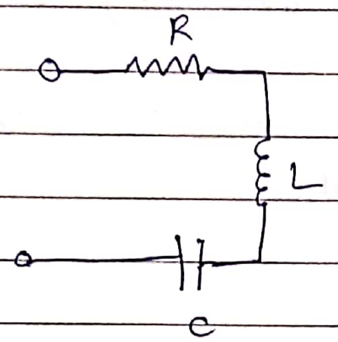
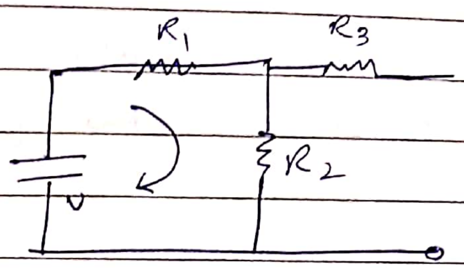
Electric Circuit & Systems

→ Network
No close path for flow of current.
→ Circuit
closed path. for flow of current. (sp. kind of network)
(atleast 1)
⇒ Every circuit is a network.



Network



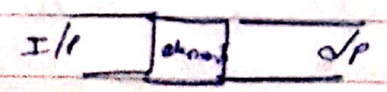
Circuit

⇒ System
→ Combination of different network & circuit who work together to fulfil a objective.

Units :

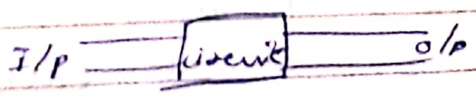
Unit 1 — Electric circuit
(consists of one or more electrical elements)
DC & AC circuit.
DC → source.
AC → source

Analysis



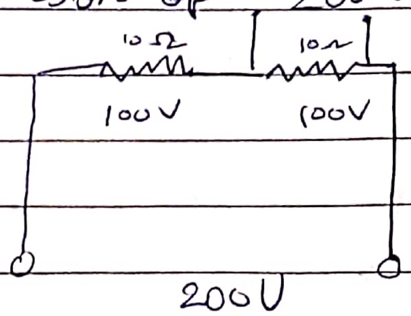
input known
& circuit parameters

Synthesis



Determine circuit
parameters

Eg: Conversion of 200V to 100V.



I = 10A .

→ Change do not take place for long time, then it is static state

→ change takes ~~for~~ place in circuit after working, then it is transient state.

⇒ DC & AC circuit analysis

Resistance: Obs. to flow of current.

Inductance: Obstruction to change of current.

Capacitance: opposes the change of voltage.

↑ ↳ never connect in d.c. circuit.

AC (all elements)

⇒ Unit 2 → Magnetic circuit

⇒ Unit 3 → electrical machines (m/c)

Machines :- reduces human effort. (any equipment)

↓ Fan

Electrical energy ⟶ mech. energy

Electrical machines is a device which

→ If electrical energy $\xrightarrow[\text{motor}]{}$ mech. energy.

$\xleftarrow[\text{generator.}]{}$

⇒ Unit 4 – Semiconductor devices

Diode, transistor

silicon controlled rectifier.

MOSFET

half wave] rectifier
full wave

⇒ Unit 5 – Digital electronics

Logic gates

flip flops → memory card is made up of flip flops

Adder

Subtractor.

Unit 1
Electrical Circuits

EMF → minimum P.D
V → P.D

Ohm's law

$$V \propto I$$

$$V = RI$$

→ every voltage, cannot be emf.
→ emf always across generating source.
→ Voltage is potential diff due to which current flows.
↳ rate of flow of charge.

→ Electric elements:-

Active
→ gives energy to circuit (sources).
↳ give energy to system.
(energy law)
one energy → elec. energy
(elec source)

Passive
→ which consumes / absorb energy & store it.
- Resistance
- Inductance
- Capacitance

*⇒ **Classification of Sources:**

Independent
are those whose output not affected by change in circuit parameter

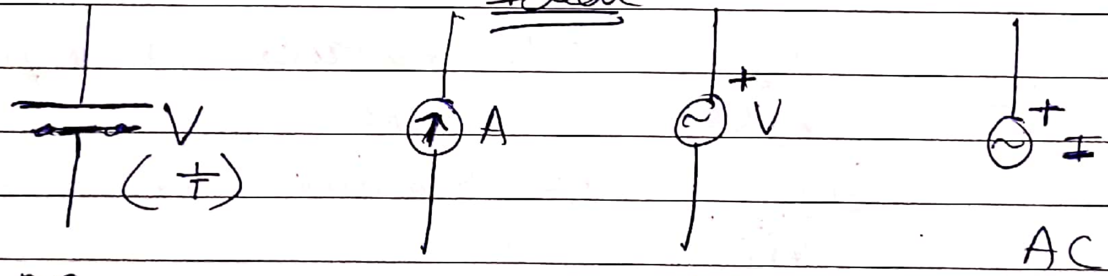
dependent
output is affected by change in circuit parameter.

- AC
  - Voltage source (provides constant voltage to the circuit).
  - Current source (sp. source which delivers current in circuit)
- DC
  - VS
  - CS

- AC
  - VS
  - CS
- DC
  - VS
  - CS.

⇒ Independent Sources:

Ideal



DC	DC	AC	AC
VS	CS	VS	CS

⇒ ϕ → phase

Sources

- Independent
  - VS
    - AC
      - 1ϕ
        - ideal
        - practical
      - 2ϕ
    - DC
  - CS
    - AC
      - 1ϕ
      - 2ϕ
    - DC
- dependent
  - AC
  - DC
    - VS
      - CCVS (Current controlled VS)
      - VCVS
    - CS
      - CCCS
      - VCCS (voltage controller)

⇒ Internal Resistance — Ideal → 0

d. c. source → 0

~~Ideal~~ ~~&~~

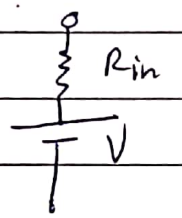
Internal Impedence (AC)

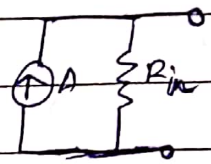
dc → 0.

Prac. d.c source	ideal dc source
→ voltage parallel.	voltage series
DC VS	DC CS

AC → const. rms

DC → const. voltage





⇒ Source: any equipment that converts non-electrical energy to electrical energy.

⇒ Ideal : Source (VS)(AC) : int. resistance or impedence is zero.

Source (CS)(DC) : int resistance or impedence is ∞.

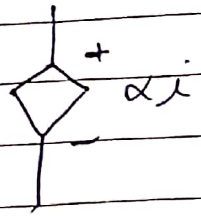
CS —
- AC ⇒ $Z = \infty$
- DC ⇒ $R = \infty$

VS —
- AC ⇒ $Z = 0$
- DC ⇒ $R = 0$

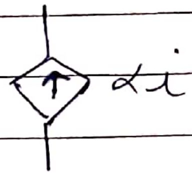
Practical
- → VS —
  - → AC Z = low value
  - → DC R = low value
- → CS —
  - → AC Z = high value
  - → DC Z = high value

⇒ Dependent Sources:

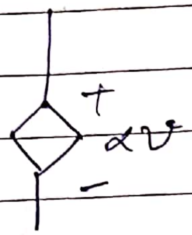
CCVS



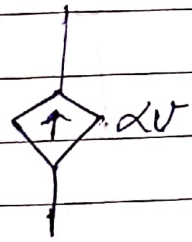
CCCS



VCVS



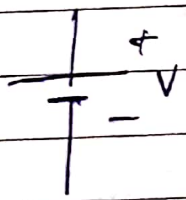
VCCS



Symbols:

independent Source:

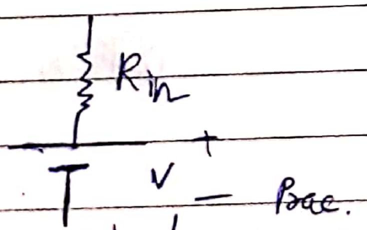
DC Source (VS)



ideal sources

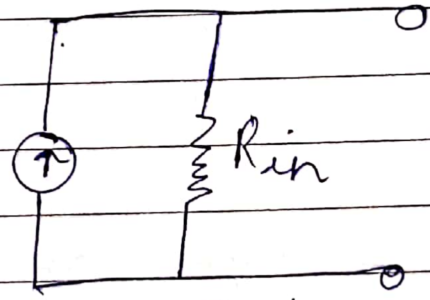
DC current

ideal



~~Practical source,~~

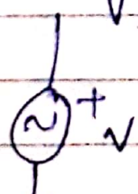
~~Ideal sources~~



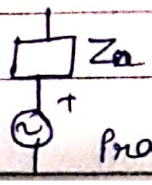
Practical

⇒ AC Source (Independent):

VS

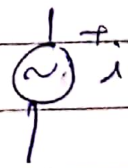


ideal

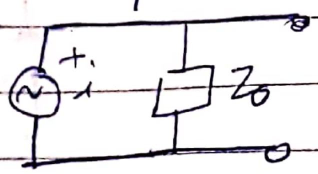


Practical

CS



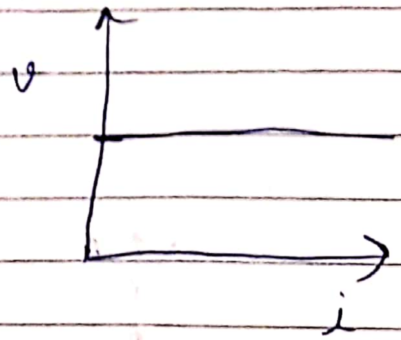
Ideal



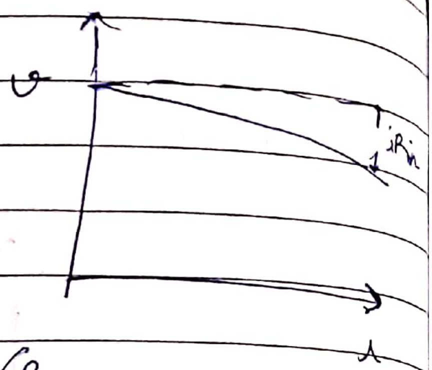
Practical

⇒ Characteristics of sources:

Ideal (VS)

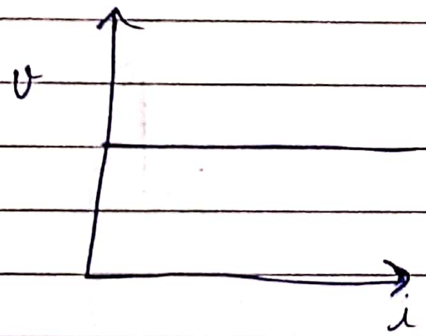


Practical (VS)

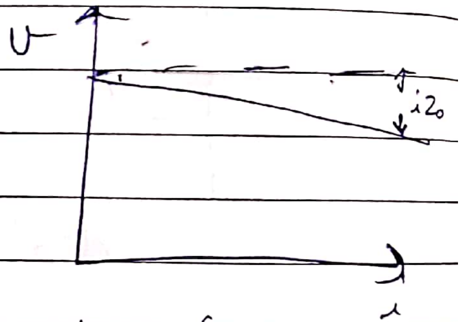


(Because of R_{in} in the circuit)

Ideal (CS)



Practical (CS)



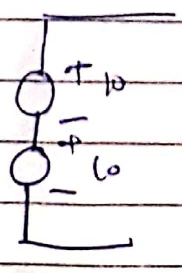
(Z_0)

⇒ Types of Connections:

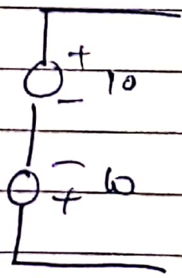
1) Series → current remains same, voltage divides. (Resist↑)
2) Parallel → current divides, voltage same (Resis↓)

New 3) Star Delta

eg →

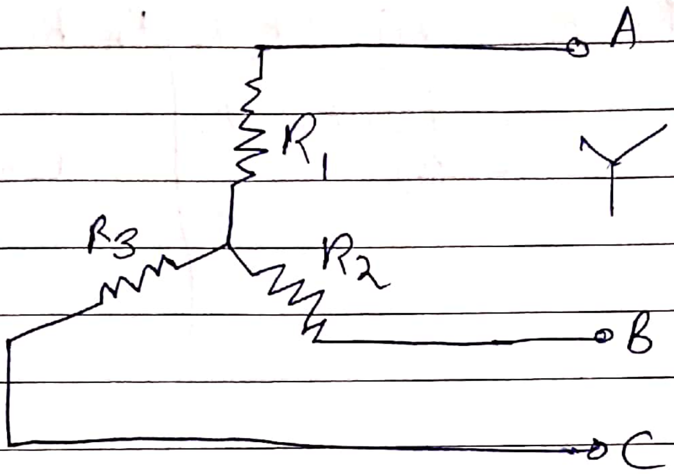


$V = V_1 + V_2 = 20V$

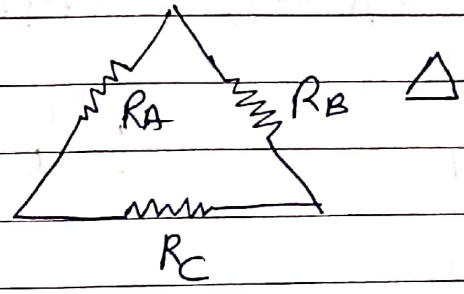


$V = 0V$.

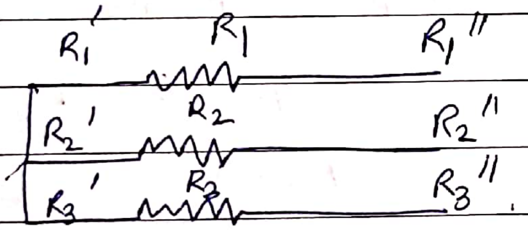
⇒ Star Delta Connection:

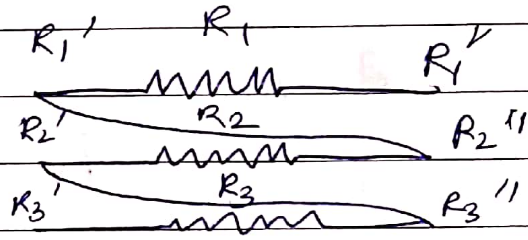


Star connection



Delta Connection





Delta connection.

