b/w I_Y & $V_{YB} = (30+\phi)$. So, reading of watt meter 2

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

As load is balanced $V_{RB} = V_{YB}$ = Line voltage V_L and $I_Y = I_R$ = line current I_L

$$\therefore \quad W_1 = V_L I_L \cos(30-\phi)$$

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

$\therefore$ Total power $= W_1 + W_2 = V_L I_L [\cos(30-\phi) + \cos(30+\phi)]$

$= V_L I_L [2\cos 30 . \cos\phi] + \sin 30 \sin\phi$

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

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Two Wattmeter Method:-

$W_1 + W_2 = V_L I_L \cos(30° - \phi) + V_L I_L \cos(30° + \phi) = \sqrt{3} V_L I_L \cos\phi$ — ①

$W_1 - W_2 = V_L I_L \cos(30° - \phi) - V_L I_L \cos(30° + \phi) = V_L I_L \sin\phi$ — ②

Divide eqⁿ ② by ①

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

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

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

Q.-1) Phase voltage and current of a star connected inductive load is 150 V and 25 A. Power factor of load is 0.707 lagging. Assuming that the system is 3-wire and power is measured by using 2 wattmeters, find the readings of wattmeters.

solⁿ:-

$V_{ph} = 150V$

$V_L = 150\sqrt{3} = 259.807\ V$

$I_L = I_{ph} = 25A$

Total power $= \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 150 \times \sqrt{3} \times 0.707 \times 25$

$= 450 \times 0.707 \times 25$

$W_1 + W_2 = 7954\ W$ — ①

$\cos\phi = 0.707$

$\phi = \cos^{-1}(0.707)$

$\phi = 45°$

$\tan\phi = 1$

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

$1 = \sqrt{3}\frac{(W_1 - W_2)}{7954} \Rightarrow W_1 - W_2 = \frac{7954}{\sqrt{3}} = 4592\ W$ — ②

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eq^n ① + ②

$$2W_1 = 7954 + 4592 = 12546$$

$$W_1 = 6273W$$

$$W_2 = 1681W$$

Q. ② In a balanced 3-phase 400 V circuit, the line current is 115.5A, when power is measured by 2-wattmeter method 1 wattmeter reads 40kW & other reads zero. What is the power factor of the load?
If power factor is unity & line current will be same what would be the readings of each wattmeter?

⑥ The degree to which a magnetic field can magnetize a material

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Unit - III
MAGNETIC CIRCUITS

Some important definitions :-

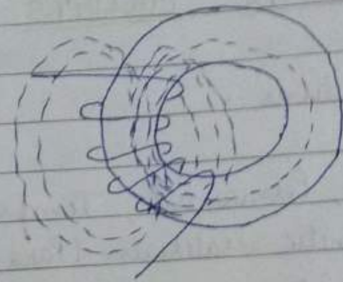
1. Magnet
   (Natural, Artificial, Permanent, Temporary)
2. Classification of Magnetic Materials (Para, Ferro, Non, Dia)
3. Magnetic field and its properties
4. Magnetic Induction
5. Magnetic Flux → No. of magnetic field lines passing through surf
6. Magnetic Intensity or Magnetising Force (H)
7. Permeability → $\mu = B/H$ (Measure of ability of material to supp the formation of mag field within
8. Relation b/w 'B' & 'H' $(B = \mu H)$
9. Magnetic effect of electric current
10. Magnetic field produced by a Solenoid
11. Electromagnet
12. Magnetic Circuit - route or path followed by magnetic f
13. MMF (Magneto motive force) - work done in carrying unit magnetic pole once through entire mag. ckt.
14. Reluctance (S) -
    Opposition offered to the magnetic flux

$$S = \frac{l}{a \mu_0 \mu_r}$$

15. Permeance -
    Reciprocal of reluctance
16. Leakage flux and fringing :-

When a current is passed through the a solenoid, magnetic flu set up. most of the flux is set up in the core and na as useful flux 'ϕ_u'. However some of the flux i just set up around the coil & is not utilized for any useful work. It is called leakage flux 'ϕ_L'.

So, total flux $\phi_T = \phi_u + \phi_L$.



②

Fringing-

When flux is set up in a core which consist of an air gap also. The flux passes through air gap as well and tends to bulge outwards at the interface of air gap. This increases the effective area in the air gap and decreases the flux density. This phenomena is known as fringing. Fringing is directly proportional to length of air gap.

17. Comparision b/w Magnetic & Electrical Circuits

<u>Similarities</u> - path in which e⊖ flow from a voltage /current source

(I) Definitions (Electric & Magnetic ckts) ... paths containing a ...

(II) Flux (Magnetic), Current (Electrical)

(III) No. of turns MMF factor that sets up flux, EMF - Electric potential for a source

(IV) Reluctance, Resistance

(V) Permeance, Conductance

(VI) Permeability, Conductivity

(VII) Reluctivity, Resistivity

(VIII) Flux density, Current density

(IX) Magnetic intensity, Electric intensity

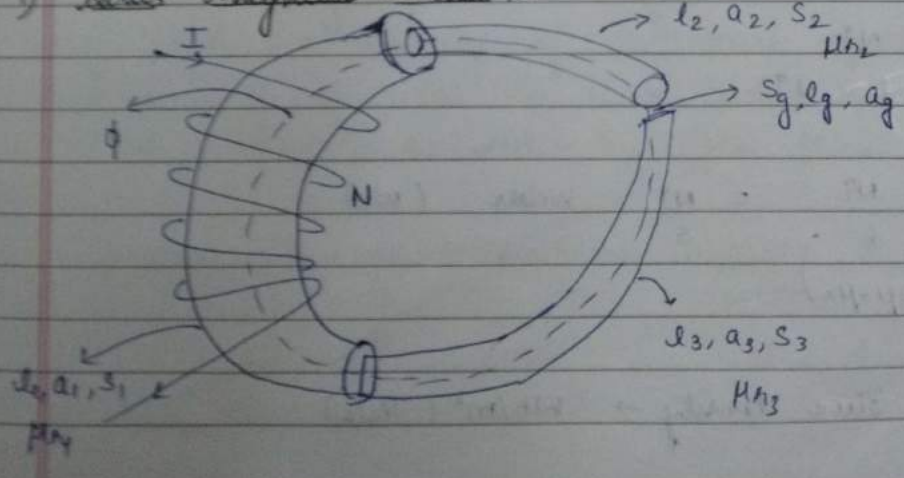
$$H = \frac{NI}{l} \qquad E = \frac{V}{d}$$

Dissimilarities:-

Magnetic	Electrical
(I) Magnetic flux does not flow but it sets up in the magnetic circuit.	(I) Electric current actually flows in an electric circuit.
(II) For magnetic flux there is no perfect insulator. It can be ~~one~~ set up even in non-magnetic materials like air, rubber, glass.	(II) For electric current, there are large no. of perfect insulators like air, glass, rubber
(III) The reluctance of a magnetic circuit is not constant rather it varies with the value of B. It is because the value of μ_r changes continuously	(III) The resistance of an electric circuit is almost constant as its values depends on the value of 'ρ' which is almost constant.
(IV) Once the magnetic flux is set up in a magnetic material, no energy is further expanded.	(IV) Energy is expanded continuously as long as current will flow through the circuit.

Analysis of Magnetic Circuits:-

1) Series Magnetic Circuit :-



Total reluctance, $S = S_1 + S_2 + S_3 + S_g$

$$= \frac{l_1}{a_1 \mu_0 \mu_{r_1}} + \frac{l_2}{a_2 \mu_0 \mu_{r_2}} + \frac{l_3}{a_3 \mu_0 \mu_{r_3}} + \frac{l_g}{a_g \mu_0}$$

Total MMF $= \phi . S$

$$= \phi \left[\frac{l_1}{a_1 \mu_0 \mu_{r_1}} + \frac{l_2}{a_2 \mu_0 \mu_{r_2}} + \frac{l_3}{a_3 \mu_0 \mu_{r_3}} + \frac{l_g}{a_g \mu_0} \right]$$

$\because \quad B = \frac{\phi}{A}$

$$= \frac{B_1 l_1}{\mu_0 \mu_{r_1}} + \frac{B_2 l_2}{\mu_0 \mu_{r_2}} + \frac{B_3 l_3}{\mu_0 \mu_{r_3}} + \frac{B_g l_g}{\mu_0}$$

$\because \quad H = \frac{B}{\mu_0 \mu_r}$

$\therefore \quad = H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g$

Some important formulae-

1) $H = \frac{NI}{2\pi r}$ ampere turns/metre (AT/m)

2) $H = \frac{\phi}{A \mu_0 \mu_r}$

3) $H.l = NI$ (According to Work Law)
= Total ampere turns

$$Hl = NI$$

$$\frac{\phi}{A \mu_0 \mu_r} . l = NI$$

$$\phi = \frac{NI}{\left(\frac{l}{A \mu_0 \mu_r}\right)} = \frac{NI}{S} \text{ Weber (Wb)}$$

Flux density $\rightarrow$ Wb/m^2 (Tesla)

4) $\phi = \frac{MMF}{Reluctance}$

Q-1) Flux density of 1.2 Wb/m^2 is required in the 2mm air gap of an electromagnet having an iron path 1m. long. Calculate the magnetising force and current required if the electromagnet has 1273 turns. Assume $(\mu_r)_{Fe} = 1500$.

Sol:-

$l_g = 2mm$, $l = 1m$, $N = 1273$, $\mu_r = 1500$, $\frac{\phi}{a} = 1.2T$.

$$H = H_1 l_1 + H_2 l_2$$
$$= \frac{B}{\mu_0 \mu_r} \cdot l_1 + \frac{B}{\mu_0} \cdot l_2$$
$$= \frac{1.2}{\mu_0}\left[\frac{1}{1500} + 2\times10^{-3}\right]$$
$$= \frac{1.2}{4\pi\times10^{-7}} \times 2.67\times10^{-3}$$
$$= 2546.5$$

$$I = \frac{Hl}{N} = \frac{\text{Total ampere turns}}{N}$$
$$= \frac{2546.5}{1273} = 2A$$

Q-2) An iron ring of mean length 1m has an air gap of 1mm & a winding of 200 turns. If the relative permeability of iron is 500 when a current of 1A flows through the coil. Find the flux density.

Sol:-

$l_g = 1mm$, $l_T = 1m$, $N = 200$ turns, $\mu_r = 500$, $I = 1A$, $B = ?$

$\cancel{B = \frac{\phi}{A}}$

$$mmf = \phi \cdot S$$
$$NI = \phi\left[\frac{l_1}{a\mu_0\mu_r} + \frac{l_g}{a\mu_0}\right]$$

$$200 \times 1 = \frac{B\phi}{\mu_0}\left[\frac{0.999}{500} + 10^{-3}\right]$$

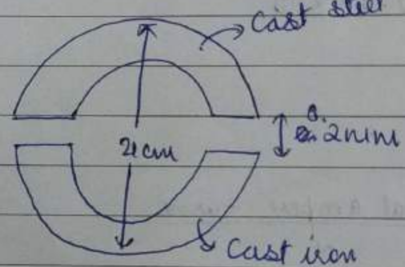
$$200 \times 4\pi \times \cancel{10^{-7}}^{\,10^{-4}} = B\left[2.99 \times 10^{-3}\right]$$

$$B = 0.084T$$

Q-3) A ring has a diameter of 21 cm and a cross sectional area of $10 cm^2$. The ring is made up of semi-circular sections of cast iron & cast steel, with each joint have a reluctance equal to an air gap of 0.2 mm. Find the ampere turns required to produce a flux of 8×10^{-4}. The values of μ_r for cast steel & cast iron are 800 166.

Sol:-

$$\frac{\phi}{a_1 \mu_0 \mu_{r_1}} + \frac{\phi}{a_2 \mu_0 \mu_{r_2}} + \frac{\phi}{a_3 \mu_0}$$



$$\frac{8 \times 10^{-4}}{4\pi \times 10^{-7}}\left[\frac{10^{4}}{800 \times \pi \times (10.5)^2} + \frac{}{166 \times \pi}\right]$$

$$+$$

$$\frac{{}^{2}\cancel{8} \times 10^{-4}}{\cancel{4}\pi \times 10^{-7} \times 10 \times 10^{-4}}\left[\frac{1}{800} + \frac{1}{166} + 1\right]$$

$$\frac{2 \times 10^{6}}{\pi}\left[1.007\right]$$

$$= 6.4125 \times 10^{5}$$

$$l = \frac{\pi D}{2} = \frac{\pi \times 21 \times 10^{-2}}{2} = 0.329 = 0.33m$$

Total ampere turns $= 0.33 \times 6.4125 \times 10^{5}$

$$= 2.116 \times 10^{5}$$

Q.- 4) The ring shaped core as shown in figure is made up of material having relative permeability of 1000. The flux density in the smallest area of cross-section is 2T. If the current through the coil is not to exceed 1.5A. Compute the no. of turns in the coil.

$l_1 = 10$ cm., $a_1 = 4$ cm^2, $l_2 = 15$ cm, $a_2 = 3$ cm^2, $l_3 = 20$ cm, a_3...

