Network analysis

Part - 01 (DC circuit Analysis)

1) Basics of fundamentals. (most Imp)
2) Network theorem
3) Transient Analysis
4) Two port Network.

Part - 02 (AC circuit Analysis)

1) Sinusoidal steady state analysis
2) phasor concept
3) Power calculation
4) Resonance
5) 3-ϕ circuits
6) magnetically coupled circuit

Part - 03 (misllenears)

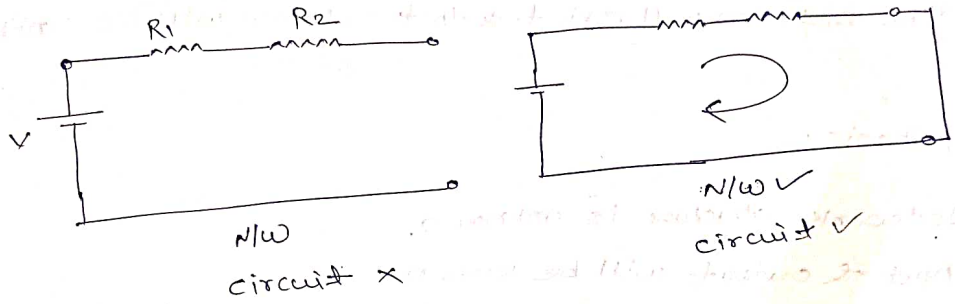
> Graph Theory

Basics of Network Lect-02

1) Network and circuit

a) Network:- It is an interconnected of electrical element that may or may not have closed path.

b) circuit:- It is also an interconnection of element but it must have atleast one closed path.



Remember:- 1) all the circuits are always Network but viceversa is not always true.

2) For a Network to be a circuit,

- It must have one closed path
- It must have atleast one Independent source.

- If any circuit or Network doesnt present any Independend source then It is called as dead Network.

2) Network analysis & synthesis

i) Analysis :-

1) The Network structure is always given

2) with the existance of Energy sources finding the Response voltage or current is known as analysis.

3) The solution will exist & that solution will be unique.

ii) Synthesis :-

1) Network structure is unknown.

2) Input & output will be known

3) and finding the Network structure using input & output relation is known as synthesis.

4) solution may or maynot exist and If solution exist then that may or may not be unique.

Imp

3) Basic Electrical Quantities

(q, I, V, P, W)

C A V W Joules/watt-sec

i) charge (q) :- It is the most fundamental quantity of Electrical Engineering.

(+) → proton $+1.6\times10^{-19}$ C

(−) → electron -1.6×10^{-19} C

* charge can not be created or destroyed, it can be only transfered from one system to another system.

ii) current (i) :- It is the rate of flow of charge.

Instantaneous current :- $i(t) = \frac{dq(t)}{dt} = 1C/1sec = 1A$

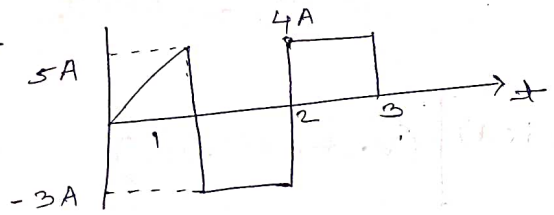
iii) $dq(t) = i(t)\, d(t)$

Integration means area under the curve.

$$q(t) = \int_{t_1}^{t_2} i(t)\, dt$$

e.g:- $\int_1^2 5\, dt = 5 \times [t]_1^2 = 5 \times (2-1) = 5C$

e.g:-



iii) voltage (V) :- It is the amount of energy wasted for the flow of 1c of charge from one point to another point in an element or circuit.

$$V = \frac{dw}{dq}$$

$w \rightarrow$ energy
$q \rightarrow$ charge

$=$ volt

$= \frac{\text{Joule}}{\text{charge}} = \frac{\text{Joule}}{\text{Coulomb}} = \frac{W}{q}$

e.g:- (iv)

$$dw = V.dq$$

If i want to find energy the integrate it

$$\int dw = \int V\,dq$$

$$W = \int V\,dq$$

* The potential must be function of charge.

iv) power & Energy

i) power :- It is rate of performing the work.

$$\boxed{p(t) = \frac{dw}{dt}} = \text{watt} = \text{Joule/sec} = V.I$$

$$\left[p(t) = \frac{dw}{dq} \times \frac{dq}{dt} = V(t) \times i(t)\right] \text{(Volt - Ampere)}$$

ii) Energy :- It is the capability to do work

$$p(t) = \frac{dw(t)}{dt}$$

$$dw(t) = p(t)\,dt$$

$$\int dw(t) = \int p(t)\,dt$$

$$w(t) = \int_{t_1}^{t_2} p(t)\,dt \Rightarrow \int_{t_1}^{t_2} V(t)\,i(t)\,dt = \text{Joule or watt-sec.}$$

watt-hour

Lect- 03

* Concept of power (V. Imp)

* A Network having atleast one independent source & other Electrical element like R, L, C Then the property of R, L & C is always absorbing the power. and while doing so the current will enter at positive terminal and leave at Negative terminal (-) of elements.

e.g:-

Absorbing power delivering power

*

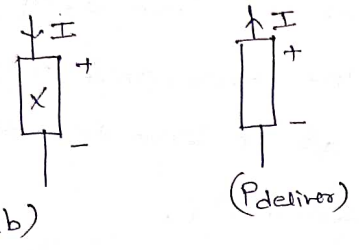
R → It always dissipate the absorbed power in the form of Heat

L → It stores the absorbed Energy in its magnetic field. It never dissipates Energy in the form of Heat

C → It stores the absorbed Energy in its Electric field It never dissipate Energy in the form of Heat.

* According to convention :-

If positive current



In Generalized form

$P_{absorbed} = +$

$P_{delivered} = -$

* Power convention

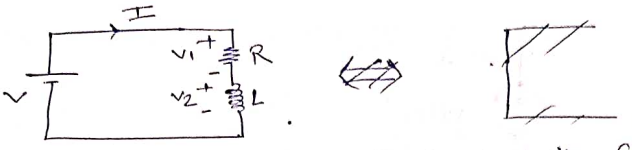
$$\boxed{\Sigma P_{Total} = 0}$$

* while calculating the total power then always use one form of power only i.e. (P_{ab} or P_d)

$$\boxed{P_{absorbed} = -P_{delivered}}$$

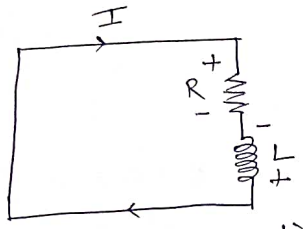
* L → while absorbing or delivering power, inductor never changes its current direction but its voltage polarity changes.

e.g:-



R → absorbing & finally dissipate in the form of Heat

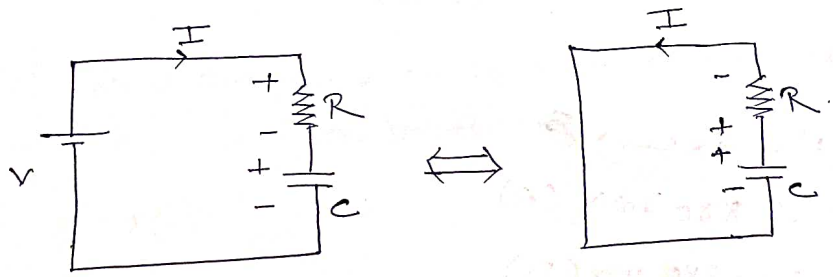
L → absorbing & finally store the energy in the form of magnetic field.