⇒ Delta - star ~~Star Delta~~ Conversion:

$$R_{AB\,Y} = R_1 + R_2$$
$$R_{BC\,Y} = R_B + R_C$$
$$R_{AC\,Y} = R_A + R_C$$

Y

$$R_{AB\,\Delta} = \frac{R_2(R_1+R_3)}{R_1+R_2+R_3}$$

$$R_{BC\,\Delta} = \frac{R_3(R_1+R_2)}{R_1+R_2+R_3}$$

$$R_{AC\,\Delta} = \frac{R_1(R_2+R_3)}{R_1+R_2+R_3}$$

Δ.

$R_{ABY} = R_{AB\Delta}$	$R_{BCY} = R_{BC\Delta}$	$R_{ACY} = R_{AC\Delta}$
$R_A + R_B = \dfrac{R_1R_2 + R_2R_3}{R_1+R_2+R_3}$ — ①	$R_B + R_C = \dfrac{R_1R_3 + R_2R_3}{R_1+R_2+R_3}$ — ②	$R_A + R_C = \dfrac{R_1R_2 + R_1R_3}{R_1+R_2+R_3}$ — ③

Add ① & ③ − ②

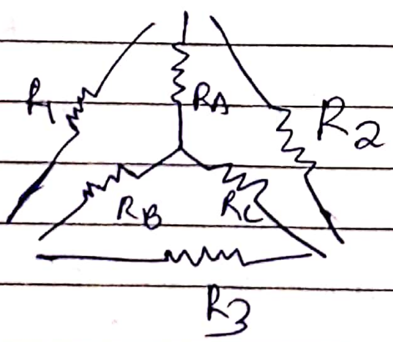
$$R_A = \frac{R_1R_2}{R_1+R_2+R_3}$$

$$R_B = \frac{R_2R_3}{R_1+R_2+R_3}$$

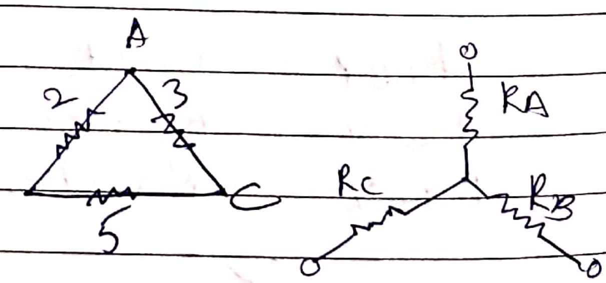
Add ① & ② − ③

$$R_C = \frac{R_1R_3}{R_1+R_2+R_3}$$

Add ② & ③ − ①



Eg:



$$R_A = \frac{2\times3}{2+3+5} = \frac{6}{10} = 0.6\,\Omega$$

$$R_B = 1.5\,\Omega$$

$$R_C = 1\,\Omega$$

⇒ Star to Delta Conversion:

$$R_A = \frac{R_1 R_2}{R_1+R_2+R_3} \quad \text{---} \; (4)$$

$$R_B = \frac{R_2 R_3}{R_1+R_2+R_3} \quad \text{---} \; (5)$$

$$R_C = \frac{R_1 R_3}{R_1+R_2+R_3} \quad \text{---} \; (6)$$

$$R_A R_B + R_B R_C + R_C R_A$$

$$= \frac{R_1 R_2^2 R_3}{(R_1+R_2+R_3)^2} + \frac{R_2 R_1 R_3^2}{(R_1+R_2+R_3)^2} + \frac{R_1^2 R_2 R_3}{(R_1+R_2+R_3)^2}$$

$$= \frac{R_1 R_2 R_3 \cancel{(R_1+R_2+R_3)}}{\cancel{(R_1+R_2+R_3)^2}}$$

$$= \frac{R_1 R_2 R_3}{R_1+R_2+R_3} \to R_A$$

$$\frac{R_A R_B + R_B R_C + R_C R_A}{R_A} = R_3$$

$$\therefore R_3 = R_B + \frac{R_B R_C}{R_A} + R_C$$

$$R_1 = R_A + R_C + \frac{R_A R_C}{R_B}$$

$$\therefore R_2 = \frac{R_A R_B}{R_C} + R_B + R_A$$

$$R_1 = 10 + 2.5 = 12.5\,\Omega$$

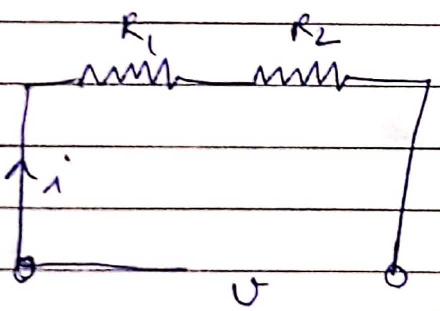
$$R_2 = 15 + 10 = 25\,\Omega$$

$$R_3 = 15 + 10 = 25\,\Omega.$$

⇒ Current & Voltage division rule:

→ Voltage division rule: works only in series

Voltage divides in elements of series connection



$$R = R_1 + R_2$$

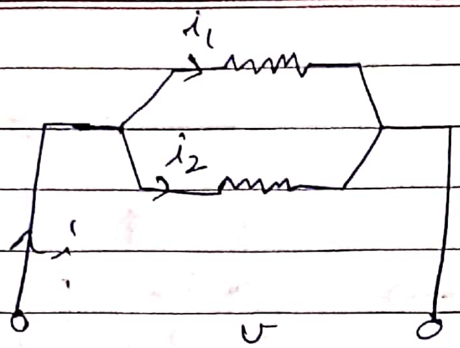
$$i = \frac{V}{R_1 + R_2}$$

$$\rightarrow V_{R_1} = iR_1$$
$$= \frac{V}{R_1 + R_2} \cdot R_1$$

$$\rightarrow V_{R_2} = iR_2$$
$$= \frac{V}{R_1 + R_2} \cdot R_2.$$

→ Current division formula/Rule:

Useful to determine current in elements connected in parallel.



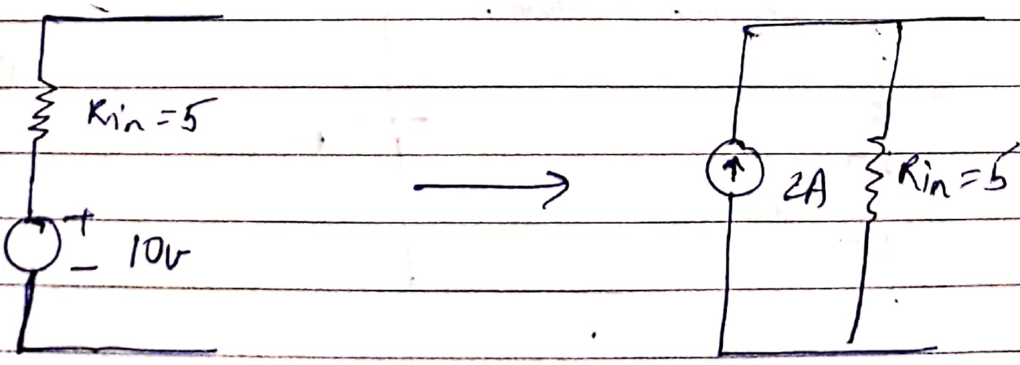
$\rightarrow R = \frac{R_1R_2}{R_1+R_2}$

$\rightarrow i = \frac{V(R_1+R_2)}{R_1R_2} \Rightarrow = \frac{iR_1R_2}{R_1+R_2}$.

$\therefore i_1 = \frac{V}{R_1}, \quad i_2 = \frac{V}{R_2}$.

i.e. $i_1 = \frac{iR_2}{R_1+R_2}, \quad i_2 = \frac{iR_1}{R_1+R_2}$.

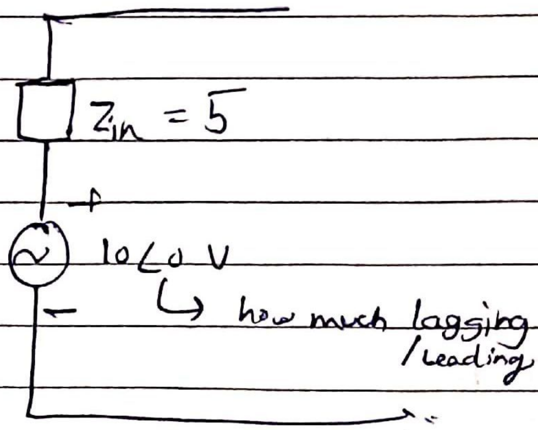
⇒ <u>Source transformation:</u> Transformation of Source



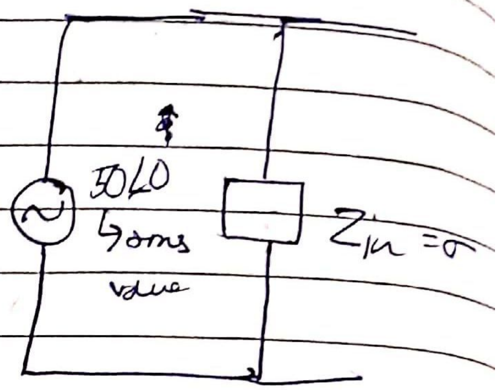
V.S $\qquad\qquad$ C.S.

$i = 2A$.

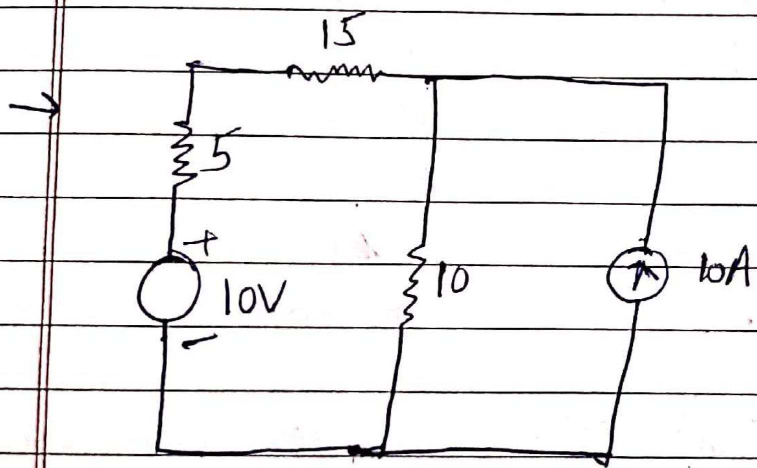
V.S → C.S possible when Rin connected in series.



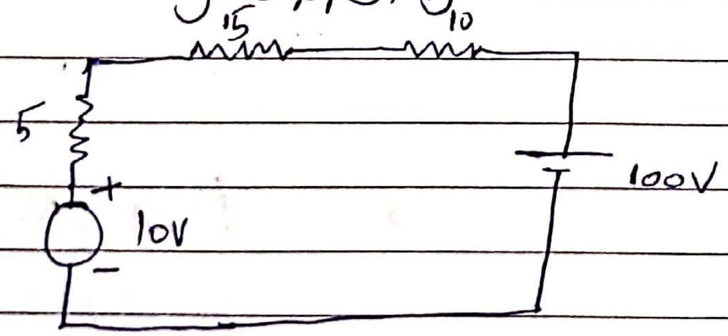
VS



CS.

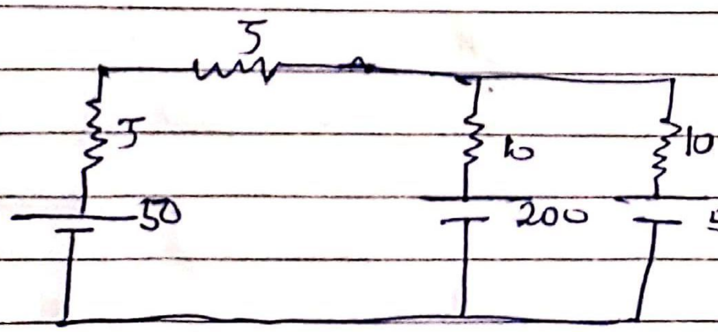


by applying CS to VS transformation method



$i = \frac{10-100}{30}$ A.

Q-



classmate

Date ____
Page ____

⇒ **Kirchoff's law :**

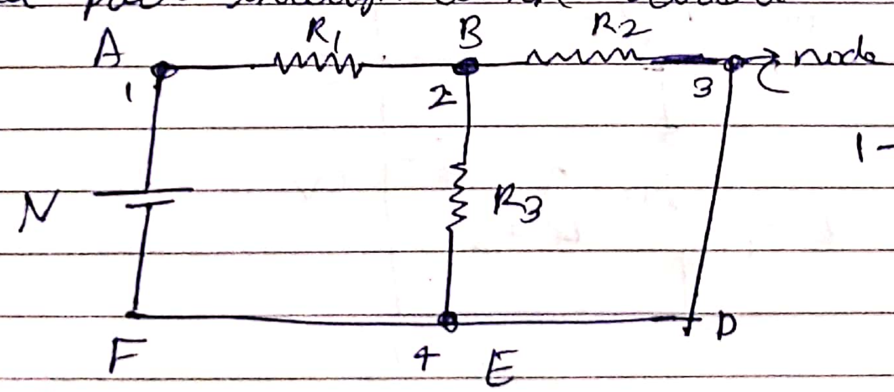
1) Kirchoff's current law :
 /Junction Rule /Conservation of charge.

2) Kirchoff's voltage law :
 / Voltage law

→ Junction at which two or more elements are connected is node.

→ Link b/w two nodes is called Branch.

→ Closed path through which current can flow is loop



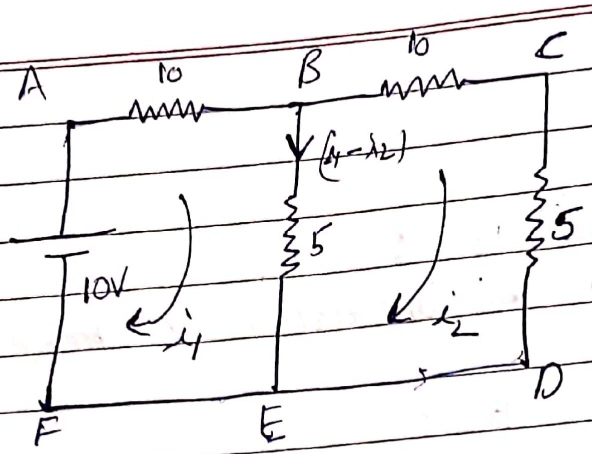
1-2 :- Branch.

⇒ Special kind of loop which doesn't have any other closed circuit inside it is called Mesh.

⇒ Every mesh is a loop, but every loop is not a mesh.