Sol:-

$\phi S = NI$, $\mu_r = 1000$

$\phi = B \times A$

$I = 1.5A$

$S = S_1 + S_2 + S_3$

$= \frac{1}{\mu_0 \mu_r} \left[\frac{l_1}{a_1} + \frac{l_2}{a_2} + \frac{l_3}{a_3} \right]$

$= \frac{1}{4\pi \times 10^{-7} \times 1000} \left[\frac{10 \times 10^{-2}}{4 \times 10^{-4}} + \frac{15 \times 10^{-2}}{3 \times 10^{-4}} + \frac{20 \times 10^{-2}}{2 \times 10^{-4}} \right]$

37.5

$= \frac{10^4}{4\pi} \left[\frac{1000}{4} + \frac{1500}{3} + \frac{2000}{2} \right]$ (250, 500, 1000)

$= \frac{10^4}{4\pi} \times 1750$

$= 1.393 \times 10^6$

Q-5) An iron ring has a cross-section of $3 cm^2$ and ~~mean diameter~~ circumference of 25 cm. An air gap of 0.4 mm has been cut across the section of the ring. The ring is wound with a coil of 200 turns through which a current of 2A is passed. If the total magnetic flux is 0.24 mWb. Find the relative permeability of iron.

Sol:-

$D = 25 cm$, $a = 3 cm^2$, $l_g = 0.4 mm$, $N = 200$, $I = 2A$, $\phi = 0.24 mWb$

$H A = \frac{\phi}{\mu_0 \mu_r}$ $\quad H.l = N.I$

$$H_1 l_1 + H_2 l_2 = N.I$$

$$\frac{B_1 l_1}{\mu_0 \mu_r} + \frac{B_2 l_2}{\mu_0} = NI$$

$$\frac{\phi l_1}{a \mu_0 \mu_r} + \frac{\phi l_g}{a \mu_0} = NI$$

$$\frac{0.24 \times 25}{3 \times 10^{-2} \times} \qquad \frac{\phi}{a \mu_0}\left[\frac{l_1}{\mu_r} + l_g\right] = NI$$

$$200 \times 2 = \frac{0.24 \times 10^{-3}}{3 \times 10^{-4} \times 4\pi \times 10^{-7}}\left[\frac{2 \times 25 \times 10^{-2}}{2\mu} + 0.4 \times 10^{-3}\right]$$

$$\cancel{400} \, 200 = \frac{\cancel{0.2} \, \cancel{24} \, 2 \times 10^{-5}}{\cancel{12} \pi \times 10^{-11} \, 10^{-6}}\left[\frac{0.393}{\mu} + 0.4 \times 10^{-4}\right]$$

$$200\pi \times 10^{-6} = \frac{0.393}{\mu} + 4 \times 10^{-4}$$

$$2\pi \times 10^{-4} - 4 \times 10^{-4} = \frac{0.393}{\mu}$$

$$10^{-4} \times 2.283 = \frac{0.393}{\mu}$$

$$\mu = \frac{10^4 \times 0.393}{2.283} = 1721.4$$

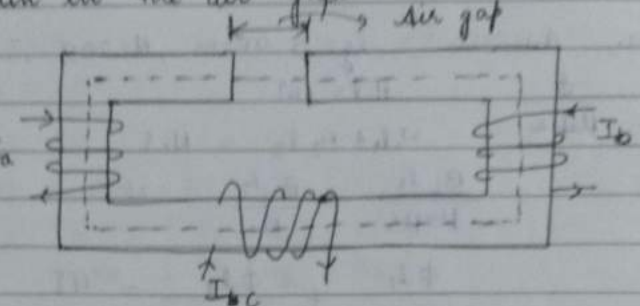
$$\cancel{400} \, 200 = \frac{0.\cancel{24} \, 2 \times 10^{-3} \, 10^{6}}{\cancel{12} \pi \times 10^{-7}}\left[\frac{0.25}{\mu} + 4 \times 10^{-4}\right]$$

$$200\pi \times 10^{-6} - 4 \times 10^{-4} = \frac{1}{4\mu}$$

$$4 \times 2.283 \times 10^{-4} = \frac{1}{\mu}$$

$$\mu = 1095$$

Q-6) A rectangular iron core shown in figure. It has mean length of magnetic path of 100 cm. Cross section of 4cm×4cm $\mu_r = 1400$ and air gap of 5mm cut in the core. The 3 coils carried by the core have no. of turns $N_a = 335$, $N_b = 600$, $N_c = 600$, and their respective currents are 1.6, 4 and 3. The direction of currents are shown in figure. Find the flux in the air gap.



Sol:-

$$mmf = \phi . S$$

$$\phi = \frac{mmf}{S}$$

① Total mmf $= N_a I_a + N_b I_b \mp N_c I_c$

$$= 335 \times 1.6 + 600\,[4-3]$$

$$= 536 + 600 = 1136$$

$$S = S_1 + S_2$$

$$= \frac{l_1}{\mu_0 \mu_r} + \frac{l_2}{\mu_0} = \left[\frac{100 \times 10^{-2}}{1400} + \frac{5 \times 10^{-3}}{1}\right]\frac{1}{\mu_0}$$

$l_1 = 100 - 0.5$

$$= \left[\frac{1}{1400} + 0.005\right]\frac{10^7}{4\pi \times 10^{-4} \times 4}$$

$$= \frac{5.714 \times 10^{8}}{4\pi\,16\pi} = \cancel{0.4547 \times 10^4}$$

$$= \cancel{4547}$$

$$\cancel{\phi = \frac{1136}{4547} = 0.2498} = 1.136 \times 10^7\ AT/Wb$$

$$\phi = \frac{1136}{1136 \times 10^4} = 10^{-4}\ Wb$$

1.6 Excitation in Magnetic Circuits:-

- Electromagnetic Induction
- Induced emf → statically → Dynamically

Expressions for Self Inductance:-

1) $e = L\frac{dI}{dt}$ ⇒ $L = \frac{e}{dI/dt}$

2) $L = \frac{N\phi}{I}$

3) $L = \frac{N^2}{S}$

Expressions for mutual Inductance:-

1) $e_m = M\frac{dI_1}{dt}$

$M = \frac{e_M}{dI_1/dt}$

2) $M = \frac{N_2\phi_2}{I_1}$

3) $M = \frac{N_1N_2}{S}$

Q-1) Calculate inductance of a toroid 25cm mean diameter & 6.25 cm² circular cross-section wound uniformly with 1000 turns of wire. Hence, calculate the emf induced when current in it increases at the rate of 100 A/s.

Sol:-

$N = 1000$, $dI/dt = 100$, $a = 6.25cm^2$, $D = 25cm$.

$L = \frac{N^2}{S}$

BL Thareja Vol. I Pg-309
Ex:- 7.18, 7.19

A flux of 0.5 mWb
900 turns

$$S = \frac{l}{a\mu_0\mu_r} = \frac{\pi \times 25 \times 10^{-2}}{\cancel{2} \times 4\pi \times 10^{-7} \times 1 \times 6.25 \times 10^{-4}} \quad 10^{9}$$

$$= \frac{10^9}{\cancel{12.5}}$$

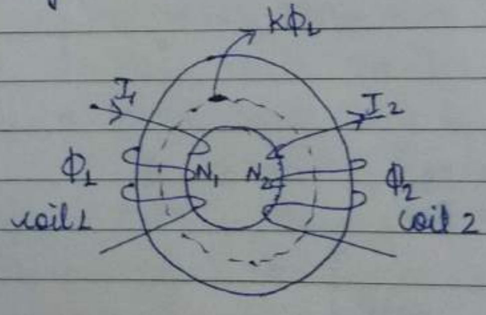
$$L = \frac{10^6}{10^9} = 10^{-3}$$

$$e = 0.1\ V$$

Coefficient of coupling :-

The fraction of magnetic flux produced by the current in one coil that links with the other is known as coefficient of coupling b/w the two coils denoted by 'K'.

If the flux produced by one coil is completely linked with other, then the value of 'K' is '1' and coils are said to be magnetically tightly coupled whereas if the flux produced by one coil does not link with the other then the value of 'K' is '0' & the coils are said to be magnetically isolated.



Consider a magnetic ckt. in which 2 coils are present coil-1 & 2. Let current I_1 flows through the coil 1, then

$$L_1 = \frac{N_1\phi_1}{I_1}$$

and $$M = \frac{N_2\phi_{12}}{I_1} = \frac{N_2 K\phi_1}{I_1} \quad \text{—— (1)}$$

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Similarly for coil 2, $L_2 = \frac{N_2 \phi_2}{I_2}$

$$M = \frac{N_1 \phi_{21}}{I_2} = \frac{N_1 K \phi_2}{I_2} \quad \text{—(2)}$$

Now, Multiply eq^n (1) & (2)

$$M^2 = \frac{N_1 N_2 K^2 \phi_1 \phi_2}{I_1 I_2} = K^2 L_1 L_2$$

$$M = K\sqrt{L_1 L_2}$$

$$\boxed{K = \frac{M}{\sqrt{L_1 L_2}}}$$

Q.1) Two identical 750 turns coils A & B lie in a parallel planes. A current changing at the rate of 1500 A/s in A induces an emf of 11.25V in B. Calculate the mutual inductance of the arrangement if the self inductance of each coil is 15 mH. Calculate flux produced in coil A (per Amp.) & the % of this flux which links with the turns of B.

Sol:-

$$\cancel{M = \frac{e}{dI_1/dt}} \quad = \quad \cancel{\Delta dI \times dt} \qquad \frac{dI_A}{dt} = 1500$$

$$e = M\frac{dI_A}{dt}$$

$$11.25 = M \times 1500$$

$$M = 7.5 \times 10^{-3} = 7.5\,mH$$

$$\cancel{\phi_{12} = \frac{M I_1}{N_2}}$$

$$\cancel{= 7.5 \times 10^{-3}}$$

$$L_1 = \frac{N_1 \phi_1}{I_1}$$

$$\frac{\phi_1}{I_1} \text{ (Flux per amp.)} = \frac{15 \times 10^{-3}}{750} = 2 \times 10^{-5}\ Wb/A$$

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

$$= \frac{M}{\sqrt{L^2}} = \frac{M}{L} = \frac{7.5}{15} = 50\%$$

H.W Q-2> Two coils: A of 12500 turns and B of 16000 turns lie in parallel planes so that 60% of the flux produced in A links with B. It is found that a current of 5A in A produces a flux of 0.6 mWb while the same current in B produces 0.8 mWb. Determine

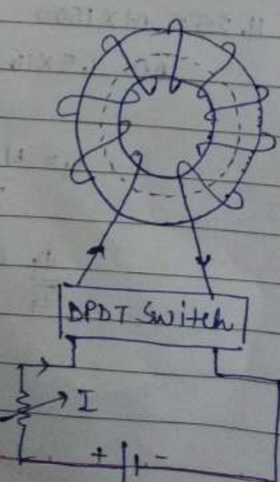
(i) mutual inductance.

(ii) coupling coefficient

[Ans: M=1.15H, k=0.586]

Magnetic Hysteresis and B-H curve:-
or Hysteresis loop

when a magnetic material is magnetised first in one dir'n then in another, it is found that magnetic flux density B' in the material lags behind the applied magnetising force 'H'. This phenomena of lagging is known as Magnetic hysteresis.



DPDT: Double Pole Double Throw

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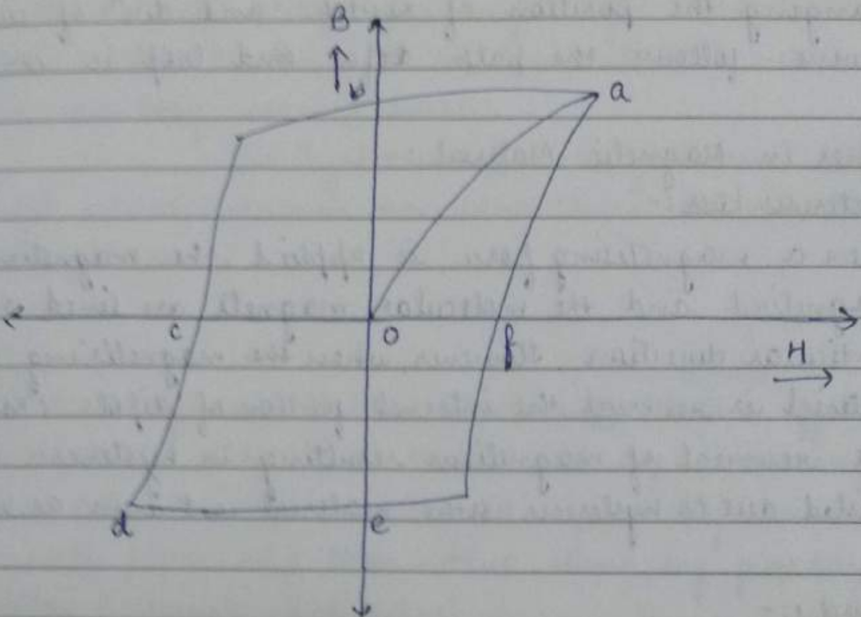
Consider a magnetic material on which a solenoid is wound uniformly. The solenoid is connected to a d.c. source through a DPDT switch.

When the field intensity H is increased gradually by increasing current in the solenoid, the flux density B also increases until a saturation point a is reached.