R → absorbing & dissipating

L → delivering

C → while absorbing or delivering power, capacitor never changes its polarity but it current direction changes.



only change current direction.

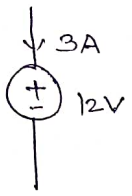
R → absorbing & dissipate

C → absorbing & store

R → absorbing & dissipate

L → delivering

e.g:-

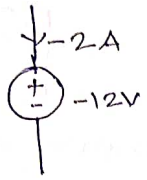


$P = 12 \times 3$

$= 36W\ (A)$

or

$= -36W\ (D)$



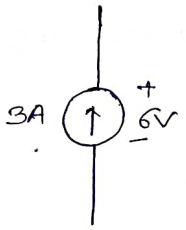
$P = -12 \times -2$

$= 24W\ (A)$

or

$= -24W\ (D)$

Lect-04



$P = 6 \times 3 = 18W\ (D)$

or

$-18W\ (A)$

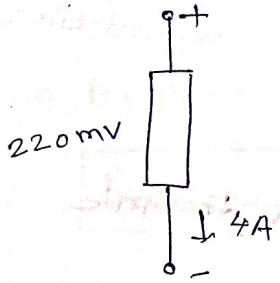
$P = (-10)(-2)$

$= 20W\ (A)$

or

$= -20W\ (D)$

*

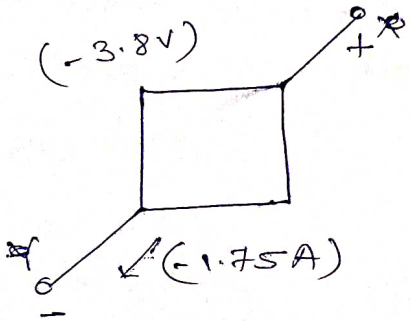


$P = 4 \times 220 \times 10^{-3}$

$= 880\ mW\ (A)$

$= -880\ mW\ (D)$

* find the Generated power

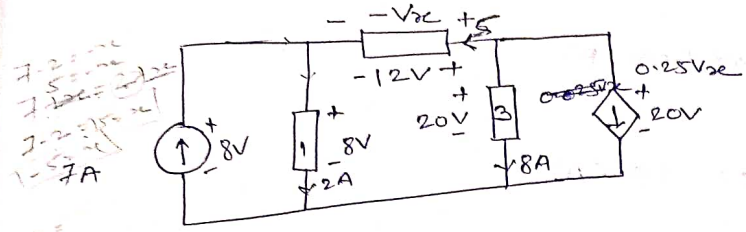


$P = -3.8 \times -1.75$

$= 6.65\ W\ (A)$

$= -6.65\ W\ (D)$

1.7) find the power absorbed by each element in the circuit shown.



① $P_1 = 7 \times 8$
$= 56W(D)$

② $P_2 = 8 \times 2$
$= 16W(A)$

③ $P_3 = -5 \times 12$
$= -60W(A)$

④ $P_4 = 20 \times 8$
$= 160W(A)$

⑤ $P_5 = 0.25V_x \times 20$

$V_x = -12V$

$\therefore \; 0.25 \times (-12) \times 20$

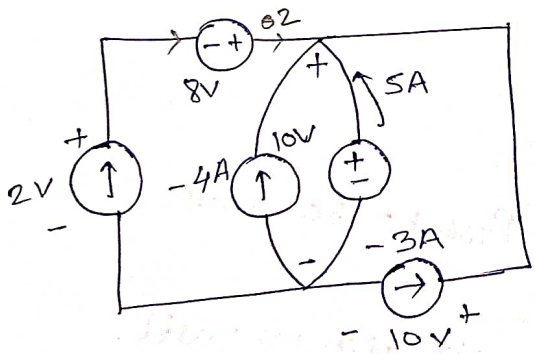
$P_5 = -60W(A)$

$\sum P_{Total} = 0$

$-56 + 16 + 160 - 60 - 60 = 0$

circuit is valid

1.8) Determine the power supplied by the left most element in the circuit given below



$-x = -4 + 5 + -3$

$\boxed{x = -2}$

$x = 2$

$P = 2V \times 2A$
$= 4W(D)$
$= -4W(A)$

* $P_{8V} = 8 \times 2 = 16W$ (D) or $-16W$ (A)

* $P_{-4A} = 10 \times -4 = -40W$ (D) or $40W$ (A)

* $P_{10V} = 10 \times 5 = 50W$ (D) or $-50W$ (A)

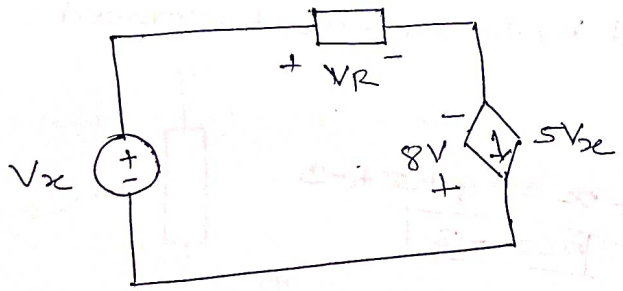
* $P_{(-3A)} = 10 \times (-3) = -30W$ (D) or $30W$ (A)

$\Sigma P_{Total} = 0$

$4 + 16 - 40 + 50 - 30 = 0W$

(circuit is valid)

Q1.9) For the circuit given below. The power deliver by dependent source will be ____ watt, if $V_R = 10V$ and $V_x = 2V$.



Sol^n:- $V_x = 2V$

$\therefore 5 \times V_x = 10A$

$P_{8V} = 8 \times 10 = 80W$ (D)

$P_{VR} = 10 \times 10 = 100W$ (A)

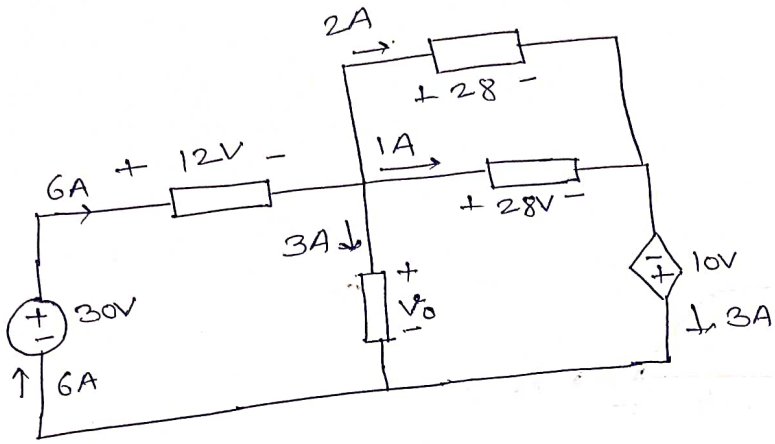
$P_{Vx} = 2 \times 10 = 20W$ (D)

$\Sigma P_{Total} = 80 - 100 + 20$

$= 0$

circuit is valid.