⇒ **Mesh Analysis/ Maxwell loop method :**

Eg:

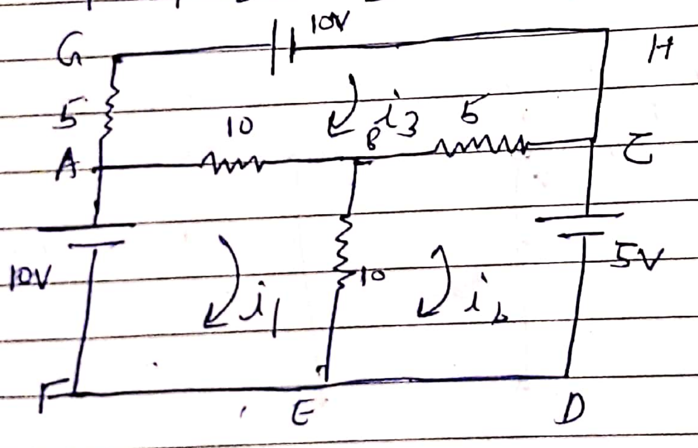


mesh 1 ABEFA

Mesh 2 BCDEB.

$$-10i_1 - 5(i_1 - i_2) + 10 = 0 \quad \text{— ①}$$

$$+5(i_1 - i_2) - 5i_2 - 10i_2 = 0 \quad \text{— ②}$$



mesh 1 ABEFA

$$10 - 10(i_1 - i_3) - 10(i_1 - i_2) = 0.$$

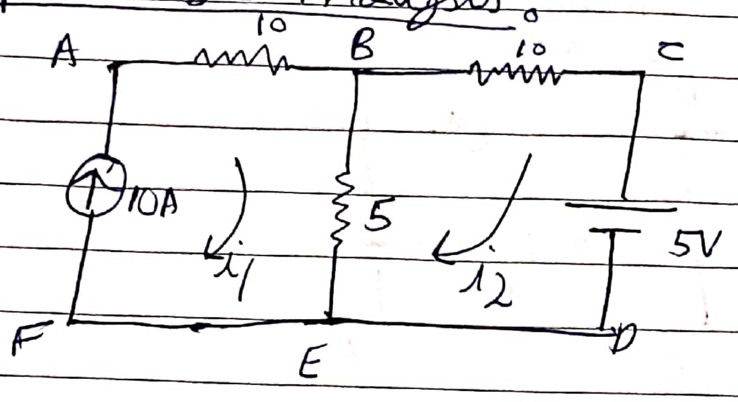
Mesh 2 BCDEB

$$-5 - 5(i_2 - i_3) - 10(i_2 - i_1) = 0$$

mesh 3 GHCBAG

$$-10 - 5(i_3 - i_1) - 10(i_3 - i_1) - 5i_3 = 0$$

Super Mesh Analysis:



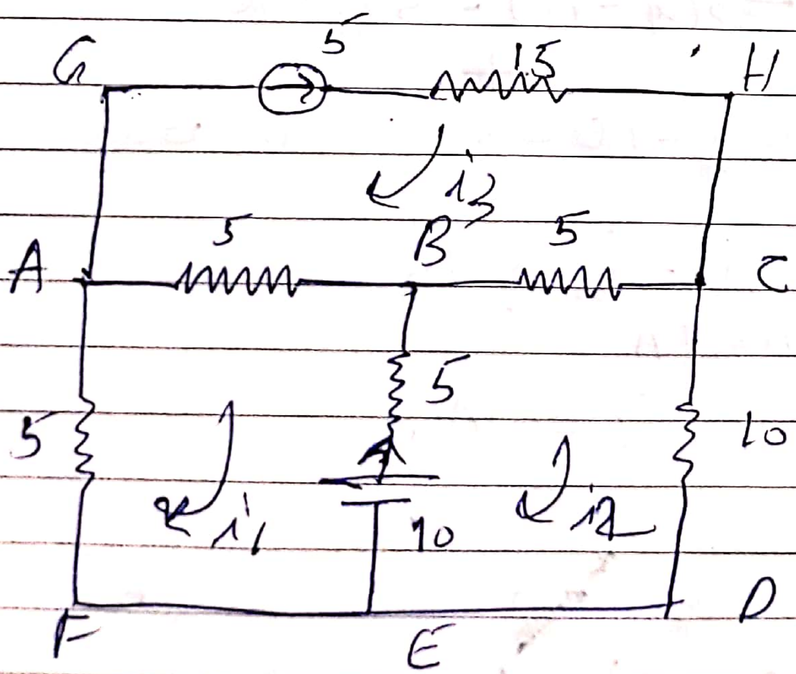
Mesh 2 BCDEB

$$-5 - 5(i_2 - i_1) - 10 i_2 = 0$$

Mesh ABEFA

$$i_1 = 10A$$

↳ C.S. (every branch has the same current)



→ Mesh 3 ~~GHCBAG~~

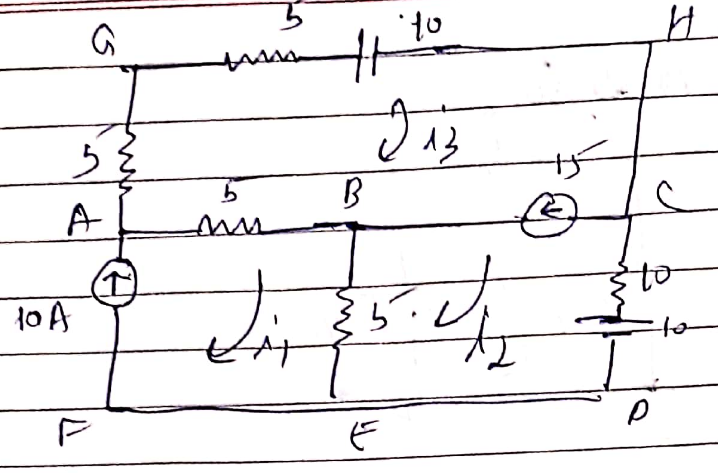
$i_3 = 5.$

→ Mesh 1 ABEFA

$$-5i_1 - 5(i_1 - i_3) - 5(i_1 - i_2) - 10 = 0$$

→ Mesh 2 BCDEB

$$10 - 5(i_2 - i_1) - 5(i_2 - i_3) - 10 i_2 = 0$$

Q. 

→ Super mesh is combination of two or more than two meshes having current source common

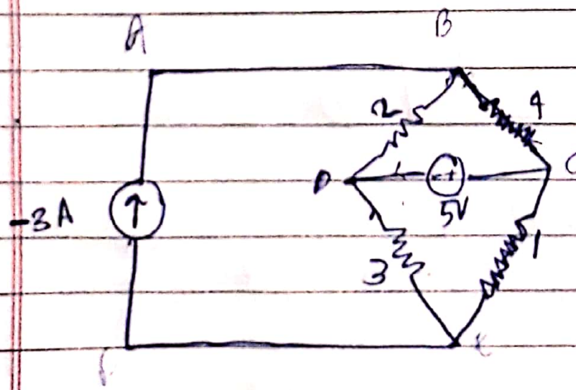
Super Mesh ~~BCDE~~ BEDCHGAB

$$-5(i_1-i_2)-5i_2-10$$
$$+$$
$$-5i_3-10-5(i_3-i_1)=0.$$

$$i_3-i_2=15$$

mesh ABEFA

$$i_1=10A.$$

Q. 

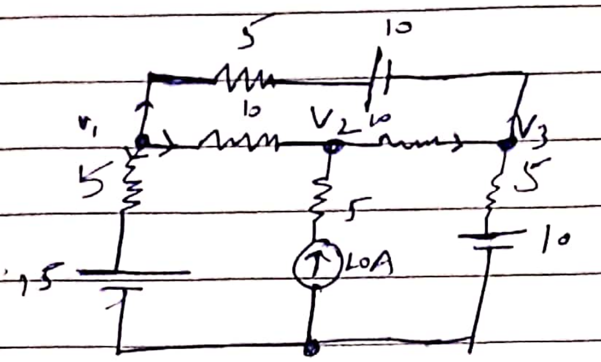
Mesh ABCEFA

$$i_1=-3.$$

$$-2(i_1-i_2)-4i_2$$
$$+-3(i_3-i_1)-1i_3=0$$

$$i_3-i_2=5$$

Nodal Analysis:



KCL at node 1:

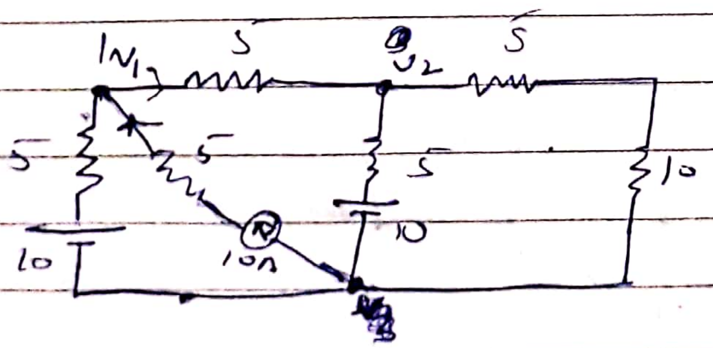
$$\frac{V_1-15}{5} + \frac{V_1-V_2}{10} + \frac{V_1-10-V_3}{5} = 0 \quad \text{--- (1)}$$

KCL at node 2:

$$\frac{V_2-V_1}{10} + \frac{V_2-V_3}{10} - 10 = 0 \quad \text{--- (2)}$$

KCL at node 3:

$$\frac{V_3-V_2}{10} + \frac{V_3-10}{5} + \frac{V_3+10-V_1}{5} = 0 \quad \text{--- (3)}$$

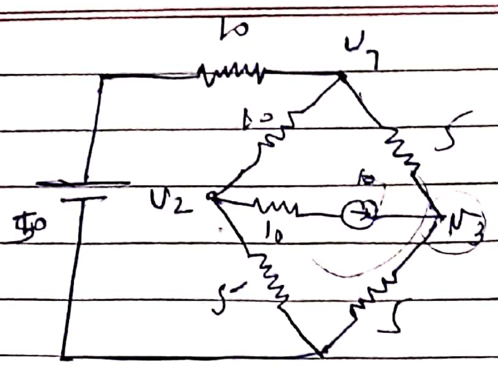


KCL at node 1:

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

KCL at node 2:

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



KCL at node 1:

$$\frac{v_1-5}{10} + \frac{v_1-v_2}{10} + \frac{v_1-v_3}{5} = 0 \quad \text{— ①}$$

KCL at node 2:

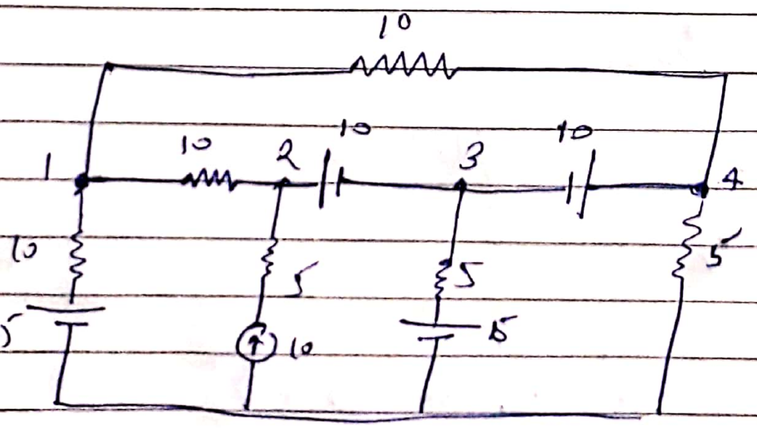
$$\frac{v_2-10}{10} + \frac{v_2-v_1}{10} \cancel{+10} + 10 = 0 \quad \text{— ②}$$

+

KCL at node 3:

$$\frac{v_3-v_1}{5} + \frac{v_3-0}{10} + 10 = 0 \quad \text{— ③}$$

node 2 & node 3 make supernode.



Supernode at 2, 3, 4.

$$\frac{V_2 - V_1}{10} - 10 + \frac{V_3 - 15}{5} + \frac{V_4 - V_1}{10} + \frac{V_4 - 0}{5} = 0 \quad \text{— ①}$$

$$V_2 - V_3 = 10 \quad \text{— ②}$$
$$V_4 - V_3 = 10 \quad \text{— ③}$$

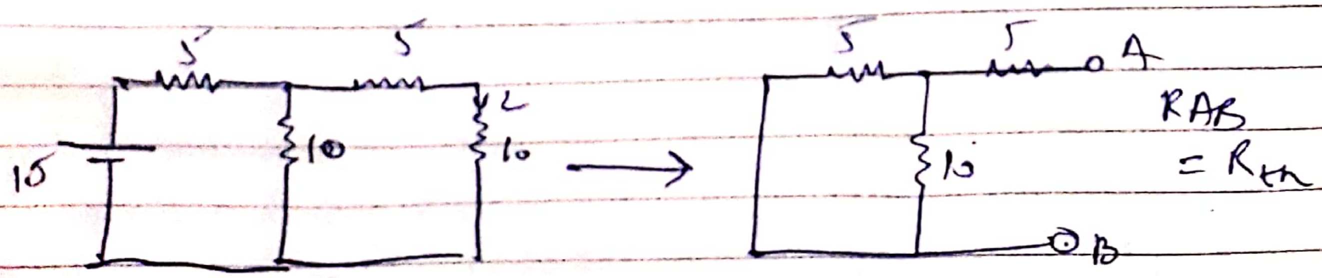
KCL for node 1;

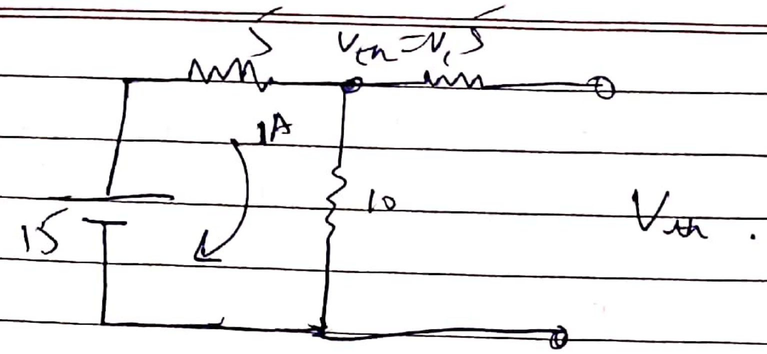
$$\frac{V_1 - V_2}{10} + \frac{V_1 - 5}{10} + \frac{V_1 - V_4}{10} = 0 \quad \text{— ④}$$

⇒ Thevnin's Theorem :

→ Types of network:
1) Active & passive network.
2) Linear & non-linear network.
↳ ~~input ∝ output~~ ↳ output $\propto \frac{1}{\text{input}}$ (not directly)
3) Lumped & Distributed network
4) unilateral & Bilateral
↳ work in one dir. ↳ work in both dir.