If now the magnetising force is gradually reduced to zero the flux density does not become zero. This phenomena is known as Residual Magnetism & Retentivity.

Residual Magnetism & Retentivity:-
The value of flux density ob retained by magnetic material is called residual magnetism & the power of retaining this residual magnetism is called retentivity of the material.

To demagnetise the magnetic ring, the 'H' is reversed by reversing the dir^n of current. When 'H' is increased in the reverse dir^n, the flux density starts decreasing & becomes zero at point c.

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Coercive Force:-
The value of magnetising force OC required to wipe off the residual magnetism is called coercive force.
To complete the loop, the magnetising force H is increased further in reverse dir^n till saturation pt. reaches. Again H is increased in the (+)ve dir^n by changing the position of switch and dir^n of current. The curve follows the path defa and loop is completed.

Losses in Magnetic Material:-
1) Hysteresis Loss:-
When a magnetising force is applied, the magnetic material is magnetised and the molecular magnets are lined of in a particular direction. However, when the magnetising force in the material is reversed the internal friction of dipole (MM) oppose the reversal of magnetism resulting in hysteresis and energy wasted due to hysteresis in the material is known as hysteresis loss.

Remedy:-
This type of losses can be minimized by using suitable magnetic material such as silicon, steel.

Formula:- $P_h = [\eta B_{max}^{1.6} f V]$ watts
where, P_h = Hysteresis loss in Watts
η = Hysteresis or Steinmetz's constant (in Joule/m^3)
(Value depends on nature of material)
f = Frequency of reversal
V = Volume (material) where magnetic reversal of magnetic material

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2> Eddy Current:-

When a magnetic material is subjected to a changing magnetic field and EMF is induced in the magnetic field material by Faraday's law. Since, the magnetic material is also conducting material, this emf circulates current within the body of the material. These currents are known as Eddy currents as these currents are not utilized for any useful work. This current produces heat $= I^2R$, losses ~~to~~ in the material which are also known as Eddy current losses.

The hysteresis and eddy current losses in a material are also known as iron losses or core losses or magnetic losses.

Remedy:-

To reduce eddy current loss, we have to ~~reduce~~ increase effective resista of the material, which can be reduced by increasing the effective area. This can be achieved by slicing the sheet steel into small pieces and laminating them by fine layers of insulation (varnish, oxide film).

Formula:-

$$[P_e = K_e B_{max}^2 t^2 f^2 V] \text{ watts}$$

where, P_e = Eddy current loss (in watts)

K_e = coefficient of Eddy current (depends on types of material)

B_m = Maximum value of flux density

f = Frequency of reversal of magnetic field

t = Thickness of lamination

To minimize such losses we can decrease eddy current by increasing the resistance of the material by reducing the effective area.

Unit - 4

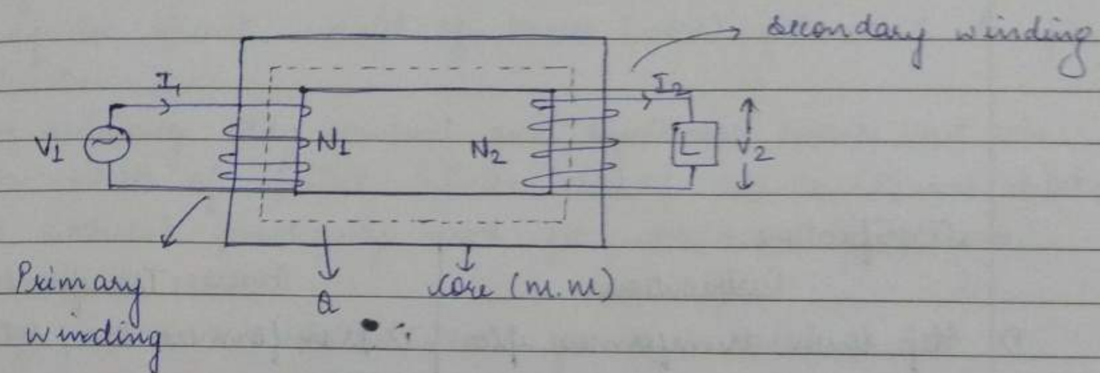
TRANSFORMERS

Transformer:-

It is static device which transfers A.C. electrical power from one circuit to another without change in frequency but voltage levels are changed.

Working Principle:-

It works on phenomena of mutual induction.



Classification:-

Distribution	Power Transformer
1) Step down transformer upto 500 KVA (kilo volt Ampere).	1) Transformers are rated above 500.
2) generally used for distribution and step down 11 kV into 3 phase 440 V.	2) These are generally used for stepping up and stepping down
3) Minimum rating is 5kV.	3) This transformers are operated during load periods only & can be disconnected during light load
4) These are energised for whole day (24 hrs).	
5) This transformer are used generally for varying load throughout the day.	4) Power transformer should have max efficiency of 80%.

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6) Due to this varying load, copper losses are different throughout the day.

7) Due to varying copper loss, max^m efficiency is nearly about 50% of full load.

Construction of Transformer:-

1) Magnetic circuit:-

(i) Magnetic circuit consist of limbs (core), yoke and damping structures.

(ii) For reducing Eddy current and hysteresis losses, we use thin sheets of special silicon steel of 0.3 to 0.35 mm thickness.

(iii) The material practically used for cores and yokes are CRGO and HRGO.

Silicon steel ⟵ [CRGO :- Cold Rolled grain Oriented
HRGO :- Hot Rolled grain Oriented]

(iv) Steel used, should possess high permeability, high resistivity & low coercive force.

2) Electric circuit:-

In this primary and secondary windings are considered usually made up of copper. (Nowadays, aluminium wires are used instead of copper).

3) Dielectric circuit:-

(i) The dielectric circuit consist of insulation used at different places in the transformer to insulate the conducting parts.

(ii) The insulation b/w core & low voltage winding is provided by

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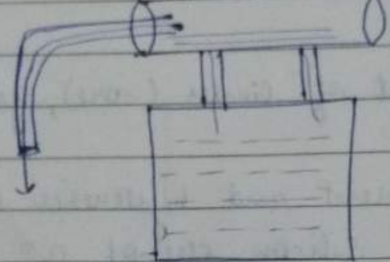
an insulation cylinder of paper, bakelite, prasse board.

(iii) oil ducts are always provided for cooling purpose.

4) Tank & Accessories :-

* Conservative Tank -

The tank is generally used for maintaining oil level in transformer during different weather conditions.



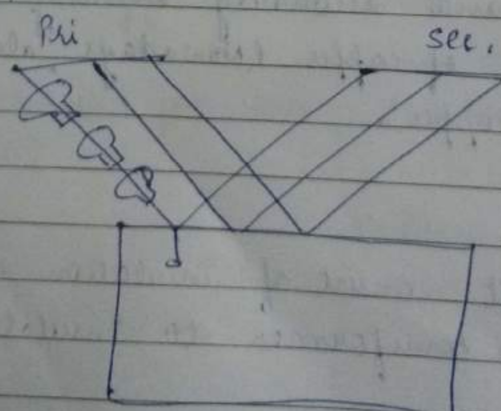
* Breather -

Breather is used for absorbing /extracting moisture from air which is mounted nearly transformer tank.

Silica gel & or calcium chlorides are used for absorbing moisture.

* Bushings :-

Bushings are nothing but simply terminal connections of the winding which are taken out and mounted with insulators.



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An Ideal Transformer-

1) The core of transformer is highly permeable so that is requires very small mmf to set up flux in the core.

2) Its leakage flux is zero, i.e. entire flux is confined to the core and links with both the windings.

3) Resistance of primary & secondary windings are negligible.

4) The losses in the transformer are zero.

*** EMF Equation of Transformer:-

When alternating voltage is applied to the primary side, it takes a magnetising current and a flux 'ϕ' is established in the core. The flux is uniformly distributed in the core & links with all the turns of both the windings. As flux 'ϕ' is of alternating nature so, due to faraday's law of EMI, an EMF is induced in primary winding which is given by

$$e_p = -N_p \frac{d\phi}{dt} \quad \text{—— (1)}$$

The main flux 'ϕ' can be expressed as-

$$\phi = \phi_m \cos \omega t$$

put this value of ϕ in eq^n (1)

$$e_p = -N_p \frac{d}{dt}(\phi_m \cos \omega t)$$

$$e_p = N_p \phi_m \omega \sin \omega t$$

The Induced emf 'e_p' will be max. when $\sin \omega t = 1$.

$$\because \sin \omega t = 1$$

$$\therefore (E_p)_{max.} = N_p \omega \phi.$$

The RMS value of induced emf in the primary side

$$(E_P)_{rms} = \frac{E_{max}}{\sqrt{2}}$$

$$= \frac{N_P \omega \phi_m}{\sqrt{2}}$$

$$= \frac{2\pi f N_P \phi_m}{\sqrt{2}}$$

$$\boxed{E_{P(rms)} = 4.44 f \phi_m N_P}$$

Similarly, for secondary winding,

$$\boxed{E_{S(rms)} = 4.44 f \phi_m N_S}$$

Transformation Ratio :-

~~$N_P I_P$~~ For an ideal transformer,

$$N_P I_P = N_S I_S$$

$$V_P I_P = V_S I_S$$

From above eqn's

$$\frac{E_P}{E_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P} = \frac{V_P}{V_S} = k \longrightarrow \text{Transformation Ratio}$$

Q-1) A single phase transformer has 350 primary & 1050 secondary turns. Net cross-sectional area of core is $55 cm^2$. The primary winding is connected to 400V, 50Hz single phase supply. Calculate

(i) Max^m value of flux density in core.

(ii) Voltage induced in secondary winding.

Sol:-

0.93T

200V.

$N_P = 350$, $N_S = 1050$

~~ϕ_m~~ $e_P = 4.44 N_P \phi_m f$

$$400 = 4.44 \times 350 \times B_m \times A_i \times 50$$

$$B_m = 0.93T$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$V_s = V_p \times \frac{N_s}{N_p} = 400 \times \frac{\overset{3}{\cancel{1050}}}{\cancel{350}} = 1200V$$

Q:- The required no load voltage ratio in a single phase 50 Hz core type transformer is $\frac{6600}{500}$ volts. Find the no of turns in each winding if the flux is to be 0.06 Wb. $\left| \frac{6600}{500} = \frac{V_P}{V_S} = \frac{E_P}{E_S} \right.$

Sol:-

$$E_S = 4.44 N_S \phi_m F$$

$$N_S = \frac{500}{4.44} \times \frac{1}{0.06 \times 50} = 37.5 \approx 38$$

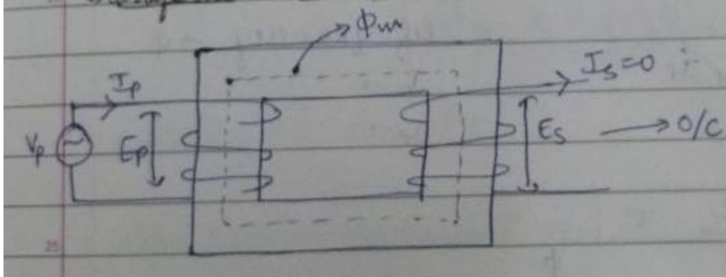
$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

$$N_P = \frac{V_P}{V_S} \times N_S = \frac{6600}{500} \times 38 = 501.6 \approx 502$$

Transformer under different loads:-

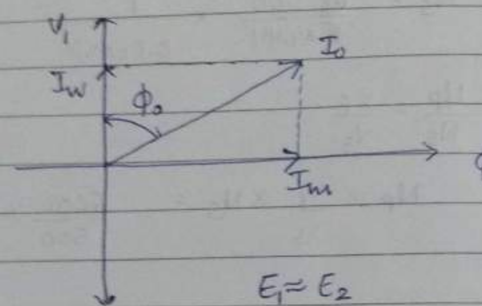
- NO Load
- ON Load
  - R
  - L
  - C

Transformer at NO Load:-



A transformer is said to be on NO load, when its secondary side is left open-circuited i.e. $I_S = 0$. In actual transformers under no load condition, a small current I_0 (usually 2-10% of rated current) called Exciting cur

Max^m value of current which transformer can bear is drawn by the primary from the supply. This current has to supply iron or core losses and small amount of copper losses in primary. As I_0 is very small, the copper losses are neglected as compared to core losses. Therefore current lags behind the voltage V_1 by an angle ϕ.