1.12) Find the value of V_o



Sol^n:- $P_1 = 6 \times 30$

$= 180\,W(D)$

$= -180\,W(A)$

$P_2 = 6 \times 12 = 72\,W(A)$

$P_3 = 3 \times V_o$

$P_4 = 2 \times 28 = 56\,W(A)$

$P_5 = 1 \times 28 = 28\,W(A)$

$P_6 = 10 \times 3 = 30\,W(D)$

$-30\,W(A)$

$\sum P_{Total} = 0$

$-180 - 72 + 3 \times V_o - 56 - 28 - 30 = 0$

$-54 + (3 \times V_o) = 0$

$-3 \times V_o = -54$

$V_o = \frac{54}{3}$

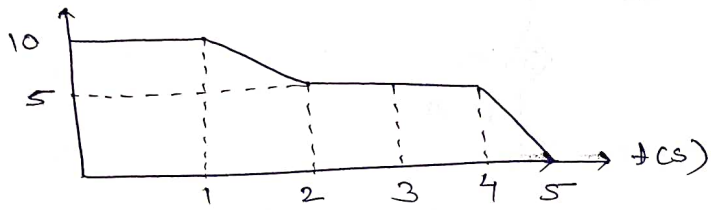
$V_o = +18\,W$

$P_3 = +54\,W(A)$

1.4) The current through an element is shown in figure. Determine the total charge that passed through the element at :-

i) $t = 1s$

ii) $t = 3s$



$\cancel{q(t)} = \cancel{dw(t)}$ $\quad i(t) = \frac{dq(t)}{dt}$

$$dq(t) = i(t)\,dt$$

$$\int dq(t) = \int i(t)\,dt$$

$$q(t) = \int i(t)\,dt$$

Approch 1:-

a) $t = 1$ sec

$$q(t) = \int_0^1 i(t)\,dt$$

$$= \int_0^1 10\,dt$$

$$= 10\,[t]_0^1$$

$$= 10\,[1-0]$$

$$= 10 \text{ coulomb}$$

b) $t = 3\,sec$

$$q(t) = \int_0^3 10\,dt$$

$$= 10\,[t]_0^3$$

$$= 10[3-0]$$

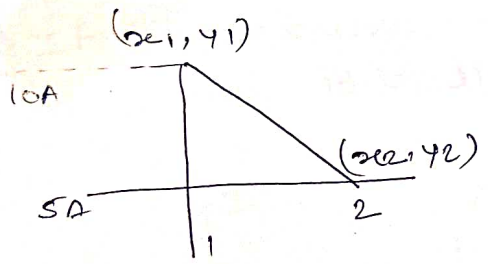
$$= 30$$ ~~calbumb~~ coulomb.

b) $t = 3\,sec$

$$q(t) = \int_0^3 i(t)\,dt = \left[\int_0^1 10\,dt + \int_1^2 i_1(t)\,dt + \int_2^3 5\,dt\right]$$

$$= 10[t]_0^1 + \int_1^2 (-5t+15)\,dt + \int_2^3 5\,dt$$

$=$



$$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

$$i(t) - 10 = \frac{5-10}{2-1}(t-1)$$

$$i(t) - 10 = -5(t+1)$$

$$\boxed{i(t) = -5t + 15}$$

$$q(t) = 10\times1 + \left[-5\left[\frac{t^2}{2}\right]_1^2 + 15\left[t\right]_1^2\right] + 5\left[t\right]_2^3$$

$$= 10 + \left[\frac{-5}{2}\left[3\right] + 15\times1\right] + 5\times1$$

$$= 15 + 15 - \frac{15}{2}$$

$$= 30 - 7.5$$

$$= 22.5 \text{ coulomb.}$$

also

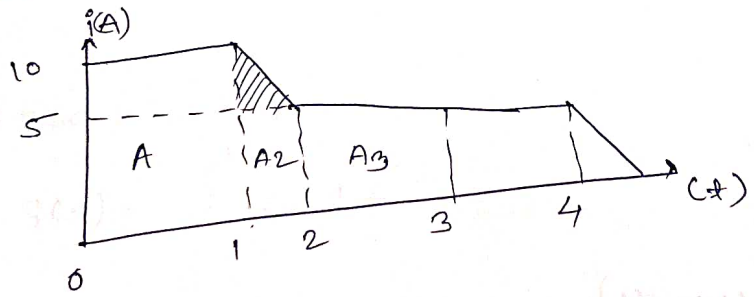
$$y = -mx + c$$

$$i(t) = \frac{-5}{1}(t) + 10$$

$$i(t) = -5t + 10$$

$$\therefore \int_0^1 -5t + 10\, dt$$

Approch 02:-



$$A_1 = q(t) = 10\times1 = 10C$$

$$A_2 = \frac{1}{2}\times5\times1 + 5\times1$$

$$A_3 = 5\times1$$

$A = q(t) = A_1 + A_2 + A_3$

$= 10 + \frac{5}{2} + 5 + 5$

$= 20 + \frac{5}{2} = 20 + 2.5$

$= 22.5\ C.$

* Characteristics of Electrical Elements.

on the basis of IV characteristic the elements are catagorised in the following category.

i) Linear or Non linear Elements

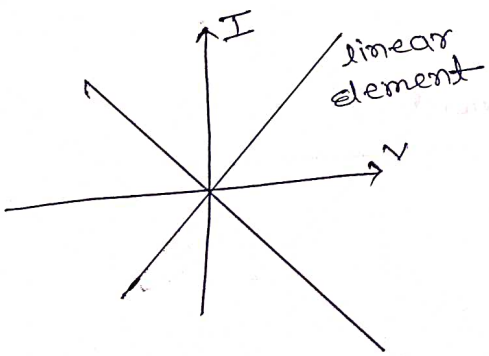
ii) Bilateral or unilateral Elements

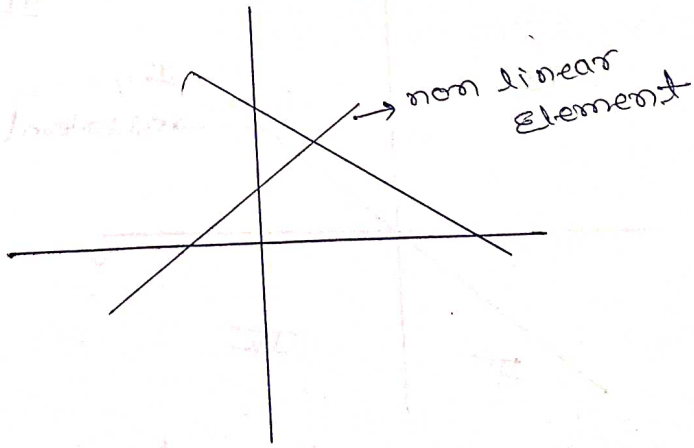
iii) Active or Passive Elements.

iv) Time varient or Time Invarients

i) Linear ~~or~~ non linear Elements

→ If the IV curve is a straight line & passing through origin then it is linear otherwise It is non linear.