⇒ Any active linear bilateral network can be replaced by Thevnin's equivalent circuit having a ~~netis~~ series combination of Thevnin's voltage V_{th} & Thevnin's resistance of R_{th}.





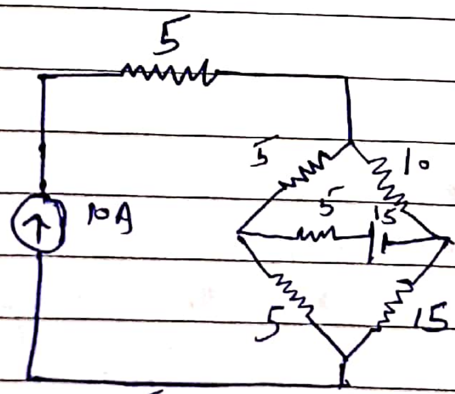
$V_{10} = 10 \times 1 = 10V$

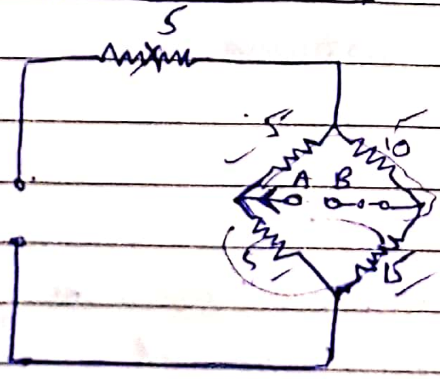
$V_{th} = 10V$

$\frac{V_1 - 15}{5} + \frac{V_1 - 0}{10} = 0$

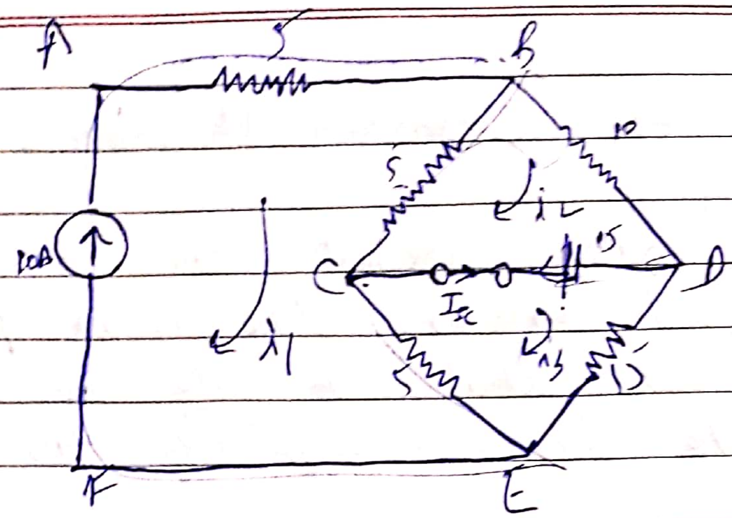
$V_1 = V_{th}$.

Q.





$R_{in} = R_{AB} = \frac{15 \times 20}{35}$ $(15 \| 20)$



Thevenins
↳ nodal

KVL in mesh ABCEFA

$i_1 = 10$ A.

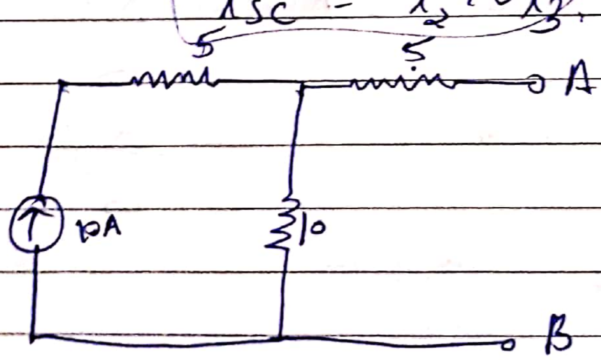
KVL in mesh BCDB,

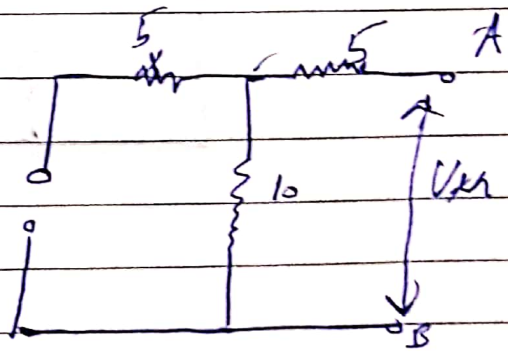
$-5(i_1 - i_2) - 10i_2 + 15 = 0$

KVL in mesh CDEC

$-15i_3 - 5(i_3 - i_1) - 15 = 0$

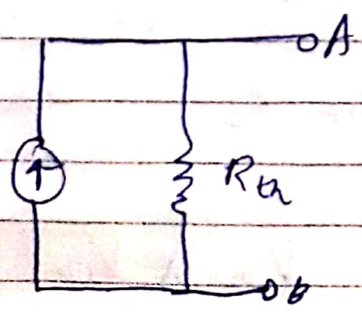
$i_{sc} = i_2 \sim i_3$.





$R_{AB} = R_{th} = 15$.

Thevenins circuit eq.



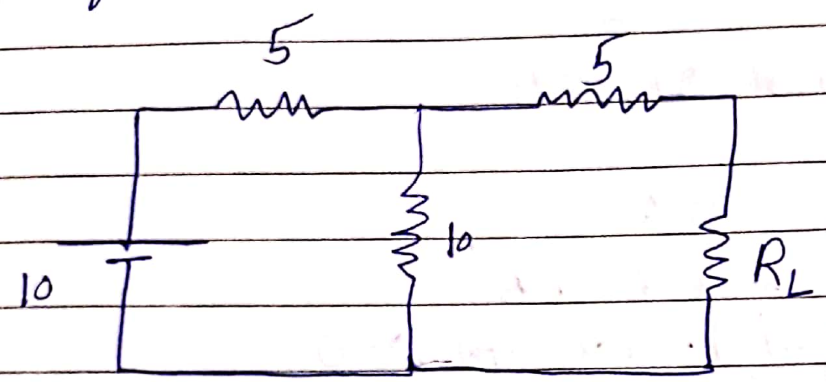
KCL at node 1,

$\frac{1}{10} - 10 = 0$

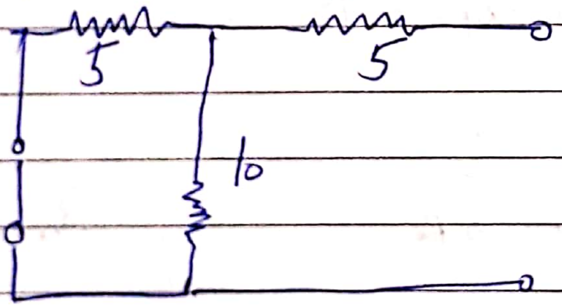
$V_1 = 100V$.

* Maximum Power transfer theorem:

→ States that in any circuit the load resistance will consume the max. power when value of that ~~node~~ resistance is equal to the Thevenin's ~~eqn~~ eq. resistance of the circuit.

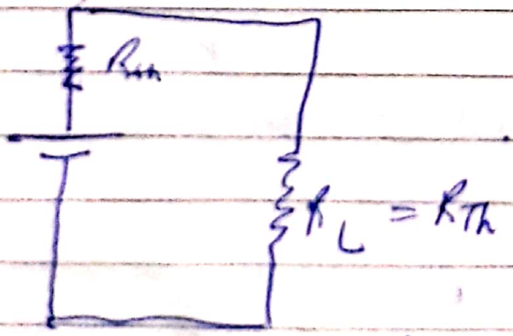


As per rule, $R_L = R_{th}$



$$R_{th} = \frac{50}{15} + 5$$
$$= \frac{125}{15}$$

$$\therefore R_L = \frac{125}{15}\,\Omega$$

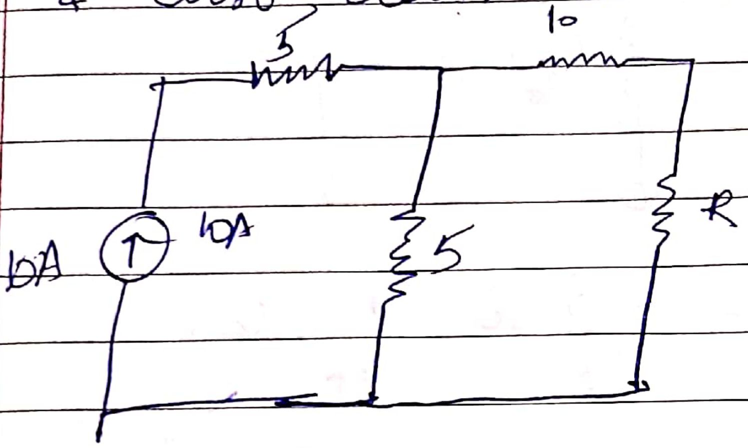


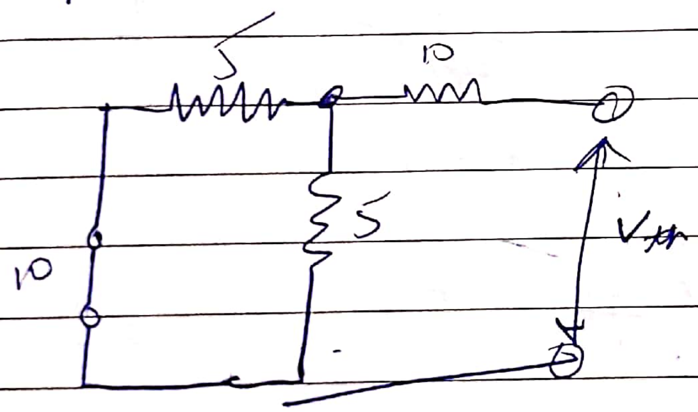
$$i = \frac{V_{th}}{R_{th}+R_L} = \frac{V_{th}}{2R_{th}}$$

$$P = V \times I = V_{th} \times \frac{V_{th}}{2R_{th}}$$

also $P = I^2 R = \left(\frac{V_{th}}{2R_{th}}\right)^2 \cdot R_{th} = \frac{V_{th}^2}{4R_{th}}$

Q. For a given circuit determine the value of R for which it will consume max. power & also determine the mag. of that power





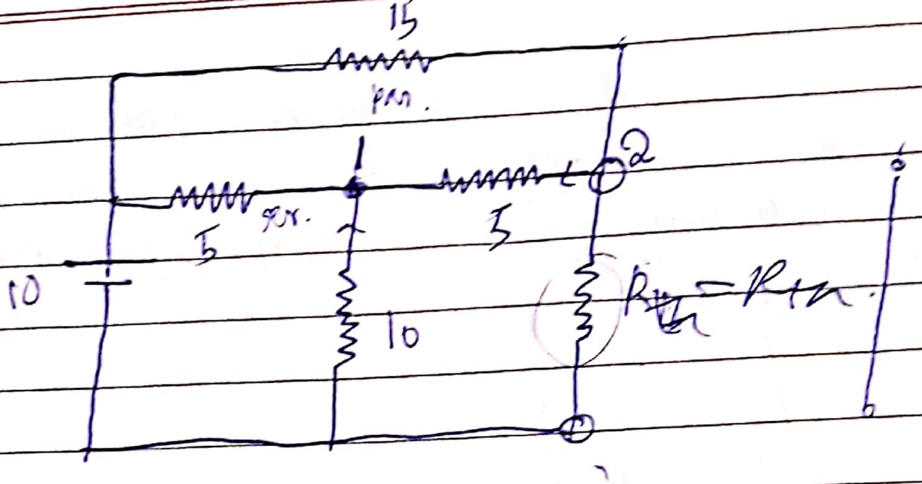
$$R = R_{th} = 15\Omega$$

$$\frac{V_1}{5} - 10 = 0$$

$$V_1 = 50V = V_{th}$$

$$P_{max} = \frac{50^2}{4 \times 15}$$

Q)



$R_L = R_{th} = \cancel{\frac{75}{14}\Omega} \; \cancel{\frac{40}{14}\Omega}$.

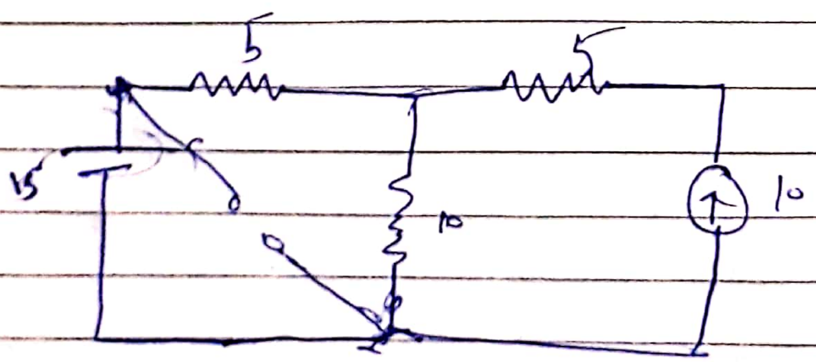
$= \cancel{\frac{20}{7}\Omega} = \frac{75}{14}\Omega$.

KCl at node 1,

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

KCl at node 2,

$$\frac{V_2 - 10}{15} + \frac{V_2 - V_1}{5} = 0$$



$\cancel{R_{th} = \frac{25}{3}\Omega}$

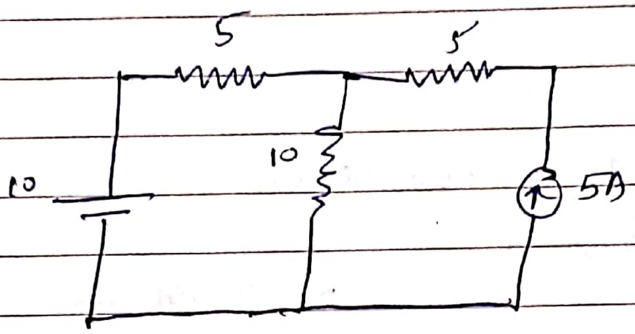
$R_{th} = 0$

$V_{th} = V_{AB}$

$= 15$

⇒ Superposition Theorem: any linear network consists of components contains current.