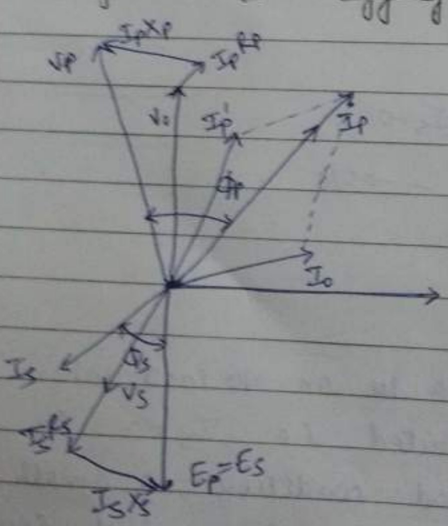


$I_W = I_0 \cos\phi_0$

$I_m = I_0 \sin\phi_0$

$I_0 = \sqrt{I_W^2 + I_m^2}$

Transformer on Lagging Load (or Inductive Load):-



Ref. quantity $\Rightarrow \phi$

$I_0 \rightarrow$

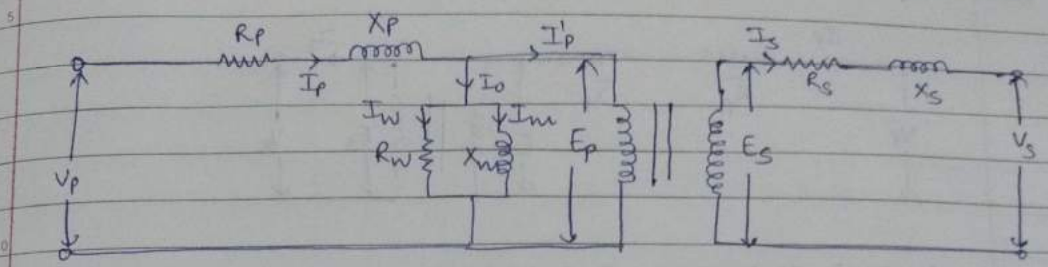
$I_P \rightarrow$

(Theory by Book)

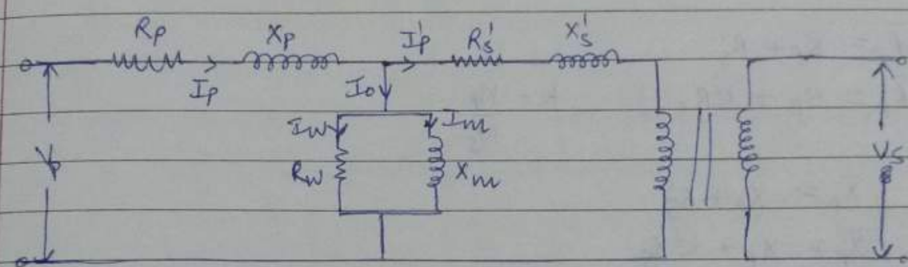
and Resistive & Capacitive do by self

Equivalent circuit of a Transformer:-

Equivalent circuit of a transformer is helpful in predetermining the behaviour of transformer under various conditions of ~~operator~~ transformer from the known equivalent circuit parameters.



(I) Refer to Primary:-

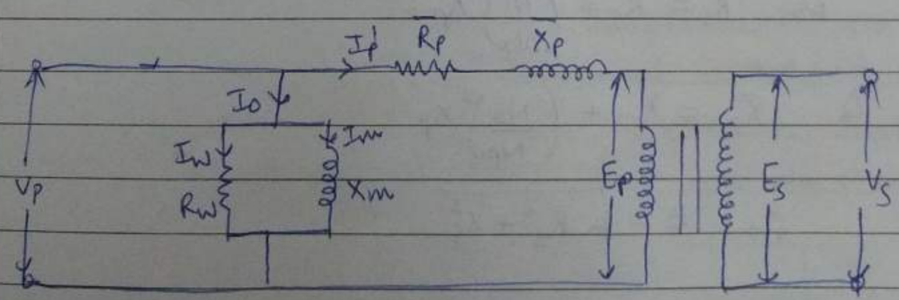


$$(I_p')^2 R_s' = (I_s)^2 R_s$$

$$\therefore \quad R_s' = \left(\frac{I_s}{I_p'}\right)^2 R_s = \left(\frac{N_p}{N_s}\right)^2 R_s = k^2 R_s$$

Similarly, $X_s' = k^2 . X_s$

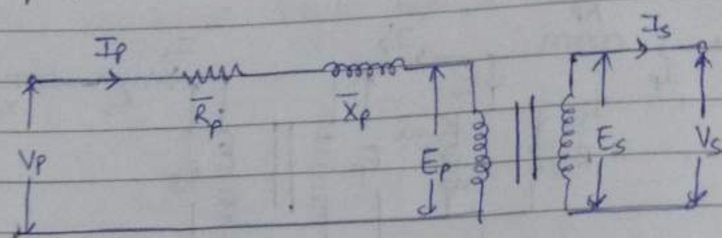
Approximate Equivalent circuit refer to 1°:-



$$\bar{R}_p = R_p + R_s'$$
$$\bar{R}_p = R_p + k^2 R_s$$

$$\bar{X}_p = X_p + X_s$$
$$\bar{X}_p = X_p + k^2 X_s$$

Simplified equivalent circuit :-



Equivalent Resistance & Reactance :-

(Refer to 1°)

$$\bar{R}_p = R_p + R_s'$$
$$\bar{R}_p = R_p + k^2 R_s, \quad k = \frac{N_p}{N_s}$$

$$\bar{X}_p = X_p + X_s'$$
$$\bar{X}_p = X_p + k^2 X_s$$

Total impedance refer to 1° :

$$\bar{Z}_p = \sqrt{\bar{X}_p^2 + \bar{R}_p^2}$$

Refer to 2°

$$\bar{R}_s = R_s + \overbrace{k^2 R_p}^{R_p'}, \quad k = \frac{N_s}{N_p}$$

or $$\bar{R}_s = R_s + \left(\frac{N_s}{N_p}\right)^2 R_p$$

& $$\bar{X}_s = X_s + \left(\frac{N_s}{N_p}\right)^2 X_p$$

$$\therefore \quad Z = \sqrt{\bar{R}_s^2 + \bar{X}_s^2}$$

Q-1) A 25 kVA, 2200 by 220V, 50Hz single phase transformer, has the following R & leakage reactance

$R_p = 0.8\,\Omega$, $X_p = 3.2\,\Omega$

$R_S = 0.009\,\Omega$, $X_S = 0.03\,\Omega$

calculate:-

(i) Equivalent resistance refer 1°
(ii) Equivalent reactance refer 1°
(iii) Equivalent resistance refer 2°
(iv) Equivalent reactance refer 2°.

Sol:-

$$\because \frac{E_P}{E_S} = \frac{V_P}{V_S} = \frac{2200}{220} = 10 = \frac{N_P}{N_S}$$

$$f = 50\,Hz$$

(i) $\because \bar{R}_p = R_p + k^2 R_s$

$= 0.8 + 100 \times 0.009$

$= 0.8 + 0.9$

$= 1.7\,\Omega$

(iii) $\bar{R}_S = R_S + \frac{1}{100} \times R_P$

$= 0.009 + \frac{0.8}{100} = 0.017\,\Omega$

(ii) $\bar{X}_p = X_p + k^2 X_s$

$= 3.2 + 100 \times (0.03)$

$= 3.2 + 3$

$= 6.2\,\Omega$

(iv) $\bar{X}_S = X_S + \frac{1}{100} X_P$

$= 0.03 + \frac{3.2}{100} = 0.062\,\Omega$

Voltage Regulation :-

The secondary terminal voltage changes with the change in load so, voltage regulation of a transformer is defined as the net change in the 2° terminal voltage from no load to full load expressed as a % of its rated voltage for the 1° voltage.

$$\%\,V.R. = \left(\frac{V_{SNL} - V_{SFL}}{V_{SFL}}\right) \times 100$$

NL : No load.
FL : Full load

Also, $\% VR = \frac{I_s(\bar{R}_s \cos\phi \pm \bar{X}_s \sin\phi)}{V_s} \times 100$

$+ \rightarrow$ lagging power factor / i.e Inductive load

$- \rightarrow$ leading power factor / i.e Capacitive load

Q-1) A 2kVA, $\overbrace{400 \text{ by } 200\text{ V}}^{k}$, 50Hz single phase transformer has following parameters as refer to 1° side -

$\bar{R}_p = 3.2$, $\bar{X}_p = 4.2$

Determine the regulation of transformer when operating at

→ full primary current supply

(i) full load with 0.8 pf lagging,

(ii) full load with 0.8 p.f. leading,

(iii) half load with 0.8 p.f. lagging

↓

half primary current supply.

Sol:-

$k = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{400}{200} = 2$

$\cos\phi = 0.8$

$\therefore \sin\phi = \sqrt{1-0.64} = \sqrt{0.36} = 0.6$

$\because$ Refer to 1°:-

$\therefore \% VR = \frac{I_p(\bar{R}_p \cos\phi \pm \bar{X}_p \sin\phi)}{V_p} \times 100$

$\because$ current, $I_p = \frac{2000V}{400V} = 5A$

$\therefore$ (i) $\% VR = \frac{5(3 \times 0.8 + 4 \times 0.6)}{400} \times 100$

$= \frac{5(2.4 + 2.4)}{4} = \frac{5 \times \overset{1.2}{4.8}}{4} = 6\%$

(ii) $\% V.R. = 0$

(iii) $\% V.R. = \frac{5}{2}\left(\frac{2.4 + 2.4}{400}\right) \times 100 = 3\%$

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Losses in Transformer:-

Losses in Transformer
- Core/Iron losses
  - Hysteresis
  - Eddy Current

  (fixed/constant losses)
- Copper losses

  Variable losses (in windings)

— In general, Cu losses occur in all those parts of the transformer that carry electric current. Cu-losses are directly $\propto$ to square of current and resistance.

$\therefore$ for of $1^\circ \propto I_p^2 R_p$

for $2^\circ \propto I_S^2 R_s$

$\therefore$ Total Cu-loss $= I_p^2 R_p + I_S^2 R_s$

Efficiency of a Transformer:-

Efficiency is defined as the ratio of output power to the input power.

$$\% \eta = \frac{\text{O/P Power}}{\text{I/P Power}}$$

$$= \frac{\text{O/P Power}}{\text{O/P Power + Losses}}$$

$$= \frac{V_s I_s \cos\phi}{V_s I_s \cos\phi + P_i + P_c}$$

Condition for Maximum Efficiency:-

The efficiency of a transformer at a given load & power fa[ctor] is given by :-

$$\frac{V_s I_s \cos\phi}{V_s I_s \cos\phi + P_i + I_s^2 R_{es}}$$

Divide numerator & denominator by I_s

$$= \frac{V_s \cos\phi}{V_s \cos\phi + \frac{P_i}{I_s} + I_s R_{es}} \quad \text{--- (1)}$$

The terminal voltage V_s is approximately constant for given load. Thus for a given power factor in load the efficiency if denominator is min^m & numerator should be treated as constant. So, max^m cond^n is obtained by differentiating the denominator wrt I_s & equating it to zero.

$$\Rightarrow \frac{d}{dI_s}\left(V_s \cos\phi + \frac{P_i}{I_s} + I_s R_{es}\right) = 0$$

$$\Rightarrow 0 - \frac{P_i}{I_s^2} + R_{es} = 0$$

$$\Rightarrow R_{es} = \frac{P_i}{I_s^2}$$

$$\Rightarrow I_s^2 R_{es} = P_i$$

$$\Rightarrow P_c = P_i$$

Thus eff of transformer will be max. when both the los[ses] are equal.

$$\% \eta_{max} = \frac{V_s I_s \cos\phi}{(V_s I_s \cos\phi + 2P_i)} \times 100$$

The value of secondary at which eff will be max is given by:-

$$I_s^2 R_{es} = P_i$$

$$\boxed{I_s = \sqrt{\frac{P_i}{R_{es}}}}$$

If 'x' is the fraction of full load kVA at which the eff. of transformer is max. then,

Iron loss $= P_i$

copper loss $= x^2 P_c$

For max. eff.

$$x^2 P_c = P_i$$

$$\Rightarrow \boxed{x = \sqrt{\frac{P_i}{P_c}}} \quad \text{kVA load}$$

Output kVA corresponding to max. efficiency $= x \times$ full load kVA

$$\% \eta_x = \frac{x \times kVA \times 1000 \times \cos\phi}{x \times kVA \times 1000 \times \cos\phi + P_i + x^2 P_c} \times 100$$

Q-1) In a 25 kVA, $\frac{2000\,V}{200}$ power transformer has iron & full load Cu losses of 350 W & 400 W respectively. calculate the efficiency at unity power factor at :-

(i) full load

(ii) half load

Sol:-

(i) x=1

$$\eta = \frac{1 \times 25 \times 100\cancel{0} \times 1}{1 \times 25 \times 100\cancel{0} \times 1 + 35\cancel{0} + 1 \times 40\cancel{0}} \times 100 = \frac{2500}{2500 + 75} \times 100$$

$= 97.08\%$

$x = \frac{1}{2}$

(ii) $\eta = \dfrac{\frac{1}{2} \times 25 \times 1000 \times 1}{\frac{1}{2} \times 25 \times 1000 \times 1 + 350 + \frac{1}{4} \times 400} = \dfrac{1250}{1250 + 45}$

$= 96.52\%$

Q-2) In a 50 kVA, $\frac{1100}{220}$ V transformer, the iron & full load Cu losses are 350W & ~~40~~ 425 W respectively. calculate the efficiency at

(i) full load with unity ~~pow~~ PF

(ii) half ————

(iii) full load with 0.8 PF lagging

Sol:-

(i) $\eta = \dfrac{1 \times 50 \times 1000 \times 1}{50 \times 1000 + 350 + 425} = \dfrac{5000}{5000 + 77.5} = 98.47\%$

(ii) $\eta = \dfrac{\frac{1}{2} \times 50 \times 1000 \times 1}{\frac{1}{2} \times 50 \times 1000 + 350 + \frac{1}{4} \times 425} = \dfrac{25 \times 100}{25 \times 100 + 35 + 10.625}$

$= \dfrac{2500}{2500 + 45}$

$= 98.28\%$

(iii) $\eta = \dfrac{1 \times 50 \times 1000 \times 0.8}{50 \times 1000 \times 0.8 + 350 + 425}$

$= 98.1\%$

(iv) determine the max. efficiency & load at which max. eff. occurs. (assuming load to be resistive i.e. $\cos\phi = 1$)

Sol:-

Load at which, $x = \sqrt{\dfrac{P_i}{P_c}} = \sqrt{\dfrac{350}{425}}$

eff. will be max.