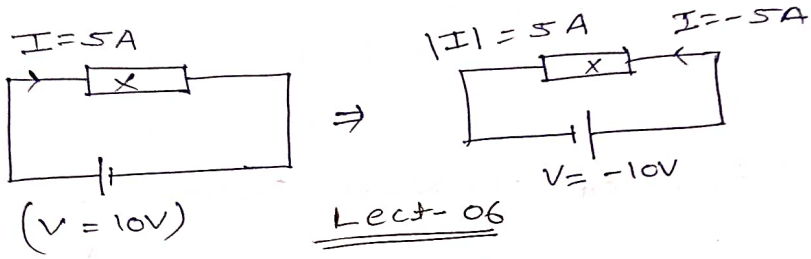




Linear Element → R, L & C

non-linear element → Diode, Transistor, (BJT, MOSFET)

ii) Unilateral & Bilateral Element



Lect- 06

Imp

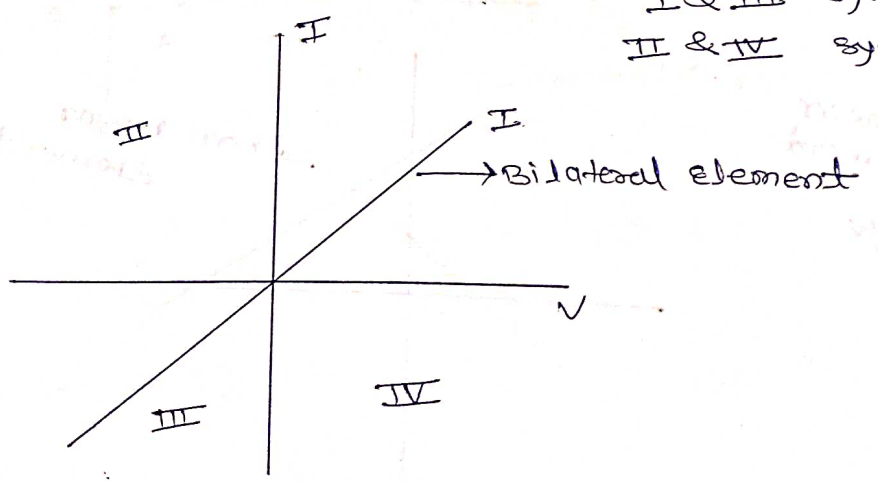
If the element is bilateral in nature then the magnitude of current after reversal of voltage polarity & before Reversal must Remain same.

* on the basis of I-V curve

* Bilateral Elements always offer same impedance in Every region of (I-V plane).

* Unilateral Elements offer different impedances in (I-V plane)

I & III symmetrical
II & IV symmetrical

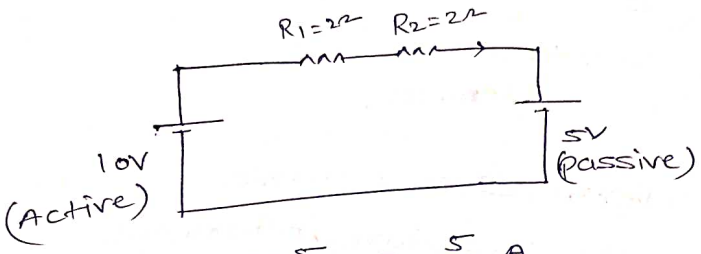


Bilateral Element

iii) Active and passive elements

* if any element or network is capable of delivering Net amount of power or energy to the external world, then the element is known as active, otherwise passive

* The active or passive nature depends upon circuit condition.



$$I = \frac{10-5}{4} = \frac{5}{4} A$$

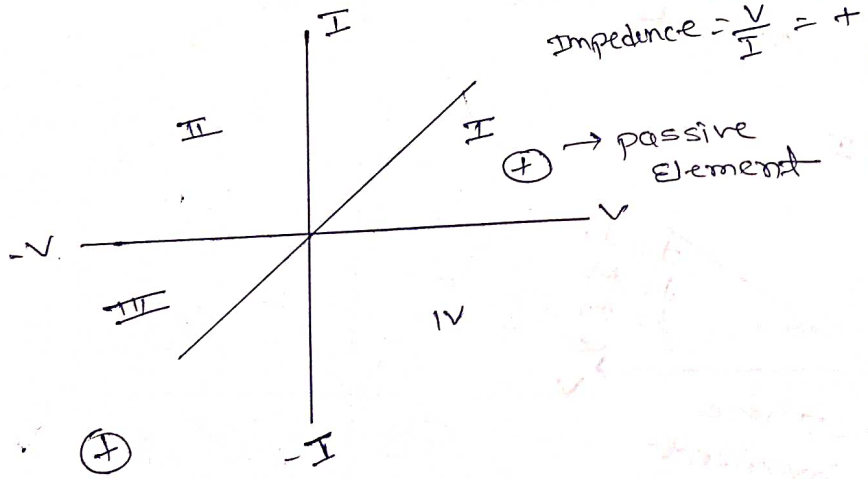
$$P_{10V} = \left(10 \times \frac{5}{4}\right) W (D)$$

$$P_{5V} = \left(5 \times \frac{5}{4}\right) W (A)$$

* on the basis of IV curve

i) Active elements offer always negative impedance

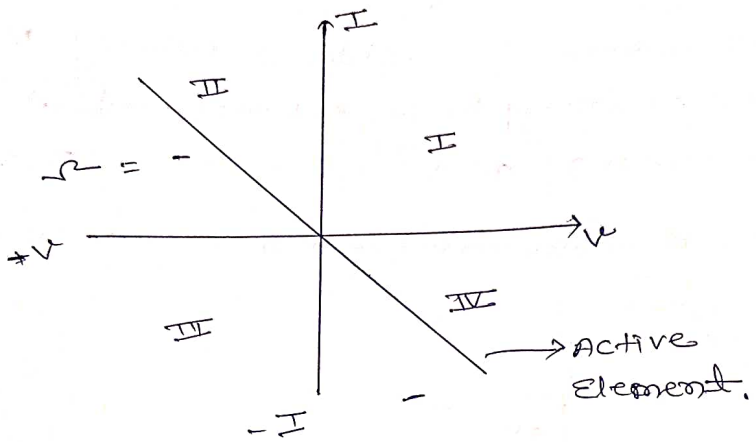
ii) passive elements offers always possitive impedance



Impedance $= \frac{V}{I} = +$

→ passive Element

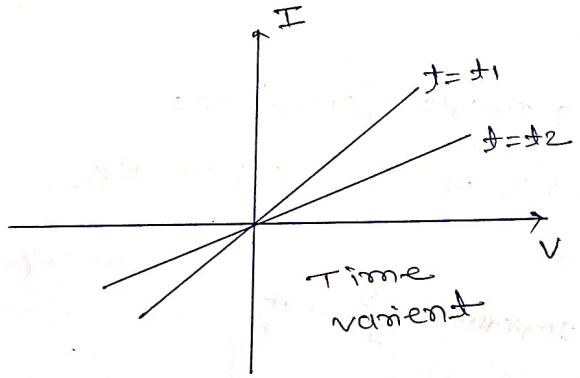
e.g:- ①



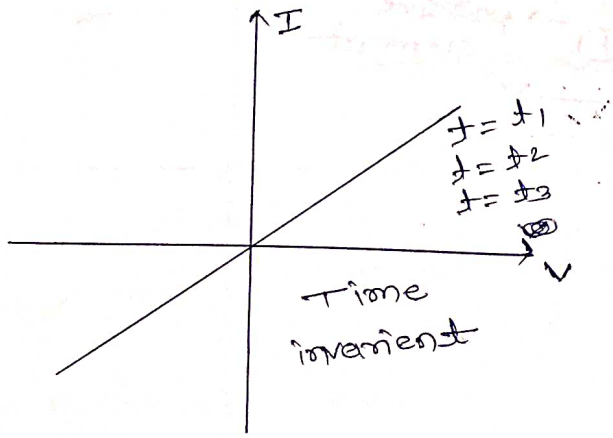
* If there is any negative slope in ~~IV~~ I-V curve then the Element will be active in nature, otherwise it will be passive.