→ Consider a 10V source. Replace 5A current source by internal resistance i.e ∞



$i = \frac{10}{15} A$, upward to downward.

Thevenins Theorem
5) num.
submition monday.

Laplace transform:

$$\Rightarrow \boxed{F(t) = \int_0^{\infty} e^{-st} f(t).dt}$$

$\Rightarrow L(1) = \frac{1}{s}$ $\quad L(10) = \frac{10}{s}$, $\quad L(15) = \frac{15}{s}$.

$\boxed{L(n) = \frac{n}{s}}$,

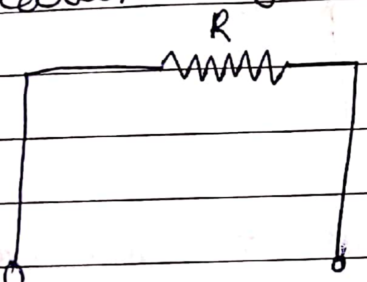
$L(e^{at}) = \int_0^{\infty} e^{-st} . e^{at} . dt = \frac{1}{s-a}$.

~~Write temp of water~~
~~LPF in series~~

$V_L = L \frac{dV}{dt}$

~~experiment~~

→ Verification of Ohm's law:



$R_1 = 458\ \Omega$
$R_2 = 450\ \Omega$

① Measure value of Resistance by multimeter.
② connect one resistance breadboard
③ Give DC supply to the circuit.

1) $V = 10V$
$R = 322\ \Omega$
$I = \frac{10}{322} = 0.0310A.$
Actual value of $I = 0.04A$

2) $V = 15V$
$R = 322V$
$I = \frac{15}{322} = 0.046A,$
Actual value $= 0.05A.$

3) $V = 20V$
$R = 322V$
$I = 0.0621A$
Actual value $= 0.07A$

4) $V = 25V$
$I = 0.077A$
Actual value $= 0.08A$.

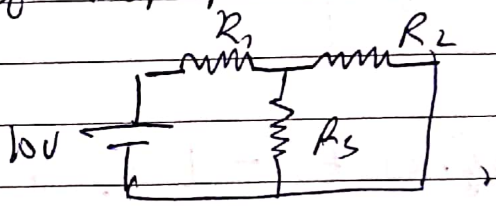
5) $V = 30V$
$I = 0.09V$
Actual value = 10V

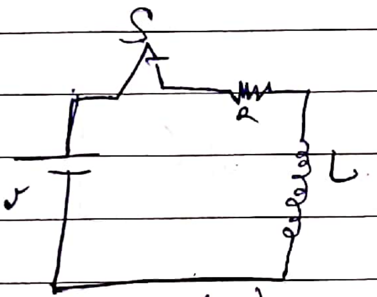
Scanned by CamScanner

* Verification of KVL:

1) Connect all three resistance in series
2) give 10V supply.
3) measure voltage drop across all resistances.

* Q. Verification of superposition Theorem:





$$i(t) = \frac{V'}{R} = \frac{V'}{R}e^{-R/L\,t}.$$

$$V_L(t) = Ve^{-R/L\,t}.$$

Q. A series RL circuit is feeded by voltage source 100V with help of switch. The switch is closed at $t=0$. Determine the current

a) Find exp.
b) Voltage across inductor. exp.
c) Time constant

Assume $R = 10\,\Omega$, $I = 1mH$.

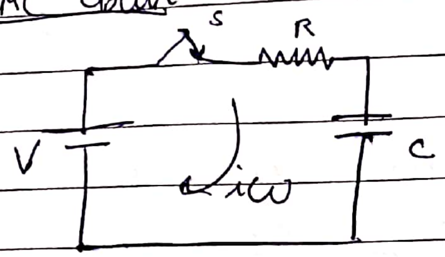
$V = 100V$,

$$i(t) = \frac{V}{R}\left(1-e^{-R/L\,t}\right) = \frac{100}{10}\left(1-e^{-10/1\times10^{-3}\,t}\right)$$

$$V_L(t) = Ve^{-R/Lt}$$

$$\tau = \frac{L}{R} = \frac{1\times10^{-3}}{10}\ sec.$$

RC circuit



$$V = \cancel{R}\cdot Ri(t) + \frac{1}{C}\int i(t)\,dt.$$

Take Laplace

$$\frac{V}{S} = Ri(S) + \frac{1}{C}\left[\frac{i(S)}{S} - V_L(0^-)\right]$$

$$V_L(0^+) = 0,$$

$$i(S) = \frac{V}{S\left(R+\frac{1}{CS}\right)}$$

$$i(S) = \frac{V}{R\left(S+\frac{1}{RC}\right)}$$

take inverse laplace

$$i(t) = \frac{V}{R}e^{-t/RC}$$

$$V_c(t) = \frac{1}{C}\int_0^t i(t)\,dt$$

$$= \frac{1}{C}\int_0^t \frac{V}{R}e^{-t/RC}\cdot dt$$

$$= \frac{V}{R} \left[\frac{e^{-t/RC}}{-1/RC} \right]_0^t$$

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

→ $i(t) = \frac{V}{R} e^{-t/RC}$

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

⇒ AC circuit Analysis:

$V(t)$, $V = V_m \sin \omega t$,

1) Peak Value
2) Aversage
3) Rms value
4) Inst. value.

Q. PT for AC cycle avg value is

$\frac{V_m}{2}$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T f^2(t)\,dt} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} V_m^2 \sin^2 \omega t \, d\omega t} = \frac{V_m}{\sqrt{2}},$$

$$\frac{V_m}{\sqrt{2\pi}} \sqrt{\int_0^{2\pi} \left(\frac{1-\cos 2\omega t}{2}\right) d\omega t} = \frac{V_m}{\sqrt{2\pi}} \cdot \sqrt{\left(\frac{1}{2}\omega t - \frac{1}{2} \times \frac{\sin 2\omega t}{2}\right)_0^{2\pi}}$$

$$= \frac{V_m}{\sqrt{2\pi}} \sqrt{\pi - \frac{1}{4}}$$

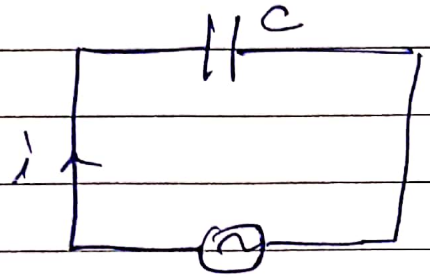
$$= \frac{V_m}{\sqrt{2}\,\cancel{\sqrt{\pi}}} \cdot \cancel{\sqrt{\pi}} = \frac{V_m}{\sqrt{2}}.$$

$\Rightarrow$ form factor $= \dfrac{\text{Rms}}{\text{Average}}$

→ AC circuit analysis:

$$V(t) = i(t)R$$

Capacitive circuit



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

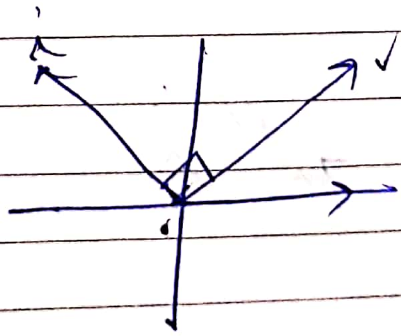
$$V(t) = V_m \sin\omega t$$

$$i(t) = C\frac{dV(t)}{dt}$$

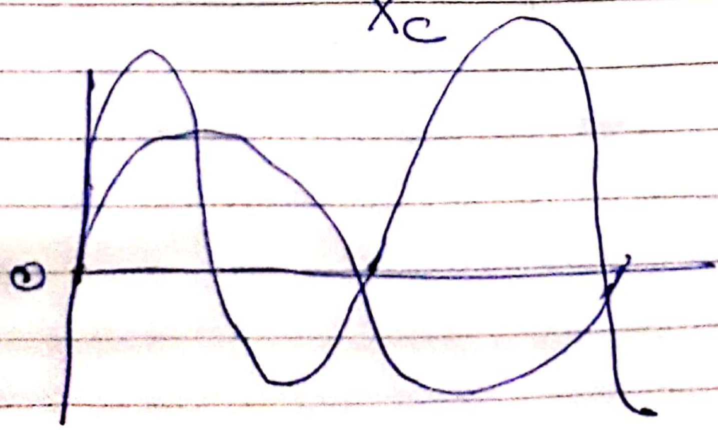
$$= C\frac{d(V_m \sin\omega t)}{dt}$$

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

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



$$\therefore I_m = \frac{V_m}{X_C}.$$



Q. A 10Ω resistance is feeded by AC source of 200V, 50Hz freq. Determine

i) V
ii) I
iii) V_{rms}, I_{rms}
iv) ϕ & P Factor angle
v) Power factor
vi) phasor & time diagram.

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

$V = V_m \sin \omega t$

$V = 200\sqrt{2} \sin 50 \times 3.14 \times t$

$200\sqrt{2} = V_m$

$V = IR$

$V_m = 200V$

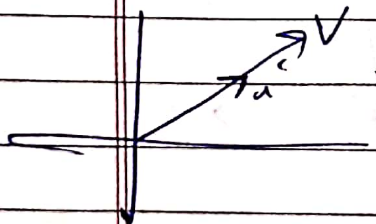
$\omega = 50Hz$

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

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

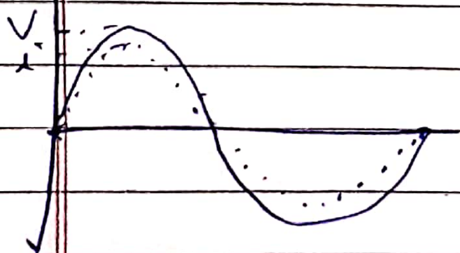
$= \frac{200\sqrt{2}}{10} \sin 2\pi f t$

$\phi = 0°$

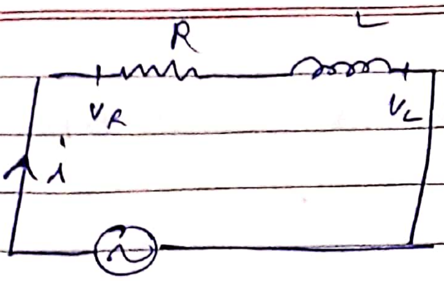


$i = 20\sqrt{2} \sin 50 \times 3.14 \times t$

$P_F = V i \cos \phi$



RL circuit analysis:



$$V_R = iR$$

$$V_L = i X_L \rightarrow V^2 = V_R^2 + V_L^2$$

$$\frac{V^2}{i^2} = R^2 + X_L^2$$

$$Z^2 = R^2 + X_L^2$$

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

$$i(t) = \frac{V(t)}{Z} = \frac{V_m \sin(\omega t - \phi)}{Z}$$

$$i(t) = \frac{V_m \sin(\omega t - \phi)}{\sqrt{R^2 + X_L^2}}$$

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

$$= \frac{iX_L}{iR}$$

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

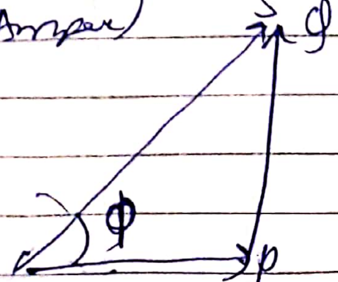
* Types of Power:

→ Active power: $VI\cos\phi = P$ (watts)

→ Reactive → $VI\sin\phi = Q$ (Volt/Ampere)

→ Apparent (Active & reactive) → S

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



Power triangle

Q. A series RL circuit is feeded by AC source of 200V, 50Hz

$R = 10$

$L = 1mH$ $\qquad \omega = 2\pi f$

Determine:

1) exp. of V,
2) impedance
3) phase angle
4) Current expression
5) Active, reactive & apparent power.

$V_s = 200\sqrt{2} \sin 2 \times 3.14 \times 50 \times t$

$X_L = 2\pi f L$

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

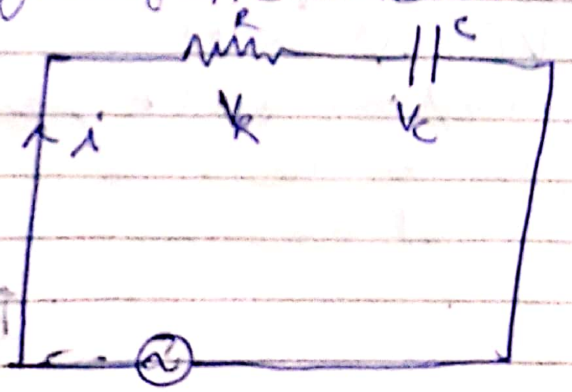
$Z = \sqrt{R^2 + X_L^2}$

$= \sqrt{10^2 + (2\times3.14\times50\times10^{-3})^2}$

$\phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{2\times3.14\times50\times10^{-3}}{10}\right)$

$\rightarrow i = \frac{V_m}{Z}\sin(\omega t - \phi)$.