$x = 0.907$

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$x = 90.7\%$ of full load KVA

O/P KVA at which eff will be max^m $= x \times$ full load KVA
$= 0.907 \times 50 \times 10^3$
$= 45.35 \times 10^3$

$$\% \eta_{max.} = \frac{1 \times 45.35 \times 10^3 \times 1}{1 \times 45.35 \times 10^3 + 350 + 350} = 98.4\%$$

Q-3) The eff. of a 400KVA single phase transformer is 98.77%, when delivering full load at 0.8 PF lagging and 99.13% at half load & unity P.F. Calculate:-

(i) Iron loss

(ii) Cu loss

sol:-

$$98.77 = \frac{1 \times 400 \times 1000 \times 0.8}{1 \times 400 \times 1000 \times 0.8 + P_i + P_c} \times 100$$

$$98.77 = \frac{32 \times 10^6}{32 \times 10^4 + P_i + P_c}$$

$$3160.64 \times 10^4 + 98.77 (P_i + P_c) = 32 \times 10^6$$

$$P_i + P_c = \frac{393600}{98.77} = 3985$$

$$\frac{99.13}{100} = \frac{\frac{1}{2} \times \overset{200}{\cancel{400}} \times 1000 \times 1}{\frac{1}{\cancel{2}} \times \overset{200}{\cancel{400}} \times 1000 + P_i + \frac{P_c}{4}}$$

$$0.9913 = \frac{2 \times 10^5}{2 \times 10^6 + P_i + \frac{P_c}{4}}$$

$$1.9826 \times 10^{5} + 0.9913 \left[P_i + \frac{P_c}{4}\right] = 2 \times 10^5$$

$$P_i + \frac{P_c}{4} = \frac{17400}{0.9913} = 17552.7$$

~~3985~~ -

$$P_i = 1012.0\ W$$
$$P_c = 2973\ W$$

→ All day efficiency :-
It is defined as ratio of the output in kWH to the input in kWh for 24 hrs.

$$\%\ \eta_{allday} = \frac{O/P\ (\text{In kWh})}{I/P\ (\text{In kWh})} \text{ for 24 hrs}$$

Q-1) A 20 kVA transformer on domestic load, which can be taken as of unity P.F., has a full load efficiency of 95.3%, the Cu loss then being twice of iron loss. Calculate its all day eff. on foll. load cycle
No load ⇒ 10 hrs
Half load ⇒ 8 hrs.
full load ⇒ 6 hrs.

Sol:-

Full load -

→ O/P in kW = 20×1 = 20 kW

Full load in I/P :-
(kW)

$$= \frac{O/P}{\eta} = \frac{20}{95.3} \times 100 = 20.986\ kW$$

→ Total losses $= P_i + P_c = 20.986 - 20$

$$P_i + P_c = 0.986\ kW \quad \text{—①}$$
$$P_c = 2P_i \quad \text{—②}$$
$$P_i = 0.3287\ kW$$

Full load Cu losses, $P_c = 0.6574\ kW$

→ kWh o/p in 24 hrs $= 0 + \frac{1}{2} \times 20 \times 8 + 1 \times 20 \times 6$

$$= 200\ kWh$$

Numericals eff.; All day eff.; voltage regulation → v. Imp. testing

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→ Iron losses for 24 hrs = $0.3287 \times 24 = 7.89$ kWh

→ Cu loss for 24 hrs $= 0 + \left(\frac{1}{2}\right)^2 \times 0.6574 \times 8 + (1)^2 \times 0.6574 \times 6$

$= 5.259$ kWh

→ Input in 24 hrs. = Output (in kWh) for 24 hrs + Losses (in kWh) for 24 hrs.

$= 200 + \cancel{270}\ 7.89 + 5.259$

$= 213.149$ kWh

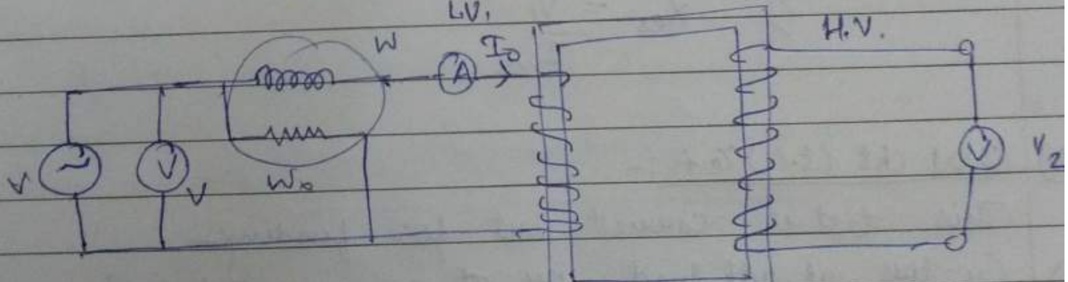
$$\% \eta_{\text{all day}} = \frac{\text{O/P (in kWh)}}{\text{I/P (in kWh)}} \text{ for 24 hrs.}$$

$$= \frac{200}{213.149} \times 100 = 93.83\%$$

Testing of Transformer:-

1) O.C. or No load Test :-

This test is carried out to find no load iron losses an[d] no load current I_0 which is helpful in finding no load parallel branch parameters R_0 and X_0.



This test is usually carried out on low voltage side i.e. am[meter], wattmeter, voltmeter are connected on low voltage side. T[he] primary winding ~~(low voltage winding)~~ is connected to [...]

voltage with normal freq. & sec side should left open or connected with a voltmeter.

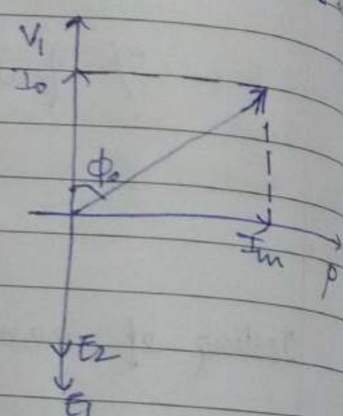
Since, the secondary (High voltage winding) is open, the current drawn by the primary is no load current I_0 measured by ammeter. As the value of no load current I_0 is very small, the Cu losses in primary & secondary winding are negligible. ∴ Wattmeter reads iron or core loss.

Let wattmeter reading $= W_0$, voltmeter reading $= V_1$ & ammeter reading $= I_0$, then iron loss of the transformer is

$$P_i = W_0$$

$$V_1 I_0 \cos\phi_0 = W_0$$

No load PF $\cos\phi_0 = \frac{W_0}{V_1 I_0}$



$$I_W = \frac{W_0}{V_1} = I_0 \cos\phi_0$$

$$I_m = \sqrt{I_0^2 - I_W^2} = I_0 \sin\phi_0$$

No load parameter:

1) $R_{es} = \frac{V_1}{I_W}$

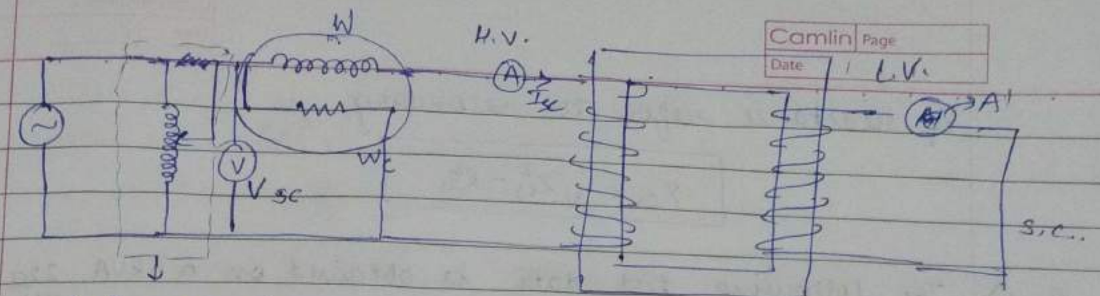
2) $X_{es} = \frac{V_1}{I_m}$

2) Short ckt (S.C) Test :-

This test is carried out for finding–

1) Cu-loss at full load or at any desired load

2) Equivalent Impedance (Z_{es} or Z_{ep}), Eq. resistance (R_{es} or R_{ep}) and Equivalent leakage reactance. (X_{es} or X_{ep}).



Auto transformer

This test is gen. carried out on high v side A, V, W are connected on & LV winding in sickted by a thick strip or by connecting an ammeter. The HV winding is supplied with A.C voltage with normal frequency along with an auto transformer so that full load current gradually flows in both the windings which are measured by ammeters A and A'. LV winding is essential for HV winding, failing which an excessive current will flow in both the windings which may damage them. As we apply low voltage, flux set up in the core will also be very small, therefore iron losses would be negligible. Therefore wattmeter reading only shows Cu loss.

Let wattmeter reading be W_c,

A reading be I_{sc} & V reading be V_{sc}.

∴ Full load Cu loss will be given by:

$$P_C = I_{sc}^2 R_{es}$$

∴ Eq. res refer to secondary,

$$R_{es} = \frac{P_c}{I_{sc}^2} = \frac{W.R.}{(A)^2}$$

Now, $V_{sc} = I_{sc} \cdot Z_{es}$

Eq. impedance refer to sec.

$$Z_{es} = \frac{V_{sc}}{I_{sc}} = \frac{VR.}{AR.}$$

Eq. reactance refer to secondary

$$\boxed{X_{es} = \sqrt{Z_{es}^2 - R_{es}^2}}$$

Q-1) The following test data is obtained on a 5kVA, 220 V / 440 V single phase transformer.

O.C. test → 220V, 2A, 100W (LV) → P_i

S.C. test → 40V, ~~H.S.~~ 11.4A, 200W (HV) → P_c

Determine % eff & % voltage regulation at full load at 0.9 PF lagging.

Sol^n:-

$$\eta = \frac{1 \times 5 \times 1000 \times 0.9}{1 \times 5 \times 1000 \times 0.9 + 100 + 1^2 \times 200}$$

$$= \frac{4500}{4500 + 300} = 93.75\%$$

$\sqrt{1-0.19}$

$\sqrt{1-0.81}$

$\sqrt{1-0.9}$

$\sqrt{0.1}$

$$11.4\left[\cancel{\frac{220}{2} \times 0.9} + \cancel{\frac{220}{11.4} \times 0.9}\right] \qquad \cancel{R_{es} = \frac{220}{2}} = 110$$

$$\frac{200}{(11.4)}$$

$$\cancel{\frac{11.4\left[\frac{200}{(11.4)^2} \times 0.9 + 3.14 \times 0.435\right]}{40}}$$

$$\cancel{Z_{es} = \frac{200}{}} \quad \frac{40}{11.4} = 3.5$$

$$\frac{11.4 \times \left[1.54 \times 0.9 + 3.14 \times 0.435\right]}{40}$$

$R_{es} = 1.53$

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$R_{es} = \frac{W}{(A)^2} = 1.539\,\Omega$

$Z_{es} = \frac{V}{A} = 3.509\,\Omega$

$X_{es} = \sqrt{Z_{es}^2 - R_{es}^2} = 3.153\,\Omega$

$\cos\phi = 0.9$

$\sin\phi = 0.435$

$\%VR = \frac{\overset{11.4}{I_s}\,(R_{es}.\cos\phi + X_{es}\sin\phi)}{\underset{440}{V_s}}$

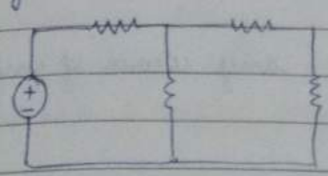
$\%VR = 7.2\%$

Q- Write a short note on Auto-transformer.
(Prepare for 10 marks).

CIRCUIT ANALYSIS TOOLS

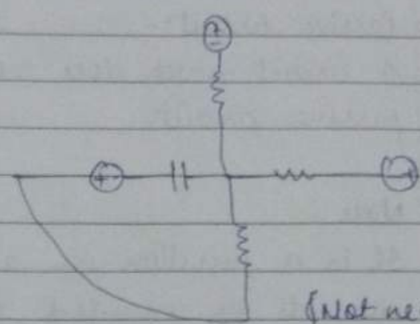
Circuit & Network -

Every circuit is a network but not vice versa.



Circuit

(Closed loop must be there)



Network [Not necessary closed loop]

1) Circuit :-

A conducting path through which an electric current either flows or is intended to flow is called a circuit.

2) Linear circuit -

A circuit whose parameters (R, L, C) are constant or obeys Ohm's law is called a linear circuit.

3) Non-linear circuit -

A circuit whose parameters change with voltage or current or does not obey Ohm's law is called Non-linear circuit.