②

iv) Time varient or Time invarient

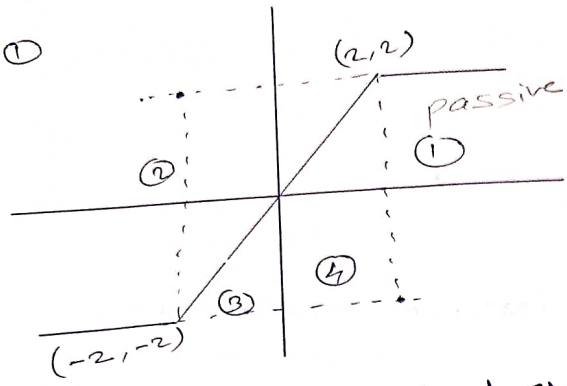


③



e.g:-

①



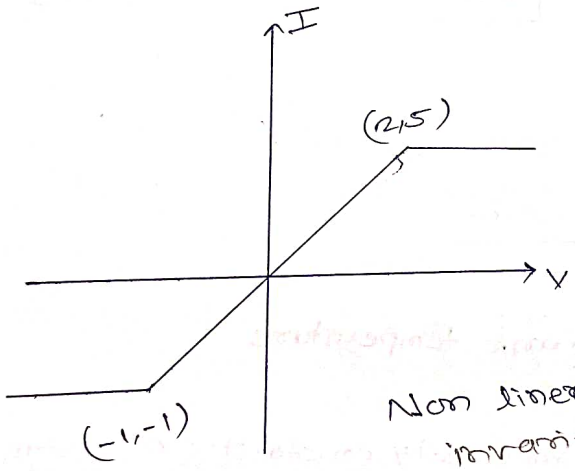
slope $= \frac{2}{2} = 1$

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

Non linear, Bilateral element, ~~Activ~~ passive element

time invariant.

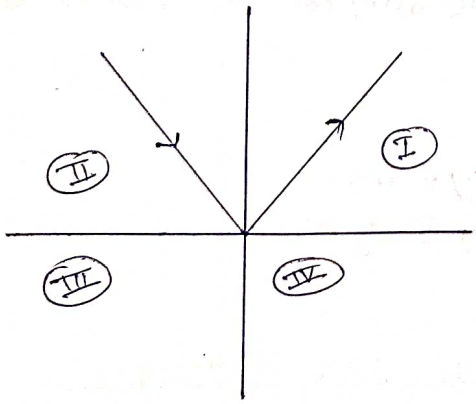
②



Non linear, unilateral, passive element

invariant

③



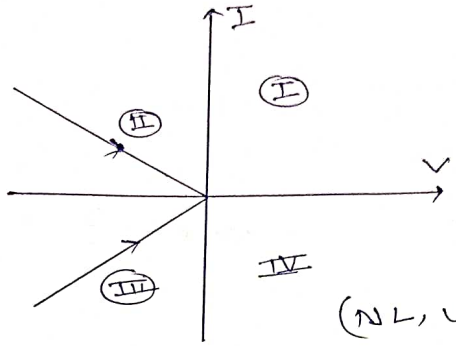
non linear, unilateral,

Active element

invariant.

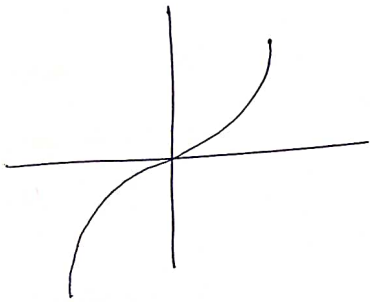
GARIMA NAGPUR

iv)



(NL, Unilateral, Active)

v)



[NL, Bi-lateral, passive]

Lect-07

* Ohm's law, o.c. s.c.

* i) ohm's law : At constant temperature

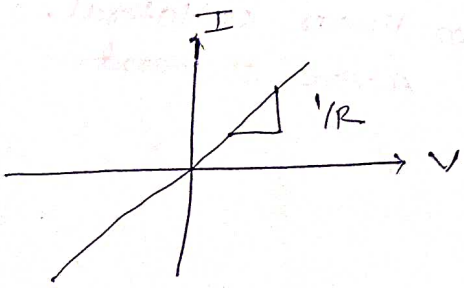
$V \propto I \rightarrow [V = R.I]$ proportionality constant (Resistance)

or

$I \propto V \rightarrow [I = \frac{1}{R}.V]$ proportionality constant (conductance)

$[I = G.V]$

*



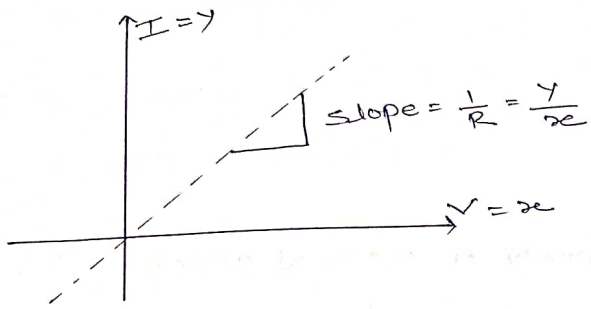
$y = mx$

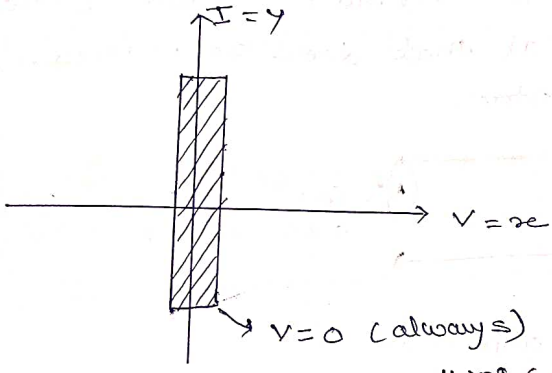
$I = \frac{1}{R}.V$

* Now we have two cases

case I) If slope is increased

$\uparrow$slope $= \frac{y}{x} = \frac{I\uparrow}{V\downarrow}$





I = anything $(+, 0, -)$

slope $= \infty$

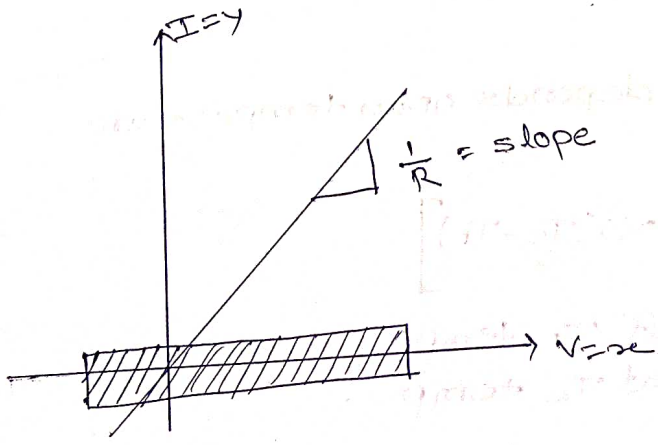
$\frac{1}{R} = \infty$, $(R = 0)$

S. C. $\rightarrow$ condition

In short ckt voltage is always zero

case II) if slope is decreased

$\downarrow$slope $= \frac{y}{x} = \frac{I\downarrow}{V\uparrow}$



$I = 0$ (always)

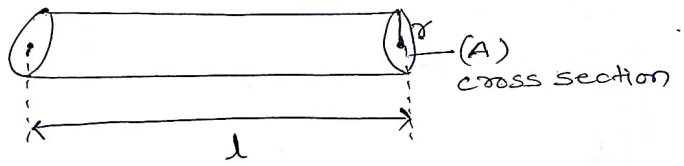
$V =$ anything $(+, 0, -)$

Slope $= 0$

$\frac{1}{R} = 0$, $R = \infty$

O.C. $\rightarrow$ condition

* Resistance $\rightarrow$ It is the property of material which apposes the flow of current & the material that does so is known as resistor.