⇒ Analysis of RC circuit:



$V_R = iR$

$V_C = I X_C$

$V = \sqrt{V_R^2 + V_C^2}$

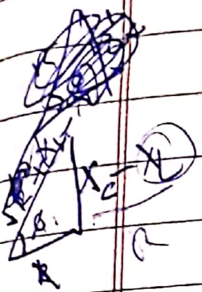
$$V^2 = i^2R^2 + i^2X_C^2$$

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

$$i(t) = \frac{v(t)}{Z}$$

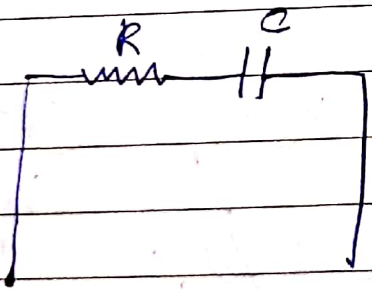
$$= \frac{V_m \sin(\omega t+\phi)}{\sqrt{R^2+X_C^2}}$$

$$= \frac{V_m}{\sqrt{R^2+X_C^2}} \sin(\omega t+\phi)$$



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

$$P = v(t)\, i(t).$$

Q 

A series RC circuit is feed 200V AC & 50Hz freq. Determine the following:

a) exp. for supply voltage

$\frac{1}{50\times1\times10^{3}}$

a) $V = 200\sqrt{2} \sin 2\times3.14\times50\times t$

b) $I = \frac{200\sqrt{2}}{10} = 20\sqrt{2} \sin 2\times3.14\times50\times t$

c) $Z = \sqrt{100 +}$

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

$Q = VI\sin\phi$

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

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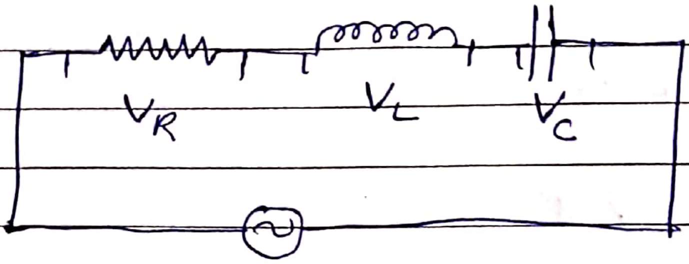
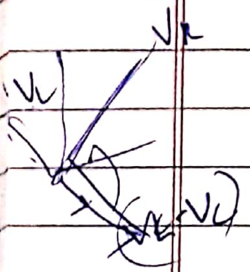
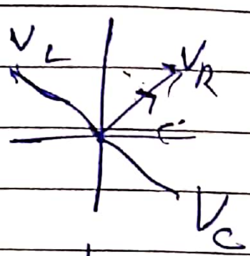
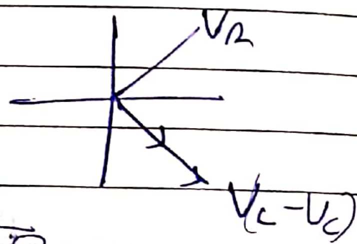
$\Rightarrow$ Series RLC circuit:



$V = V_m \sin \omega t$







$V_R = iR$

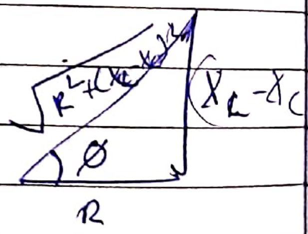
$V_L = iX_L$

$V_C = iX_C$

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

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

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



$X_C > X_L$ $(+\phi)$

$X_L > X_C$ $(-\phi)$

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

$i(t) = \frac{V(t)}{Z} \sin(\omega t \pm \phi)$.

$\tan\phi = \frac{X_L - X_C}{R}$

Q. $V = 100 \sin 20t$

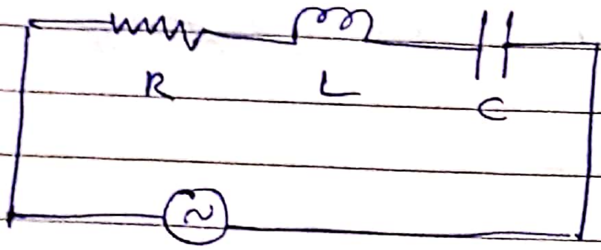
$mH = 10^{-3} H$

$\mu F = 10^{-6} F$

$Z = \sqrt{10^2 + (20 \times 10^{-3} - \frac{1}{2 \times 10^{-6}})}\ \Omega$ $\quad \phi = \tan^{-1} \frac{X_L - X_C}{R}$

$i = \frac{V(t)}{Z} \sin(\omega t + \phi) = \frac{100}{Z} \sin(20t + \phi)$

⇒ Series Resonance:



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

$$X_L = \omega L$$

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

$$X_C = X_L$$

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

$$\omega^2 LC = 1$$

$$\omega^2 = \frac{1}{LC}$$

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

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

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

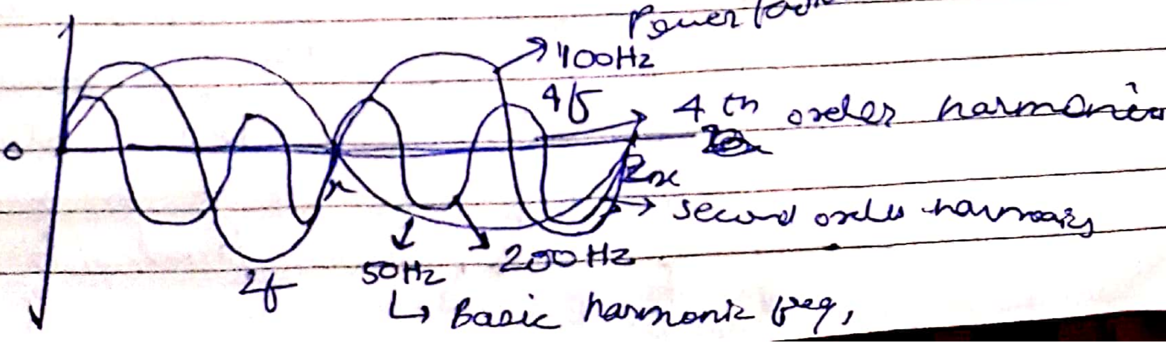
$$X_L = X_C$$

$$\therefore Z = R$$

1) Impedance will be minimum
2) Current will be max.
3) Resistive circuit.
4) voltage & current will be in same phase.
5) phase angle 0
6) PF will be unity

Power factor

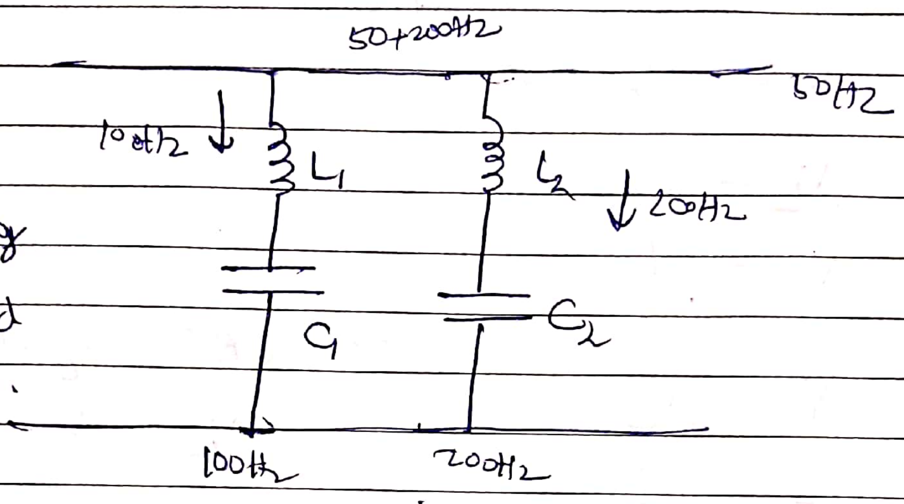
* Harmonics:



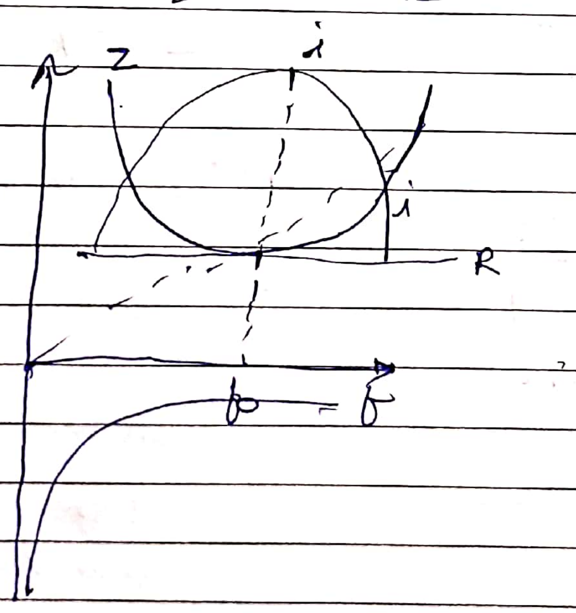
⇒ **Harmonics:** Sinosoidal ~~f~~ signals whose frequency different than base ~~frequency~~ signal.

50Hz + 100Hz + 200Hz

Filtering of distorted signals.



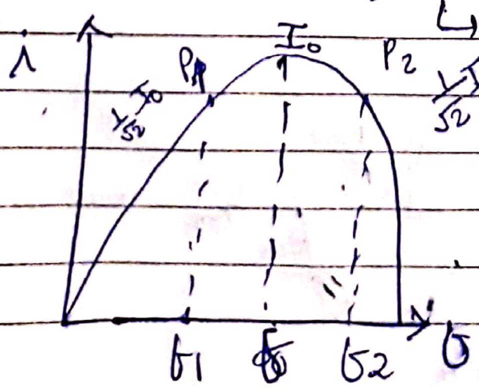
* Resonance condition



$X_L = \omega L$

$= 2\pi f L$

* Half Power frequencies,



↳ at which current will be $\frac{1}{\sqrt{2}}$ times the resonance ~~condit~~ current.
Those pts are called

$$\boxed{\text{Bandwidth} = f_2 - f_1}$$

Date
Page

$$P_0 = \left(\frac{V}{\sqrt{R^2+(X_L-X_C)^2}}\right)^2 R = \frac{1}{2} I_0^2 R = \frac{1}{2}\left(\frac{V}{R}\right)^2 R$$

(at half power freq. pt.)

$$\frac{V^2}{R^2+(X_L-X_C)^2} \cdot R = \frac{1}{2}\frac{V^2}{R}$$

$$R^2+(X_L-X_C)^2 = 2R^2$$

$$X_L - X_C = R^2$$

$$\boxed{R = X_L - X_C}$$

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

$$\omega^2 LC - \omega CR - 1 = 0$$

$$LC\left(\omega^2 - \frac{\omega \cancel{C} R}{L\cancel{C}} - \frac{1}{LC}\right) = 0$$

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

$$\omega_1 = \frac{\frac{R}{L} \pm \sqrt{\frac{R^2}{L^2} + 4\times 1\times\frac{1}{LC}}}{2\times 1}$$

$$\rightarrow \omega_1 = \frac{R}{2L} + \sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}$$

$$\rightarrow \omega_2 = \frac{R}{2L} - \sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}$$

$$f_1 = \frac{R}{4\pi L} + \frac{1}{2\pi}\sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}$$

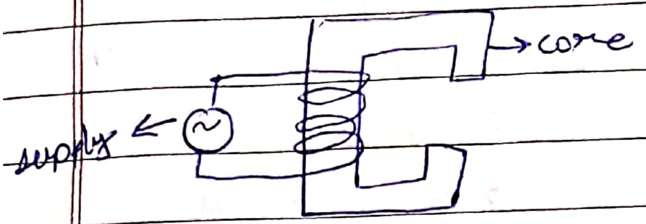
$$f_2 = \frac{R}{4\pi L} - \frac{1}{2\pi}\sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}$$

$$\text{Bandwidth} = f_2 - f_1$$

$$= -\frac{1}{\pi}\sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}.$$

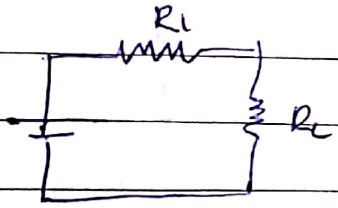
Unit 2: Magnetic Circuit.

magnetic circuit



MMF (magnetomotive force)
- magnetic flux
- Reluctance
- magnetic field intensity.

Elec. circuit

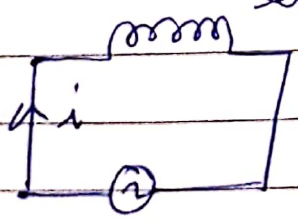


EMF
- Current
- Resistance
- Elec. field intensity
- Conductivity

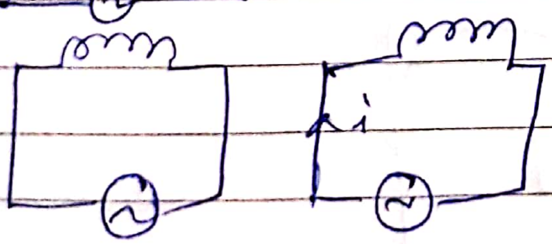
→ Faraday: 1) Change in flux generates emf in a coil

→ 2) Induced emf $(\varepsilon) = -\frac{d\phi}{dt} = -N\frac{d\phi}{dt}$ ↳ turns.

Self-Induction



self induced emf



emf induced due to current in one coil.

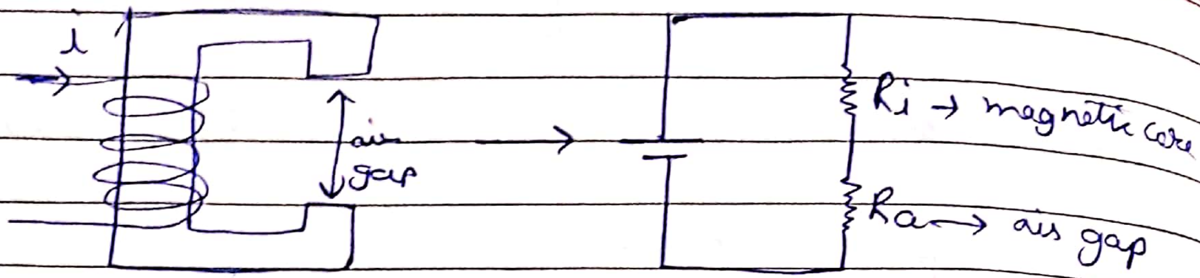
mutual inductance → magnetic material

Reluctance opposes the flow to flux

⇒ Types of magnetic circuit:

a) series
b) parallel

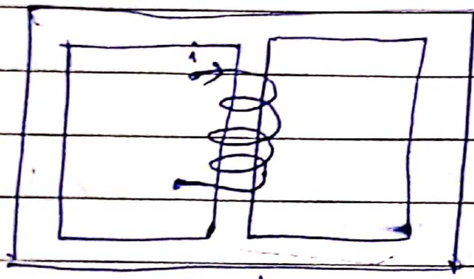
→ Series magnetic circuit:

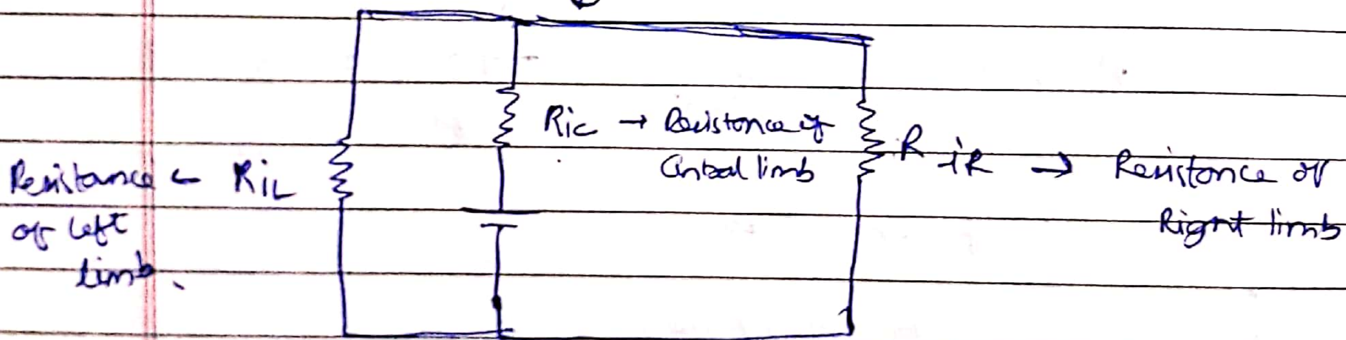


magnetic circuit

equivalent electrical circuit

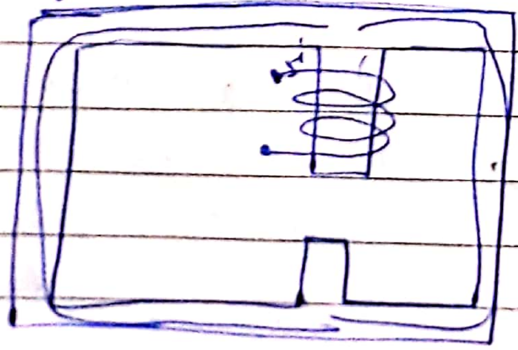
→ Parallel magnetic circuit:

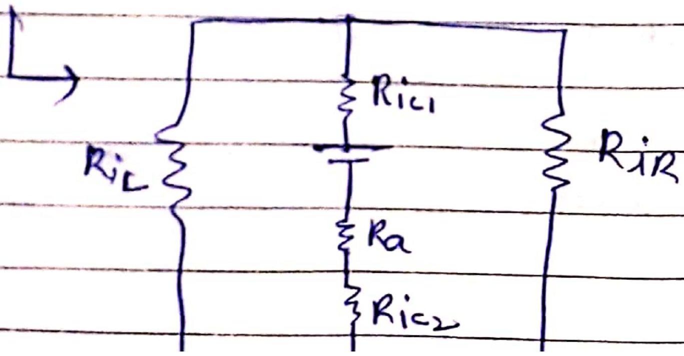




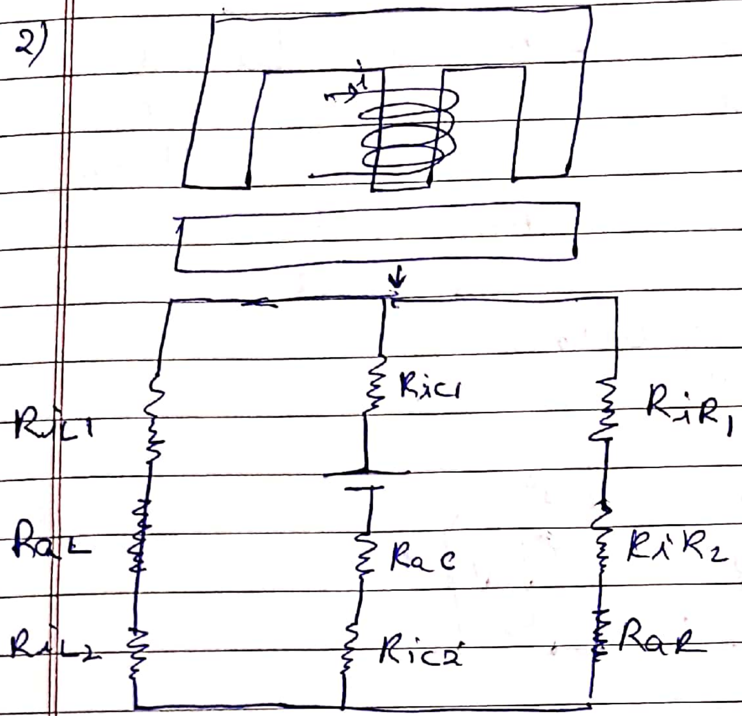
equivalent circuit.

eg: 1)





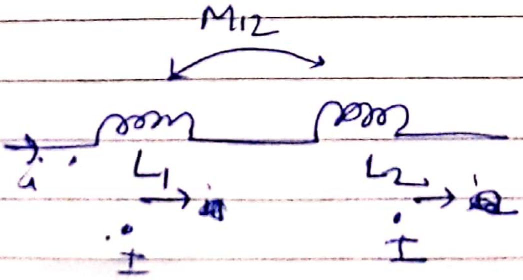
2)



→ **magnetically coupled coils:**

Dot convention rule: Dot convention rule helps to determine the polarity of induced emf in magnetically coupled coil.

As per rule, a dot will be placed at that end of the coil which are having similar polarity of induced emf.



→ away from dot towards +

→ on away one towards (−)

$$e_{11} = -L_1 \frac{di}{dt} \qquad e_{22} = -L_2 \frac{di}{dt}$$

$$e_{12} = -M_{12} \frac{di}{dt} \qquad e_{21} = -M_{21} \frac{di}{dt}$$

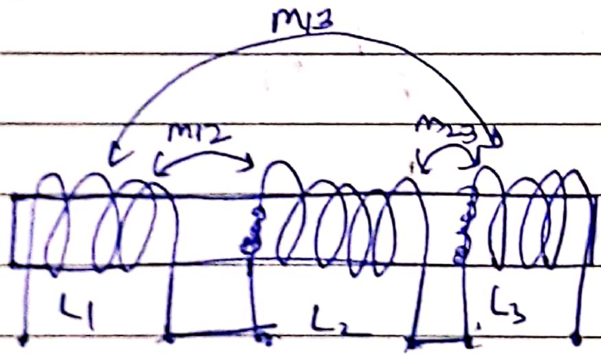
Total emf,

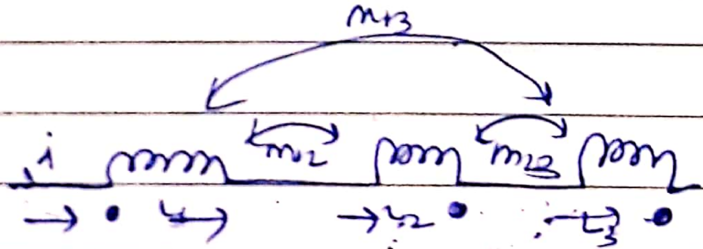
$$e = -L_1 \frac{di}{dt} + -M_{12}\frac{di}{dt} - L_2 \frac{di}{dt} + -M_{21}\frac{di}{dt}$$

$$= -(L_1 + L_2 + 2M_{12}) \frac{di}{dt}$$

∴ equivalent Inductance

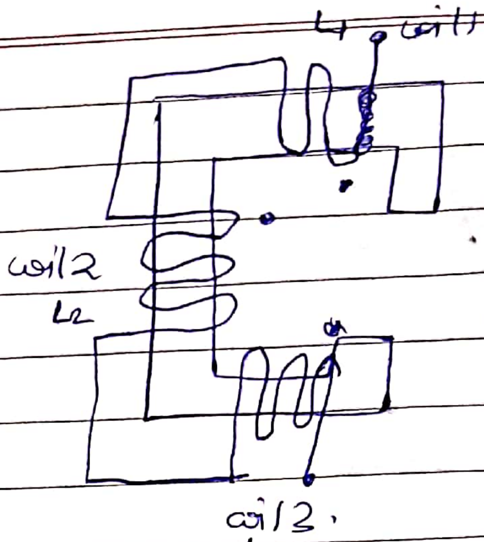
⇒

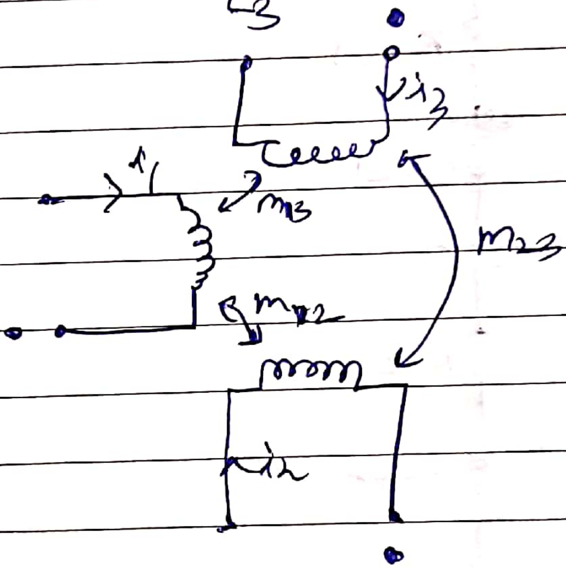




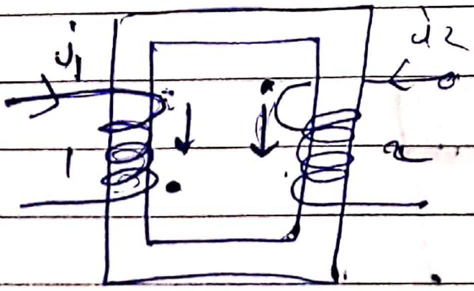
$$-L_1 \frac{di}{dt} - \left(-M_{12}\frac{di}{dt}\right) - \left(-M_{13}\frac{di}{dt}\right)$$

$$-L_2 \frac{di}{dt} - \left(-M_{23}\frac{di}{dt}\right)$$



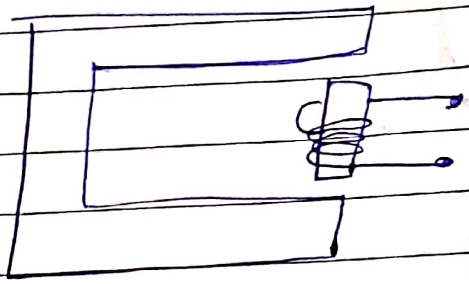


⇒

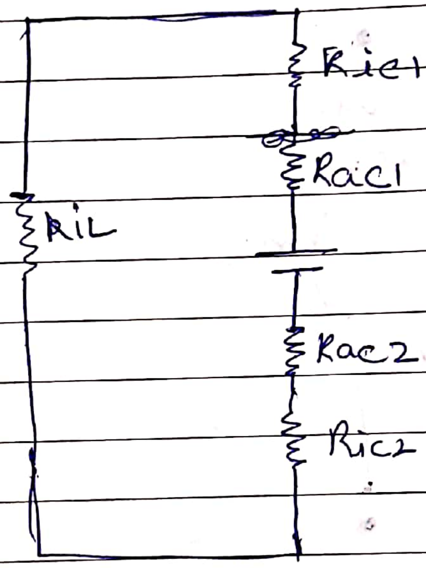


$$e_1 = -L_1 \cdot \frac{di_1}{dt} - \left(-M_{12} \cdot \frac{di_2}{dt}\right)$$

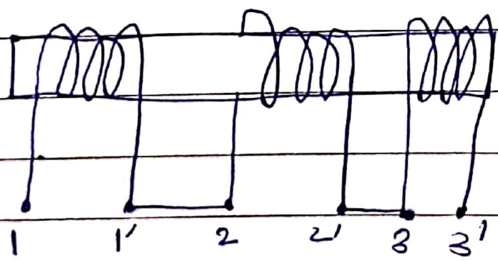
$$e_2 = -L_2 \frac{di_1}{dt} - \left(-M_{21} \cdot \frac{di_2}{dt}\right).$$



→ elec. equivalent circuit.



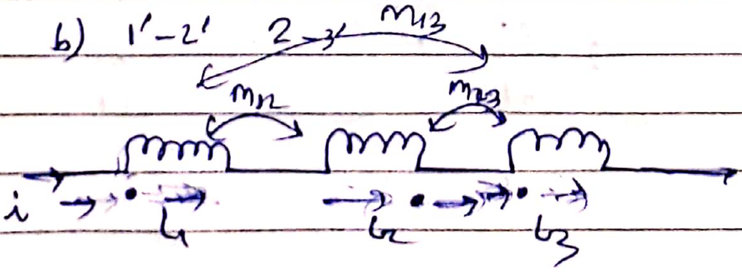
C)



series

a) 1'-2 2'-3

b) 1'-2' 2-3'

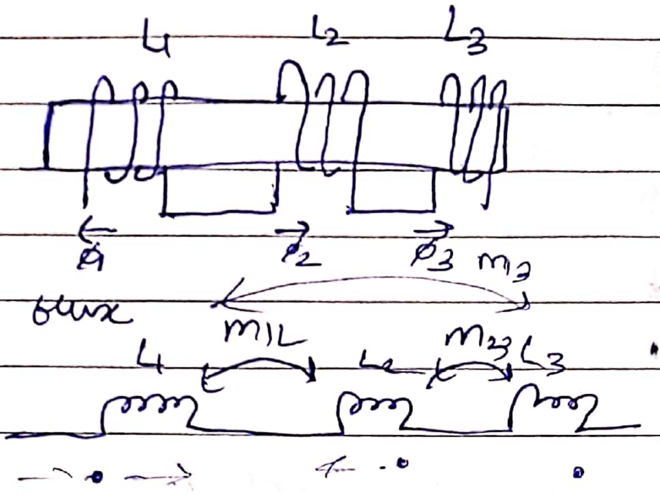


$$-L_1\frac{di}{dt} + \left(-M_{12}\cdot\frac{di}{dt}\right) + \left(-M_{13}\cdot\frac{di}{dt}\right)$$

$$-L_2\cdot\frac{di}{dt} + \left(-M_{23}\cdot\frac{di}{dt}\right)$$

$$-L_3 \frac{di}{dt} - \left(-M_{13}\frac{di}{dt}\right)$$

1/9



$$\mathcal{E} = -L_1\frac{di}{dt} - \left(M_{12}\frac{di}{dt}\right) - \left(-M_{13}\frac{di}{dt}\right)$$

$$-L_2\frac{di}{dt} - \left(-M_{12}\frac{di}{dt}\right) - M_{23}\frac{di}{dt}$$

$$-L_3\frac{di}{dt} - M_{23}\frac{di}{dt} + M_{13}\frac{di}{dt}.$$

* Magnetic flux density: is flux per unit area.

$$B = \frac{\phi}{A} = \frac{\text{weber}}{m^2}.$$

Magnetic field intensity

$$H = \frac{Ni}{L} = \frac{\text{mmf}}{\text{length}} = \frac{F}{L}.$$

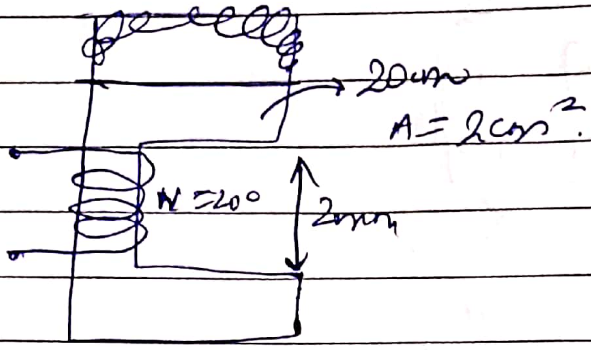
$$\phi = BA$$
$$= \mu HA$$
$$= \mu \frac{Ni}{L} A.$$
$$= \frac{Ni}{\frac{l}{\mu A}}$$
$$= \frac{Ni}{S}.$$

$S =$ Reluctance $= \frac{l}{\mu A}$.