4) Unilateral circuit :-

~~For unilate~~ A ckt. whose properties or characteristics change with the direction of its operation is called Unilateral circuit.

5) Bilateral circuit :-

A circuit whose properties or characteristics remain same in either direction is called Bilateral circuit.

6) Active circuit:-

A circuit which contains one or more than one source o
is called an active circuit.

7) Passive circuit:-

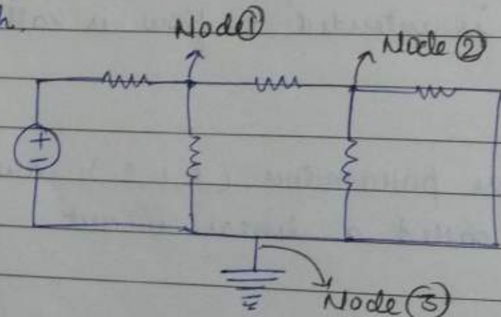
A circuit which does not contain any source of emf i
passive circuit.

8) Node:-

It is a junction in a circuit where 2 or more circ
elements are connected together.

9) Branch:-

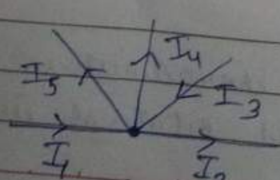
The part of a ckt. which lies b/w two junction is ca
a branch.



KCL :-

① It states that the sum of current entering a junction
equal to sum of currents leaving the junction.

② If the current towards the junction is considered positiv
those away as negative then the algebraic sum of all c
meeting at a common junction is zero.



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

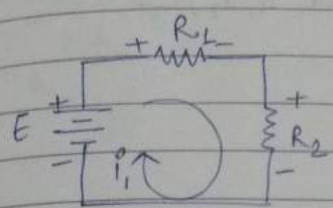
$$I_1 + I_3 - I_2 - I_4 - I_5 = 0$$

No. of equations = (Nodes − 1)

KVL :-

1. It states that - the sum of emf around any closed loop of a circuit equals the sum of potential drop in that loop.

2. If rise in voltage is considered positive and drop in voltage as negative, then the algebraic sum of potential difference around a closed loop is zero.



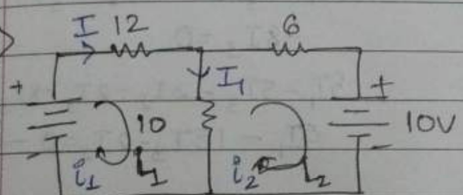
$$E = i_1R_1 + i_1R_2$$

$$E - i_1R_1 - i_1R_2 = 0$$

No. of equations = No. of loops

→ No. of eq^n's formed in KCL are always less than eq^n's formed in KVL.

Q-1)



$\cancel{12 = 12I_1}$ KVL

Method I: $12 = 12I + 10I_1$

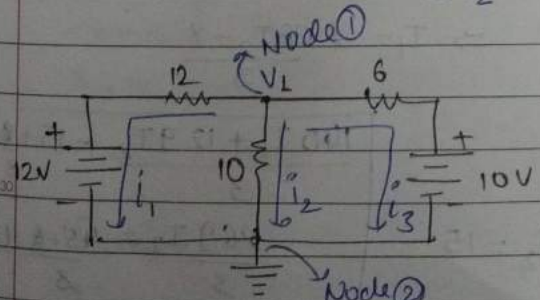
$10 = 6(I_1 - I) + 10I_1$

Method II: $12i_1 + 10(i_1 - i_2) = 12$

$6i_2 + 10(i_2 - i_1) = -10$

Or directly $\cancel{22I}$ $22i_1 - 10i_2 = 12$

$16i_2 - 10i_1 = -10$



$$i_1 + i_2 + i_3 = 0$$

$$\frac{V_1 - 12}{12} + \frac{V_1}{10} + \frac{V_1 - 10}{6} = 0$$

$$\frac{5V_1 - 60 + 6V_1 + 10V_1 - 100}{60} = 0$$

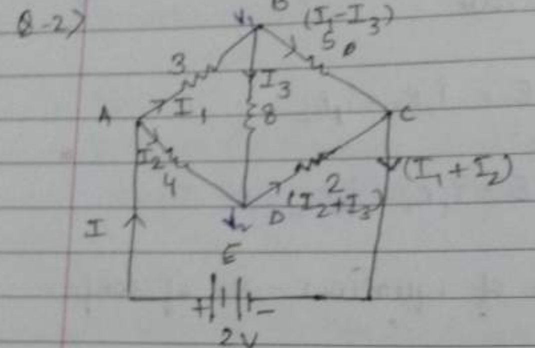
$$21V_1 = 160 \Rightarrow V_1 = \frac{160}{21} = 7.$$

$$i_1 = \frac{V_1-12}{12} = \frac{7.62-12}{12} = -0.365$$

$$i_2 = \frac{V_1}{10} = \frac{7.62}{10} = 0.762$$

$$i_3 = \frac{V_1-10}{6} = \frac{7.62-10}{6} = -0.3967$$

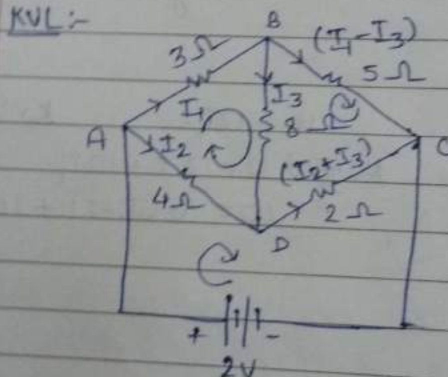
Q-2)



Find I_1, I_2, I_3.

Sol:-

KVL:-



$3I_1 + 8I_3 - 4I_2 = 0$

$5(I_1 - I_3) \cancel{+} -2(I_2+I_3)$

$-8I_3 = 0$

$5I_1 - 5I_3 - 2I_2 - 2I_3 - 8$

$5I_1 - 15I_3 - 2I_2 = 0$

$2 = 4I_2 + 2I_2 + 2I_3$

$\cancel{2 = 4I_2}$ $2 = 6I_2 + 2I$

$1 = 3I_2 + I_3$

$I_3 = 1 - 3I_2$

$3I_1 + 8(1-3I_2) - 4I_2 = 0$

$3I_1 + 8 - 24I_2 - 4I_2 = 0$

$3I_1 - 28I_2 + 8 = 0$

$\Rightarrow I_1 = \cancel{8}\ \frac{28I_2 - 8}{3}$

$5I_1 - 15(1-3I_2) - 2I_2 = 0$

$5I_1 - 15 + 45I_2 - 2I_2 = 0$

$5I_1 + 43I_2 - 15 = 0$

$\frac{5}{3}\left[28I_2 - 8\right] + 43I_2 = 15$

$\frac{140I_2 + 129I_2}{3} = 15$

$\frac{269}{\cancel{3}} I_2 = \frac{45+8}{\cancel{3}}$

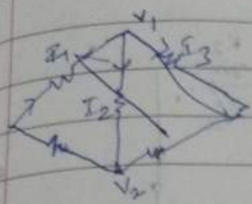
$I_2 = \frac{885}{269} = $

$$I_1 = \frac{28I_2 - 8}{3} = \frac{28\times 0.\cancel{197}^{316} - 8}{3} \cancel{= 0.828} = 0.283$$

$$I_3 = 1 - 3I_2 = 1 - 3\times 0.\cancel{197}^{316} = \cancel{0.409}\ 0.052$$

KCL:-

$$\cancel{I_1 = I_2 + I_3}$$



$$\cancel{\frac{V_1 - 2}{3} = \frac{V_1 - V_2}{}}$$

$$\cancel{\frac{(V_1-2)}{3} + \frac{}{} = \frac{V_1}{3}} +$$

$$\frac{V_1 - V_2}{8} + \frac{V_1 - 2}{\cancel{8}\,3} + \frac{V_1}{5} = 0$$

$$\cancel{15V_1 - 15V_2 + 40V_1 - 80 + 24V_1 = 0}$$

$$\cancel{79V_1 - 80 - 15V_2 = 80}$$

$$\cancel{79V_1 - 15V_2 = 80} \quad \text{—①}$$

$$\cancel{\frac{5V_1 - 5V_2 + 5V_1 - 10 + 8V_1}{40} = 0}$$

$$\cancel{18V_1 - 5V_2 = 10} \quad \text{—①}$$

$$\frac{V_2 - V_1}{8} + \frac{V_2 - 2}{4} + \frac{V_2}{2} = 0$$

$$\cancel{79V_1 + 5V_2 = 80}$$

$$\frac{V_2 - V_1 + 2V_2 - 4 + 4V_2}{8} = 0 \Rightarrow 7V_2 - V_1 = 4 \quad \text{—②}$$

$$\cancel{V_1 = 7V_2 - 4}$$

$$\cancel{18(7V_2 - 4) - 5V_2 = 10}$$

$$\cancel{126V_2 - 72 - 5V_2 = 10 \Rightarrow 121V_2 = 82 \Rightarrow V_2 = 0.67}$$

$$\cancel{V_1 = 7\times 0.677 - 4 = 0.739V}$$

$$\cancel{I_1 = \frac{V_1 - 2}{3}} = \frac{15V_1 - 15V_2 + 40V_1 - 80 + 24V_1}{120} = 0$$

$$I_1 = \frac{V_1 - 2}{3} = \frac{1.152 - 2}{3} = -0.283A \quad \cancel{= -0.485A}$$

$$I_2 = \frac{V_2 - 2}{4} = \frac{0.736 - 2}{4} = -0.316\,A$$

$$I_3 = \frac{V_1 - V_2}{8} = 0.052A$$

$$79V_1 - 15V_2 = 80 \quad \text{— ①}$$

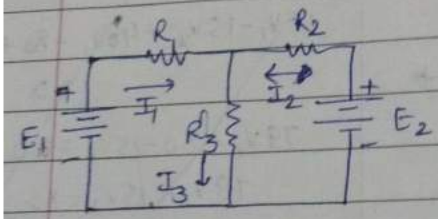
$$79(7V_2 - 4) - 15V_2 = 80$$

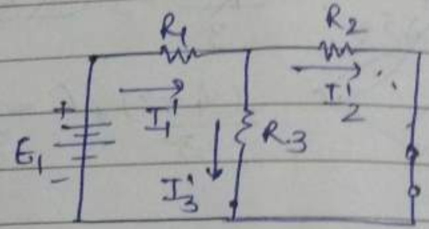
$$553V_2 - 316 - 15V_2 = 80$$

$$V_2 = \frac{396}{538} = 0.736V$$

$$V_1 = 7\times 0.736 - 4 = 1.152V$$

Superposition Theorem :-
It states that in any linear bilateral network containing more than one source of emf then the current in any branch is the algebraic sum of a number of individual currents considering the emf's separately and replacing other sources by their internal resistances.



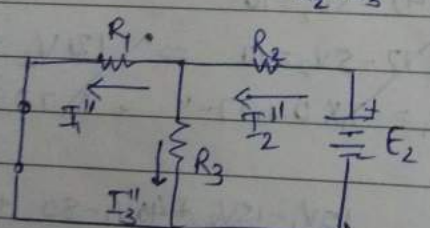


$$R'_{eq} = R_1 + \frac{R_2 R_3}{R_2 + R_3}$$

$$I_1' = \frac{E_1}{R'_{eq}}$$

$$I_2' = \frac{R_3}{R_2 + R_3} \cdot I_1'$$

$$I_3' = \frac{R_2}{R_2 + R_3} I_1'$$



$$R''_{eq} = R_2 + \frac{R_1 R_3}{R_1 + R_3}$$

$$I_2'' = \frac{E_2}{R''_{eq}}$$

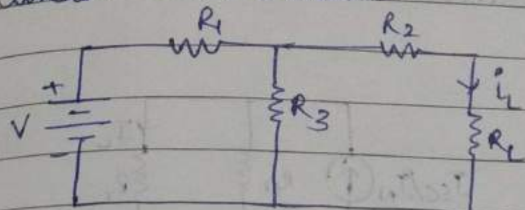
$$I_1'' = \frac{R_3}{R_1 + R_3} I_2''$$

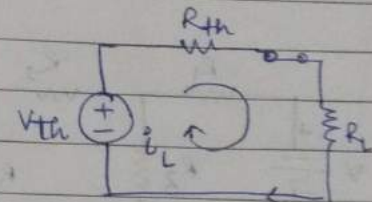
$$I_3'' = \frac{R_1}{R_1 + R_3} I_2''$$

$$I_1 = |I_1' - I_1''|$$

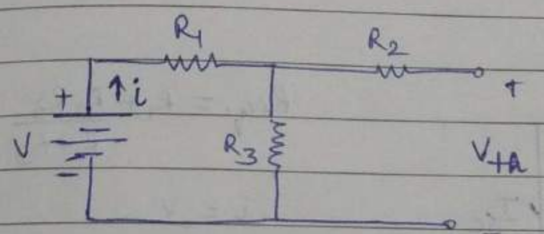
Thevenin's Theorem :-

It is used to determine the current through load resistor R_L connected across two terminals of a network which contains voltage sources and resistors, then the network can be replaced by a single source of emf called V_{Th} & a series resistor R_{Th} where V_{Th} is P.D. when R_L is removed & R_{Th} is eq. resistance as seen from the terminals under consideration.