$R = \rho \frac{l}{A} \rightarrow$ ohm $= \Omega$

$\rho \rightarrow$ Resistivity

$\rho \rightarrow \frac{1}{\text{conductivity}}$

ρ is constant for a perticular material.

$\therefore \boxed{R \downarrow \propto \frac{l \downarrow}{A \uparrow}}$

Resistance also depends upon temperature.

$$R_{T_2} = R_{T_1}\left[1 + \alpha (T_2 - T_1)\right]$$

$R_{T_1} \rightarrow$ Resistance at T_1 temp

$R_{T_2} \rightarrow$ Resistance at T_2 temp

$T_1 \rightarrow$ Temp at which R ~~has~~ is to defined

$T_2 \rightarrow$ Temp at which R ~~to~~ has to find.

$\alpha \rightarrow$ Thermal coefficient

* The rating of resistance defines the maximum power handling capability of it.

$$P_R = I^2 R = \frac{V^2}{R} = V \cdot I$$

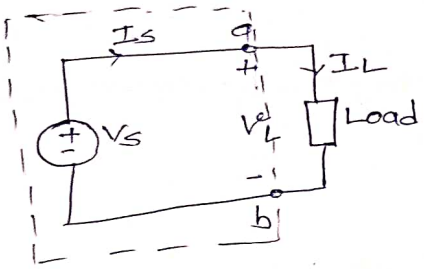
$$W = \int p(t)\, dt = \int v(t)\, i(t)\, dt$$

Electrical Energy sources

- Independent sources
  - voltage source
    - Ideal source
    - practical source
  - current source
    - Ideal source
    - practical source
- Dependent source
  - Voltage source
    - V.C.V.S
    - C.C.V.S
  - C.S.
    - V.C.C.S
    - C.C.C.S

1) Independent voltage source

a) Ideal voltage source



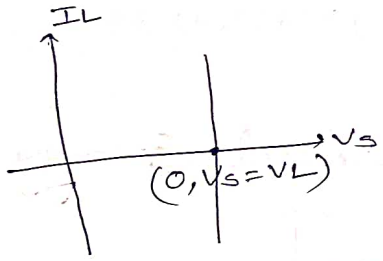
$V_{ab} = V_L = V_s$ (always)

∴ It is Independent of variation of I_L.

$V_L = f(V_s)$

$V_L \neq f(I_L)$

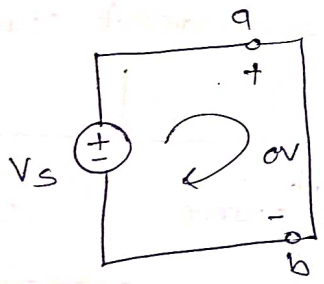
*



$I_L = +, -, 0$

Lect-08

*

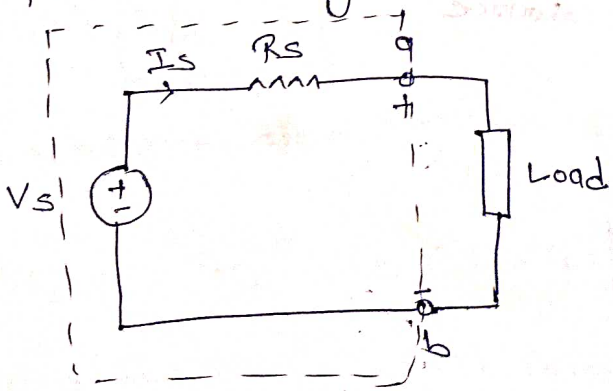


In Ideal voltage source never short

$V_s + 0 \neq 0$.

{It fails KVL}

b) practical voltage source



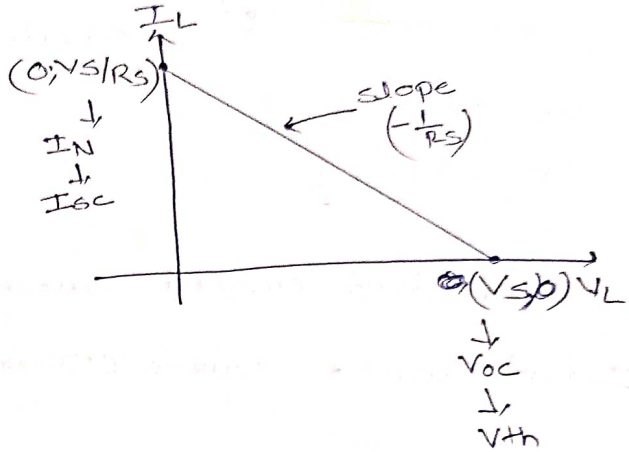
practical voltage source

$V_{ab} = V_L \neq V_s$ (always)

if the value of I_L changes then the value V_L changes due to drop in 'R_s'.

* $V_L = f(I_L)$

* I_L Vs. V_L



$$V_s - I_L R_s - V_L = 0$$

$$I_L R_s = V_s - V_L$$

$$\boxed{I_L = -\left(\frac{1}{R_s}\right) V_L + \frac{V_s}{R_s}}$$

$$y = -mx + c$$

* If $V_L = 0$ at S.C

$$I_L = \left(-\frac{1}{R_s}\right) \times 0 + \frac{V_s}{R_s}$$

$$= \frac{V_s}{R_s}$$

If $I_L = 0$ at O.C.

$$0 = -\left(\frac{1}{R_s}\right) V_L + \frac{V_s}{R_s}$$

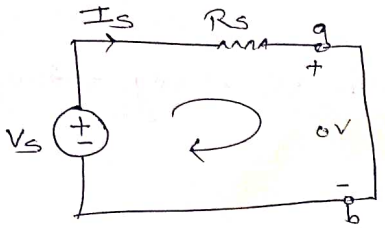
$$= + \frac{V_s \cancel{R_s}}{\cancel{R_s}} = V_L$$

$$\boxed{V_s = V_L}$$

* Ideal V.S $\rightarrow$ $R_s = 0\Omega$

Practical V.S $\rightarrow$ $R_s \neq 0\Omega$

*



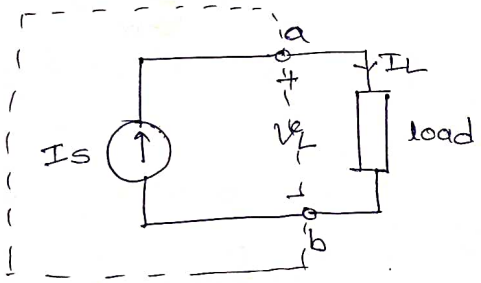
In Ideal condition voltage source never be short but in practical voltage sauce can be shorted.