Resistance $= \rho\frac{l}{a}$.

Reluctance $= \frac{l}{\mu A}$

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

Q 

A rect core made up of soft iron having $\mu = 2000$ is excited by a magnetic coil with $N = 200$ & $I = 5A$. The mean length of the flux in the core is $l = 20cm$. If the rect core is having air gap of 2mm Then determine the flux developed in a magnetic core & air gap. Assume the area of the core is $2cm^2$.

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

$$= \frac{mmF}{S}$$

$$mmF = NI = 200 \times 5 = 1000 AT$$

$$S_{i} = \frac{l_i}{\mu_0 \mu_r A} = \frac{(20 - 0.2) \times 10^{-2} m}{4 \times 10^{-7} \times 2000 \times 2 \times 10^{-4} m^2}$$

per. of Air $= 4 \times 10^{-7}$

$$S_a = \frac{l_a}{\mu_0 A} = \frac{0.2 \times 10^{-2}}{4 \times 10^{-7} \times 2 \times 10^{-4}}$$

$$S = S_i + S_a$$

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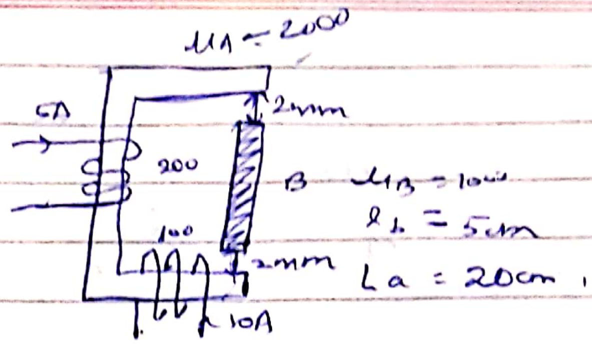
Q.



$$MMF = N_1 I_1 + N_2 I_2$$
$$= 200 \times 5 + 100 \times 10$$
$$= 2000 AT$$

$$S_a = \frac{l_a}{\mu_0 \mu_A A} \qquad A = 2cm^2$$
$$= \frac{20 \times 10^{-2}}{4\pi \times 10^{-7} \times 2000 \times 2 \times 10^{-4}}$$

$$S_b = \frac{l_b}{\mu_0 \mu_B A} = \frac{5 \times 10^{-2}}{4\pi \times 10^{-7} \times 1000 \times 2 \times 10^{-4}}$$

$$S_{air1} = \frac{l_a}{\mu_0 A} = \frac{2 \times 0.2 \times 10^{-2}}{4\pi \times 10^{-7} \times 2 \times 10^{-4}}$$

$$S = S_a + S_b + S_{air}$$

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

Q A circular ring wn. by mag. coil having $N = 200$ & $i = 10A$, air gap of 1mm. If ~~air~~ ~~of~~ $A = 2cm^2$ & mean length of flux is 20cm. Determine flux passes thro magnetic core, $\mu_r = 1000$

$$MMF = Ni$$

$$= 200 \times 10 = 2000\,AT$$

$$S_i = \frac{(20-0.1)\times 10^{-2}}{4\pi \times 10^{-7} \times 1000 \times 2 \times 10^{-4}} = \frac{l_i}{\mu_0 \mu_r A}$$

$$S_a = \frac{0.1 \times 10^{-2}}{4\pi \times 10^{-7} \times 2 \times 10^{-4}} = \frac{l_a}{\mu_0 A}$$

$$S = S_i + S_a$$

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

Unit 3 : Electrical Machines.

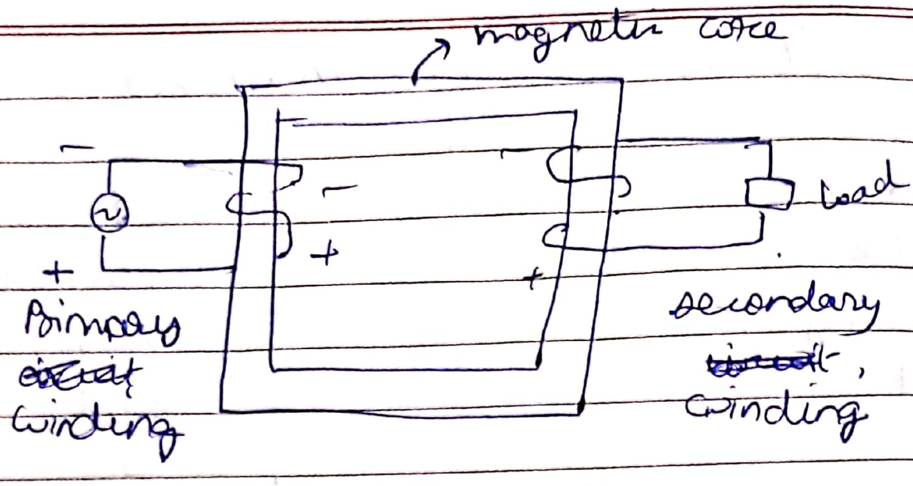
- Static
  - No moving part
  - Transformer
- Dynamic
  - moving part
  - motor ($E \to M$)
    - AC
    - DC
    - 1ϕ motor
    - 3ϕ motor
      - 3ϕ inductor motor
      - 3ϕ synchronous motor
  - generator ($M \to E$)

→ Transformer :

* Static m/c
* It is used to transfer power from one elec. circuit to other elec. circuit which are electrically isolated but magnetically coupled.
* It is used to transfer power of different voltage / I maintaining power & freq. constant.

→ ~~Windage loss~~

* highest efficiency machine (90 - 95%).



→ Operating principle: power shifted from primary – sec. circuit with help of magnetic coil (Faraday law)

$$\varepsilon = -N\frac{d\phi}{dt}$$

→ Polarity keeps on changing.

→ Expression of induced emf in Transformer:

As per faraday's second law,

$$e = -N.\frac{d\phi}{dt}$$

Change in flux between 0 to T/4

$$d\phi = \phi_{max} - 0$$

Change in time,

$$dT = T/4 - 0$$

As self emf induced in primary coil,

$$E_1 = -N_1\frac{d\phi}{dt}$$

$$= -N_1\frac{\phi_{max}}{T/4}$$

$$E_1 = -4N_1\phi_{max}f$$

Avg. Mutual ~~inductan~~ induced emf in secondary coil,

$$E_2 = -N_2 \frac{d\phi}{dt}$$

$$= -N_2 \frac{\phi_{max}}{T/4}$$

$$E_2 = -4N_2 \phi_{max} f.$$

rms value of induced emf

$$e_{1rms} = -4\phi_{max} N_1 f \times 1.11$$

$$= -4.44 N_1 \phi_{max} f$$

$$e_{2rms} = -4.44 N_2 \phi_{max} f.$$

Q. $E \propto N$ $\qquad E \propto \frac{1}{I}$

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = k}$$

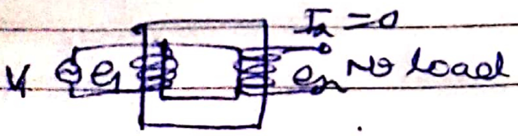
Transformation ratio.

⇒ Operation of Transformer:

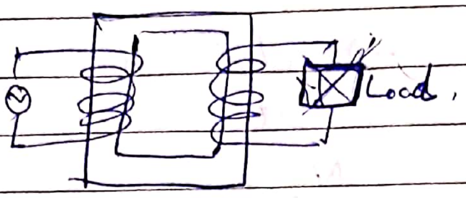
* High voltage winding is made up of thin wire
* low voltage winding is made up of thick wire

a) No load operation
b) Load operation.

→ No load connected to secondary side.



→ ~~No~~ load Operation



No load :-

Current flowing in primary winding
flux developed.
↓
e_1 e_2

2 KVA 200/100V

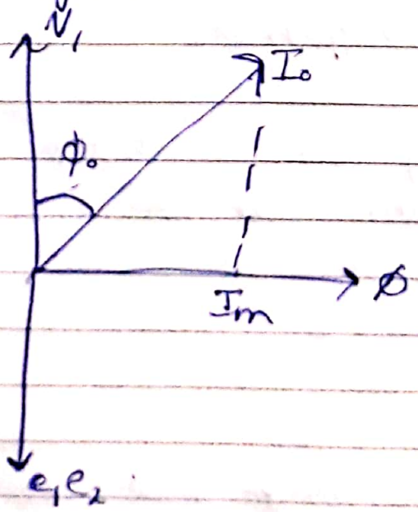
2 KVA 100/200V

$I_1 = \frac{2 \times 1000}{200} = 10A$

$I_2 = \frac{2 \times 1000}{100} = 20A.$

I_0 → Working, I_w, watt · | magnetization, I_m, wattless

→ Phasor diagram :



$\cos(90 - \phi) = \frac{I_m}{I_0}$

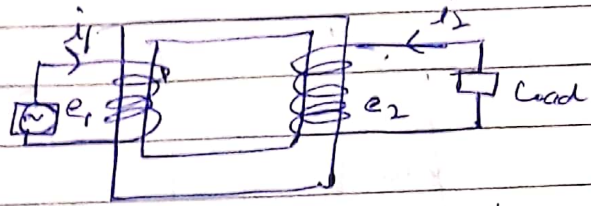
$\boxed{I_m = I_0 \sin\phi_0}$

$\cos\phi_0 = \frac{I_w}{I_0}$

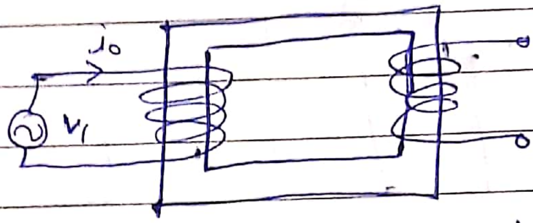
$I_w = I_0 \cos\phi_0$

load

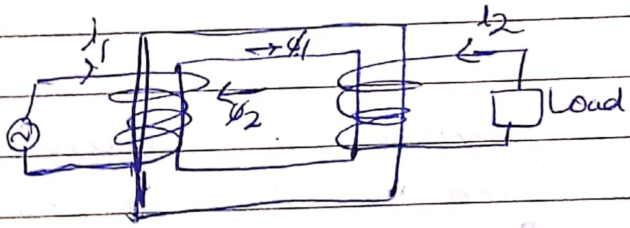
Load operation of Transformer:



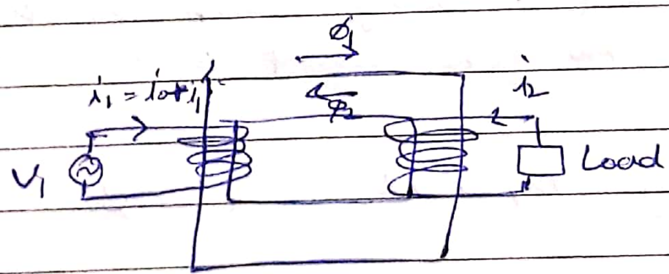
Constant flux m/C.



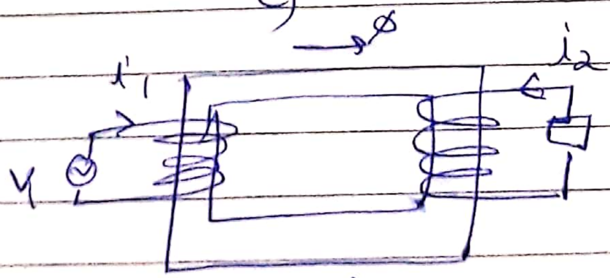
a)



b)



c)



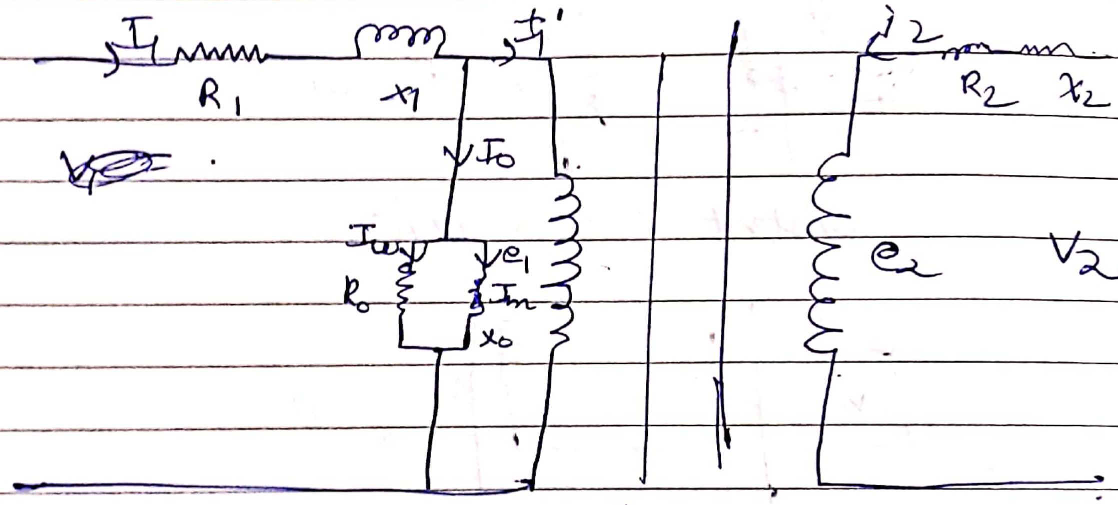
d)

$V_1 > e_1$

$V_1 = e_1 + i_1 R_1 + i_1 j X_1$

$e_2 = V_2 + i_2 R_2 + j i_2 X_2$.

→ equivalent CRT :



Q. A transformer primary is drawing 5A current under the condition when the sec. is open circuit. Dete the mag. and working component of no load current. Assume at no load current condition the factor is 0.75

Mag. component = $I_0 \sin \phi_0$