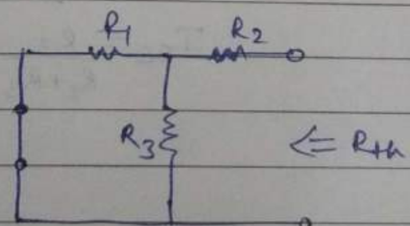
R_L, V_{Th}, R_{Th}



$$i = \frac{V}{R_1+R_3}$$

$$V_{th} = \frac{R_3}{R_1+R_3} V_s$$

V_{Th}/V_{oc}
↓
open ckt

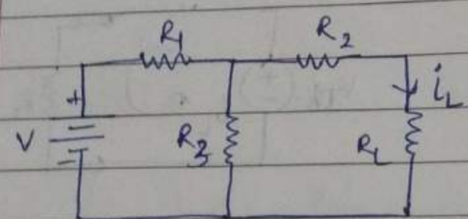


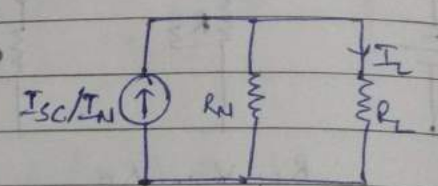
$$R_{th} = R_2 + \frac{R_1 R_3}{R_1+R_3}$$

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

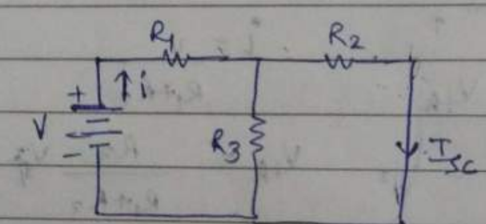
Norton's Theorem :-

It is used to find current flowing through the load. Any linear bilateral network containing independent voltage and current source may be replaced by an equivalent current source I_N in parallel with the resistance R_N where I_N is the short circuit current I_{sc} and R_N is equivalent resistance as seen from the terminals under consideration.





I_{SC}/I_N , R_N



$$Req. = R_1 + \frac{R_2 R_3}{R_2 + R_3}$$

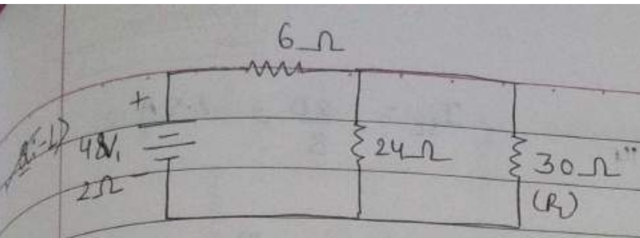
$$i = \frac{V}{Req.}$$

$$I_{SC} = \frac{R_3}{R_2 + R_3} \, i$$

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

$$I_L = \frac{R_N}{R_N + R_L} \cdot I_{SC}$$

Q-1)

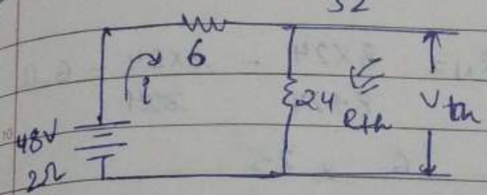


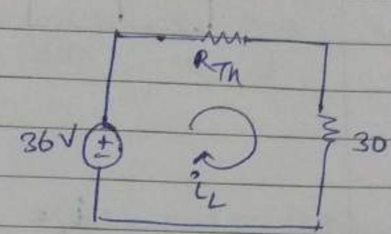
Use Thevenin's Theorem.

Sol:-

$$V_{Th} = \frac{24}{6+24+2} \times 48 = \frac{\cancel{24}^{4}}{\cancel{30}_{5}} \times 48 \quad \frac{\cancel{24}^{12}}{\cancel{32}_{2}} \times \cancel{48}^{3} = 36V$$

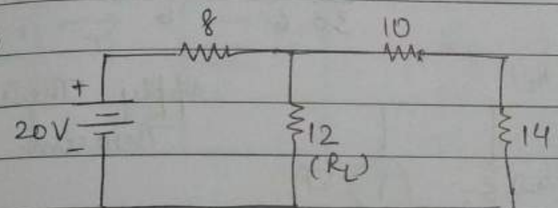
$$R_{Th} = \frac{8 \times 24}{32} = 6\Omega$$





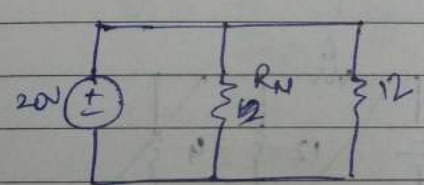
$$i = \frac{48}{32}, \quad i_L = \frac{36}{30+6} = 1A$$

Q-2)



Apply Norton's Theorem

Sol:-



$$R_{eq.} = 8 + \frac{10 \times \cancel{12}^{6}}{\cancel{22}_{11}}$$

$$= 8 + \frac{60}{11}$$

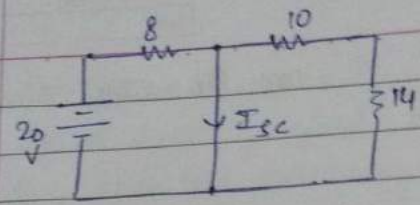
$$= \frac{88+60}{11}$$

$$= \frac{148}{11}$$

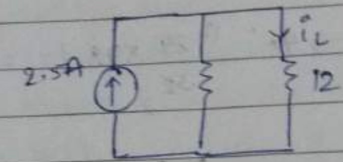
$$R_N = 10 + \frac{8 \times 12}{8+12} \quad i = \frac{20 \times 11}{148}$$

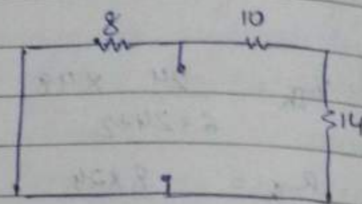
$$= 10 + \frac{\cancel{12}^{3} \times 8}{\cancel{20}_{5}}$$

$$= \frac{50+24}{5}$$



$I_{sc} = \frac{20}{8} = 2.5\,A$





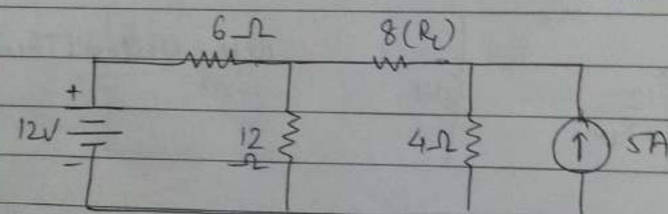
$R_N = \frac{8\times24}{8+24} = \frac{\cancel{8}\times24}{\cancel{32}4} = 6\,\Omega$

$i_L = \frac{R_N\, I_{sc}}{R_N+R_L} = \frac{6}{6+12}\times2.5$

$= \frac{\cancel{6}}{\cancel{18}3}\times2.5$

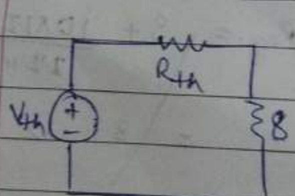
$= \frac{\cancel{25}5}{\cancel{30}6} = \frac{5}{6}A = 0.83A$

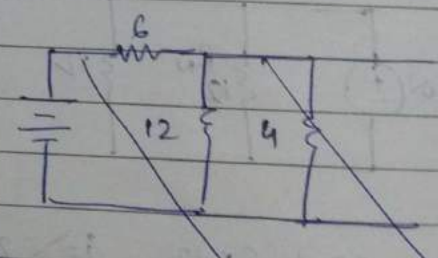
Q-3)

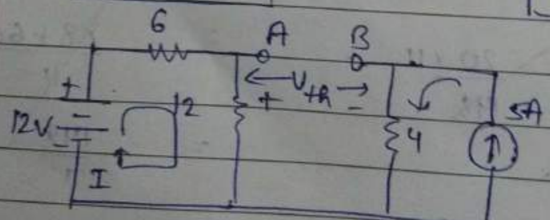


Apply Thevenin's Theorem.

Sol:-







$\frac{12\times4}{12+4} = \frac{12\times4}{16} = 3$

$I = \frac{12}{18} = \frac{2}{3}A$

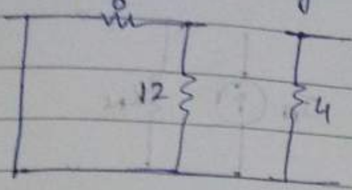
For finding V_{th}, R_L short.

$V_A = \frac{2}{\cancel{3}}\times\cancel{12}^{4} = 8V$

$V_B = 5\times4 = 20V$

$V_{th} = 8-20 = -12V$

For finding R_{th}, voltage source short.



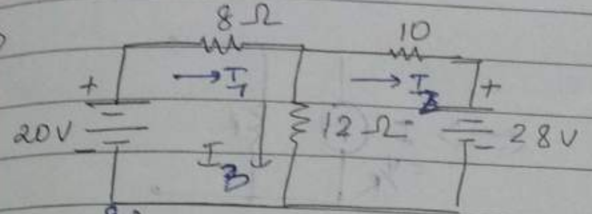
$6 + \frac{12\times4}{12+4}$

$6 + \frac{12\times4}{16}$

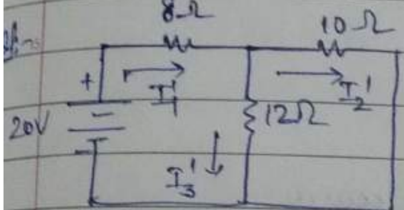
$i_L = 0.75A$

$R_{th} = \frac{6\times12}{6+12} + 4 = \frac{6\times12}{18} + 4 = 8\Omega$

(Q-4)



Apply superposition Theorem.

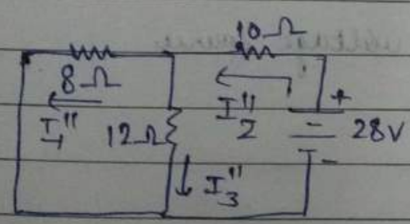


$R'_{eq} = 8 + \frac{12\times10}{22} = \frac{88+60}{11} = \frac{148}{11}\Omega$

$I'_1 = \frac{20\times11}{148} = \frac{110}{74} = \frac{55}{37}A = 1.486A$

$I'_2 = \frac{12}{22}\times\frac{55}{37} = \frac{30}{37}A = 0.811A$

$I'_3 = \frac{10}{22}\times\frac{55}{37} = \frac{25}{37}A = 0.676A$



$R''_{eq} = 10 + \frac{8\times12}{20} = \frac{50+24}{5} = \frac{74}{5}\Omega$

$I''_2 = \frac{28}{74}\times5 = \frac{85}{37}A = 2.297A$

$I''_1 = \frac{12}{20}\times\frac{85}{37} = \frac{51}{37}A = 1.378A$

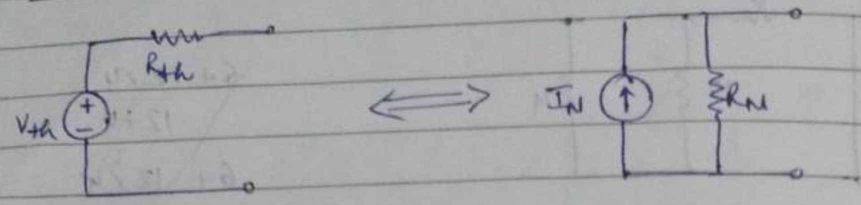
$I''_3 = \frac{8}{20}\times\frac{85}{37} = \frac{34}{37}A = 0.919A$

$I_1 = 1.486 - 1.378 = 0.108A$

$I_3 = 0.676 + 0.919 = 1.595A$

$I_2 = 0.811 - 1.378 = -0.567A$

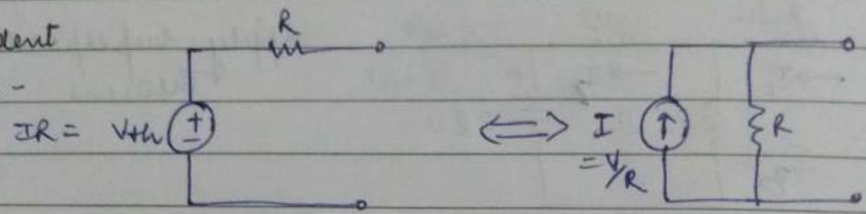
Dual Network (Thevenin & Norton) :-



(Source Conversion)

Voltage source → Current source and vice-versa
Resistance in series — Resistance in parallel

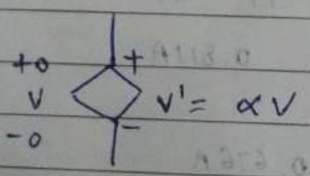
Independent sources - Voltage & Current



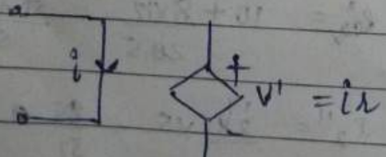
(Two sources types)

Dependent Sources :-

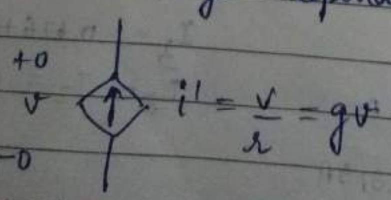
1) VDVS - Voltage dependent voltage source



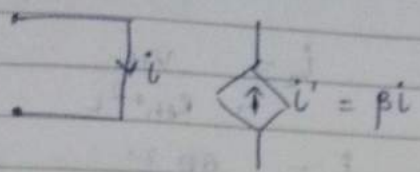
2) CDVS - Current dependent voltage source



3) VDCS - Voltage dependent current source

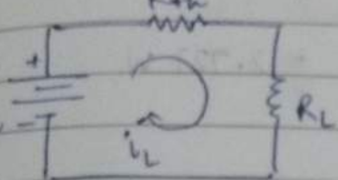


4) CDCS – Current dependent current source

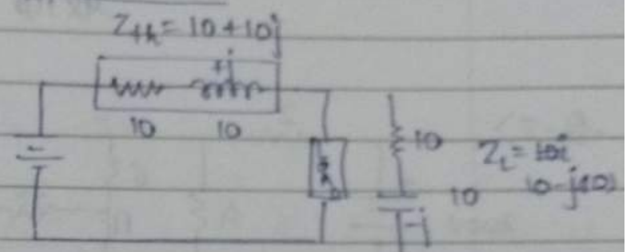


Maximum Power Transfer Theorem:-

Max^m power output is obtained from a network when the load resistance is equal to the internal resistance of the network as seen from the terminals of the load.