$V_s - I_s R_s - 0 = 0$

$\boxed{V_s = I_s R_s}$

2) Independent current source

a) Ideal current source (Theortical)

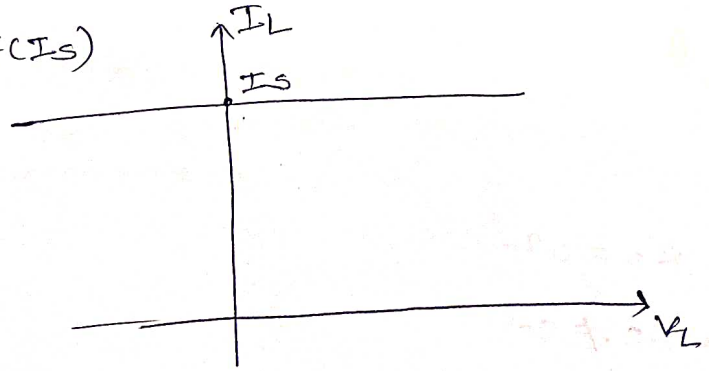


* $I_L = I_s$ (always)

* I_L does not depend upon the change in load voltage V_L,

* $I_L \neq f(V_L)$

$I_L = f(I_s)$



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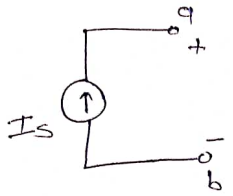


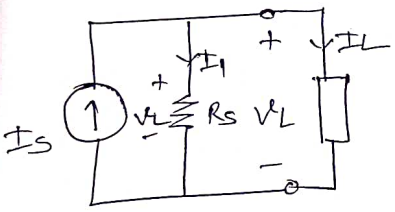
Ideal current source never be open circuited

$I_s \neq 0$

(KCL fails).

b) practical current source

* $I_L \neq I_s$ (may or may not)
* I_L depends upon the change in load voltage. (V_L)
* $I_1 = \frac{V_L}{R_s}$, $I_L = (I_s - I_1)$, $I_L = f(V_L)$.



* $I_L = I_s - I_1 = I_s - \frac{V_L}{R_s} = -\frac{1}{R_s}V_L + I_s$.

$$\boxed{I_L = -\frac{1}{R_s}V_L + I_s}$$

$y = -mx + c$

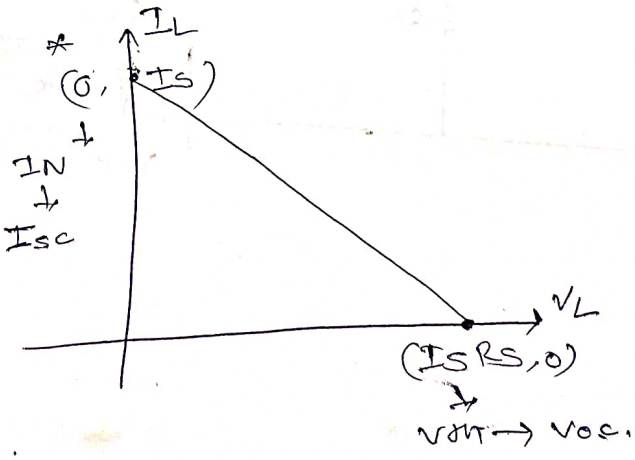
If $I_L = 0$

$$\boxed{V_L = I_s R_s}$$

If $V_L = 0$

$$\boxed{I_L = I_s}$$

*



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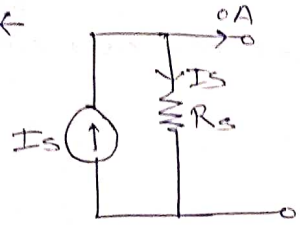


$\boxed{I_s = I_s}$

* Ideal current source

$R_s \longrightarrow \infty$

practical current source

$R_s \neq \infty$

*# Dependend source

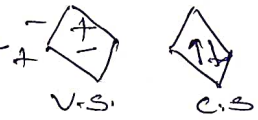
i) voltage controlled voltage source

ii) C. C. V.S

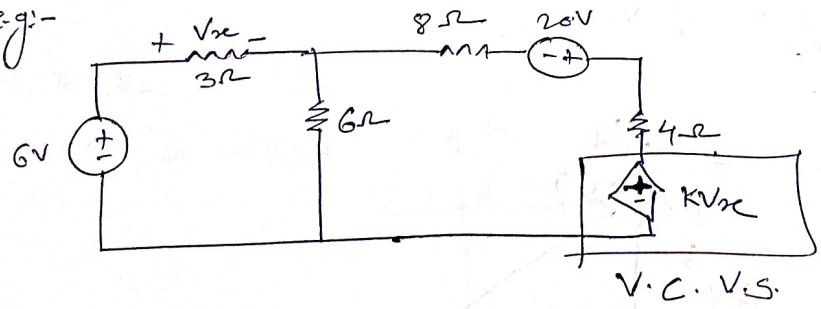
iii) V. C. C.S

iv) C. C. C.S.

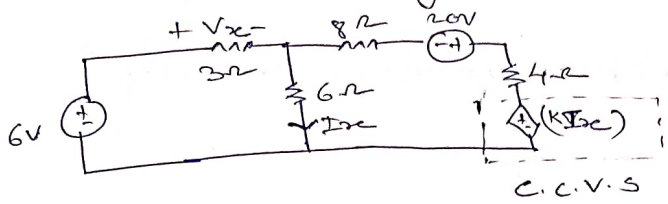
i) voltage controlled voltage source



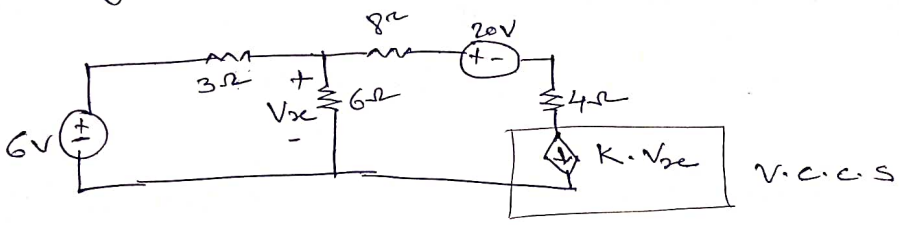
e.g:-



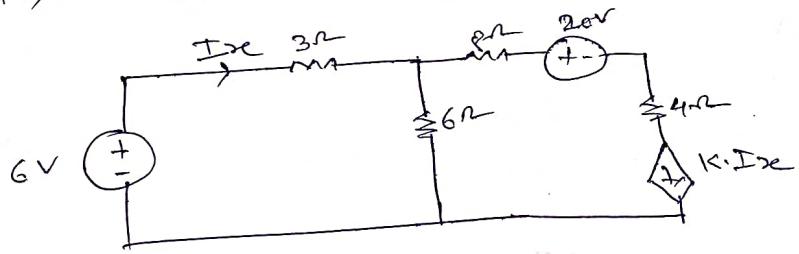
ii) current controlled voltage source



iii) Voltage controlled current source



iv) ~~vo~~, current controlled current source



Lect - 09

KVL & KCL

* This is a interconnection law.
* KVL → Kirchof's voltage Law
* KCL → Kirchoff's current law.

i) KVL → In a closed loop, the total sum of voltage is always zero.

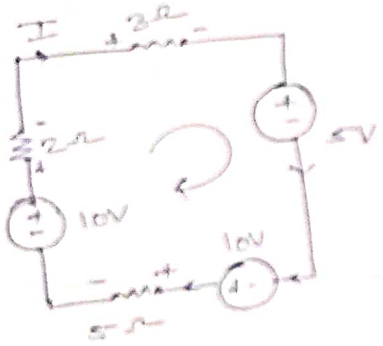
* while applying KVL, we follow certain fixed rules.

If current → − → + → voltage rise → ⊕ value

If current → + → − → voltage drop → ⊖ value

* Total voltage rise = Total voltage drop (In a loop)

* e.g:-

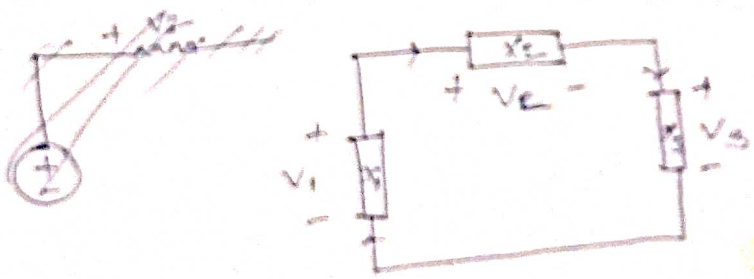


* $10 - 2 \times I - I \times 3 - 5V + 10V - 5I = 0$

$15 = 10I$

$I = 15/10 = 1.5$ Amp.