$\boxed{R_L = R_{th}} \rightarrow$ Max. Power



$Z_{th} = x + jy$

$Z_L = x - jy$

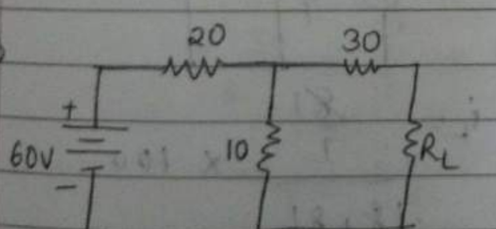
$$P_L = I_L^2 R_L = \left(\frac{V_{th}}{R_{th}+R_L}\right)^2 R_L$$

$$\frac{dP_{max}}{dR_L} = 0$$

The cond^n $R_L = R_{th}$ is derived from this eq^n.

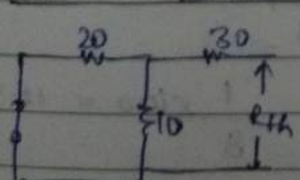
$$\boxed{P_{max.} = \frac{V_{th}^2}{4R_L}}$$

Q-1)



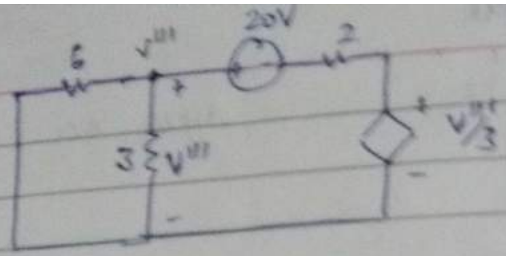
(i) Find the current through R_L where it takes values of 5Ω & 25Ω

(ii) Also calculate R_L for which the power dissipated in it would be max^m & also find this power.



$$R_{th} = 30 + \frac{20\times10}{30} = \frac{90+20}{3} = \frac{110}{3}\,\Omega$$

$= 33.36.67$

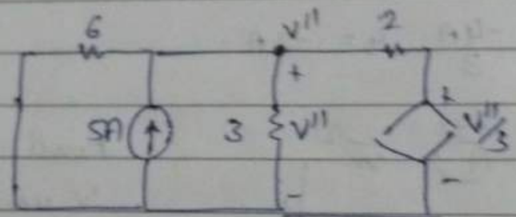


$$\frac{V'''}{6}+\frac{V'''}{3}+\frac{V'''+20-\frac{V'''}{3}}{2}=0$$

$$\frac{V'''}{6}+\frac{V'''}{3}+\frac{2V'''\cancel{+20}-60}{6}=0$$

$$V'''+2V'''+2V'''\cancel{+20}-60=0$$

$$V'''=+12V$$



$$\frac{V''}{6}+\frac{V''}{3}+\frac{V''-\frac{V''}{3}}{2}=5$$

$$\frac{V''}{6}+\frac{V''}{3}+\frac{2V''}{6}=5$$

$$V''+2V''+2V''=30$$

$$V''=6V$$

~~V'~~ $V = 6+6+12=24V$

~~Dependent Source~~ <u>Thevenin's Theorem</u>:-

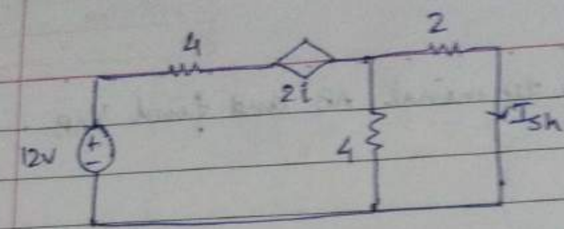
a) <u>For both dependent & independent source</u> -

i) find V_{th} across terminal AB (load)

ii) for R_{th} short circuit AB terminal & find I_{SH} → (short circuit current) & then find R_{th} as $R_{th}=\frac{V_{th}}{I_{Sh}}$

b) <u>For dependent sources only</u>:-

i) In this case V_{oc} (open ckt voltage) $=0$

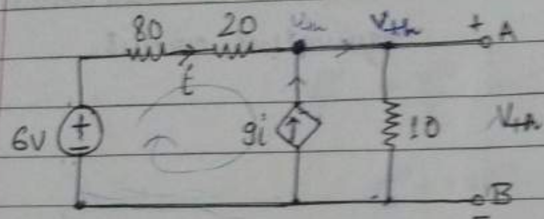


$I_{sh} = \frac{4}{6} \times 2$

$I_{sh} = \frac{4}{3}$ A

$R_{th} = \frac{V_{th}}{I_{sh}} = \frac{8 \times 3}{4} = 6\Omega$

Q-3)



Find out Thevenin's equivalent circuit.

Sol:-

$6 + 9i = 100i$
$6 = 91i$
$i = 6/91$

KCL: $\frac{V_{th} - 6}{100} + \frac{V_{th}}{10} = 9i$ —①

$i = \cancel{\frac{V_{th}-6}{100}} \quad \frac{6 - V_{th}}{100}$

put this value of i in eqⁿ ①

$-i + \frac{V_{th}}{10} = 9i$

$V_{th} = 100i$

$\cancel{V_{th} = 10 \times 8i = 80i}$

$100i = 80i - 6$

$20i = -6 \Rightarrow i = \frac{-3}{10}$ A

$100i = 6 - 100i$

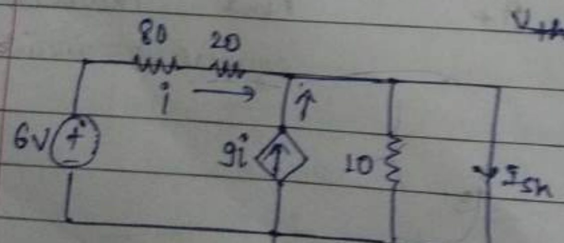
$200i = 6$

$i = \frac{6}{200}$ A

$= \frac{3}{100}$ A

$\cancel{V_{th} = -80 \times \frac{3}{10} = -24V}$

$V_{th} = 3V$



$I_{sh} = i + 9i = 10i$

$= \cancel{3A} \quad 3/10$ A

$\cancel{R_{th} = \frac{-24}{-3} = 8\Omega}$

$R_{th} = \frac{3}{3} \times 10 = 10\Omega$

Final answer should be in Polar form.

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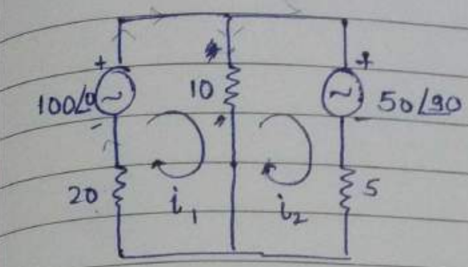
A.C. Circuits :-



Rectangular Form:-

$x+jy$

$(+,-)$

Polar Form:-

$M\angle\theta$

$(\times,\div)$

$M = \sqrt{x^2+y^2}$

$\theta = \tan^{-1}\left(\frac{y}{x}\right)$

$30i_1 - 10i_2 = 100\angle0$

$3i_1 - i_2 = 10\angle0$ — ① $= 10$

$-10i_1 + 15i_2 = -50\angle90$

$-2i_1 + 3i_2 = -10\angle90$ — ② $= -10j$

eq^n ①×3 + eq^n ②

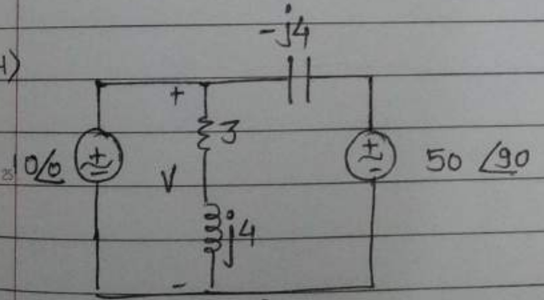
$7i_1 = 30-10j$ $\quad$ $3 \cdot -2i_1 + 3(3i_1 - 10\angle0) = -10\angle90$

$7i_1 = 10\sqrt{10}\ \angle{-18.43}$ $\quad$ $7i_1 =$

$i_1 = \frac{10\sqrt{10}\ \angle{-18.43}}{7}$, $\quad i_2 = 3i_1 - 10 = \frac{3\times10\sqrt{10}\ \angle{-18.43}}{7} - 10$

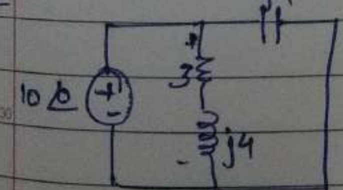
Q.2)

Q.1)



Find the value of 'V' using superposition principle.

Sol:-



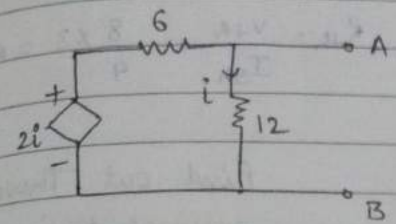
$Z_{eq} = \frac{(3+j4)(-j4)}{3+j4-j4} = \frac{-j12 + 16}{3}$

$Z_{eq} = \frac{16}{3} - 4j$

ii) Connect 1A source at terminal AB and find V_{AB}.

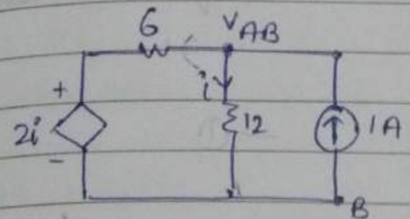
iii) $R_{th} = \frac{V_{AB}}{1A}$

Q-1)



Find out the Thevenin's equivalent circuit.

Sol:-

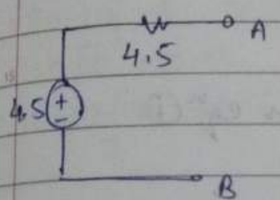


$$\frac{V_{AB} - 2i}{6} + \frac{V_{AB}}{12} = 1 \quad (1)$$

$$\frac{V_{AB}}{12} = 1$$

$$V_{AB} = 12$$

$$V_{AB} = 12i \quad (2)$$



~~12-2~~

$$\frac{12i - 2i}{6} + \frac{12i}{12} = 1$$

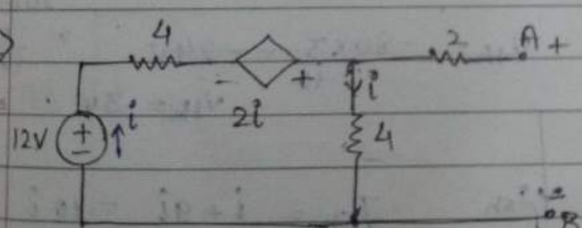
$$\frac{10i}{6} + i = 1$$

$$16i = 6$$

$$i = \frac{3}{8}$$

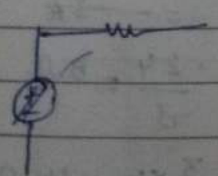
$$V_{AB} = 12 \times \frac{3}{8} = \frac{9}{2}$$

Q-2)



Find Thevenin's equivalent circuit.

Sol:-



~~2+2=4~~

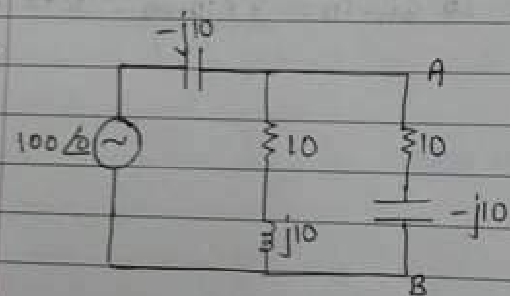
KVL: $4i + 4i = 12 + 2i$

$$6i = 12$$

$$i = 2A$$

$$V_{th} = 2 \times 4 = 8V$$

Q-2>



Find current using Thevenin's Theorem

Sol :-