* KVL satisfies Energy conservation eqn.



$$V_1 - V_2 - V_3 = 0 \Rightarrow \frac{dw_1}{dq} - \frac{dw_2}{dq} - \frac{dw_3}{dq} = 0$$

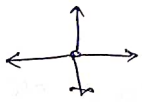
* $\omega_1 - \omega_2 - \omega_3 = 0$

* KVL does not depend upon the nature of element.

KCL → At a node the sum of total current is always zero.

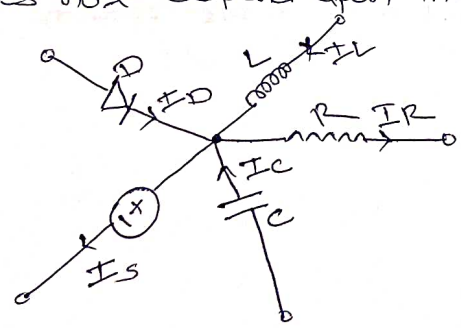
At a node → Total incoming current
= Total outgoing current

while applying KCL we must follow certain Rules.

If the outgoing current →  → ⊕ value.

If the incomming current → → ⊖ value.

* KCL does not depend upon the nature of element.



$-I_L + I_R - I_C + I_S - I_D = 0$

$$\boxed{I_D + I_L + I_C = I_R + I_S}$$

* KCL satiesfy the charge conservation principle.

$$+\frac{dq_R}{dt} - \frac{dq_L}{dt} - \frac{dq_C}{dt} + \frac{dq_S}{dt} - \frac{dq_D}{dt} = 0$$

$$dq_R - dq_q - dq_C + dq_S - dq_D = 0$$

For the validity of N/w or circuit

i) KVL satiesfied
ii) KCL satiesfied
iii) Energy conservation principle/eqn.

If any one of above condition fails, then the network or circuit will not be a valid Network.

* for the flow of current in a Network/ ckt,

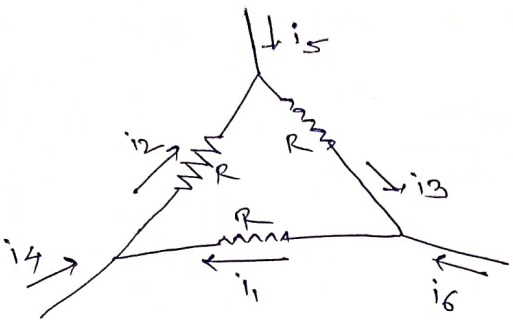
i) There must be a potential difference between two points.
ii) or there must be a atleast one independent source in the n/w or ckt.

ii) There must be a close path and also have return path.

Lec#-10

Problem solving session

Q1-65>



$R = 1\Omega$, $i_1 = 2A$, $i_4 = -1A$, $i_5 = -4A$,

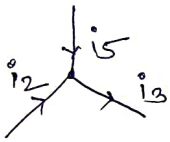
1>

$i_4 + i_1 = i_2$

$i_2 = -1 + 2$

$\boxed{i_2 = 1}$

2>



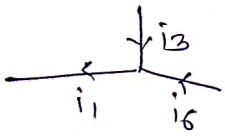
$-i_5 - i_2 + i_3 = 0$

$i_3 = i_5 + i_2$

$i_3 = -4 + 1$

$\boxed{i_3 = -3}$

3>



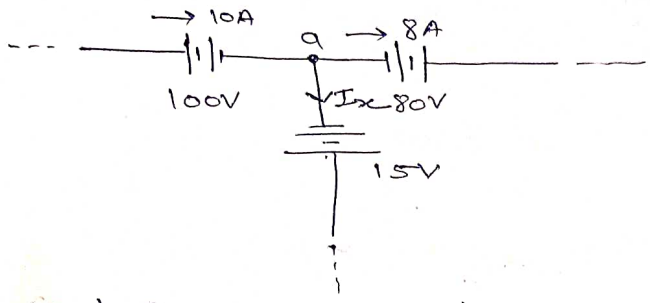
$\cancel{i_3 = -i_1 + i_6}$ $\quad -i_3 + i_1 - i_6 = 0$

$\cancel{+}\, i_3 + i_1 \cancel{=+} i_6 \quad i_3 + i_6 = i_1$ //

$3 + 2 = +i_6$

$\boxed{i_6 = +5A}$

Q.1.67)



Find P_{Total} absorbed.

Sol^n:- KCL at node 'a'

$10 = 8 + I_x$

$10 - 8 = I_x$

$\boxed{I_x = 2\,A}$

① $P_{10} = 10 \times 100$
$= 1000W\ (A)$

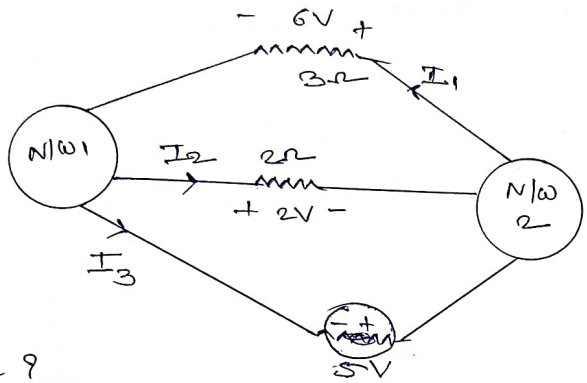
② $P_8 = 8 \times 80$
$= 640\ (D)$

③ $P_2 = 15 \times 2$
$= 30\ (D)$

$P_{Total} = 1000 - 640 - 30$
$= 330W\ (A)$
$= -330W\ (D)$

* for the complete ckt Total absorb & ~~dissipated~~ power will always be equal to zero acc. to KCP but if we talk about part of ckt then Total A or D power may be zero or something else.

Q71) The voltage developed across the 3Ω & 2Ω resistors shown in the figure are 6V & 2V respectively, with the polarity as marked. what is the power (in watt) delivered by the 5V voltage source?



$P_{5V}(D) = ?$

Sol^n:-

$I_1 = \frac{6}{3} = 2A$

$I_2 = \frac{2}{2} = 1A$

$I_3 + I_2 = I_1$

$I_3 = -I_2 + I_1$

$I_1 + I_2 + I_3 = 0$

$I_3 = -I_2 + I_1$

$= -1 + 2$

$\boxed{I_3 = 1}$

$P_{5V}(D) = 5 \times I_3 = 5 \times 1$

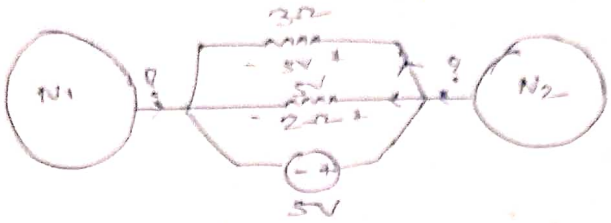
$= 5W(D)$

$= -5W(A)$

$P_{2\Omega} = 2W(A)$

$P_{3\Omega} = 12W(A)$

e.g:- Lect - 011



$P_{D5V} =$

~~Bgner~~

$I_{3\Omega} = \frac{5}{3} = 1.667$

$I_{2\Omega} = \frac{5}{2} = 2.5$

$1.667 + 2.5 = I_{5V}$

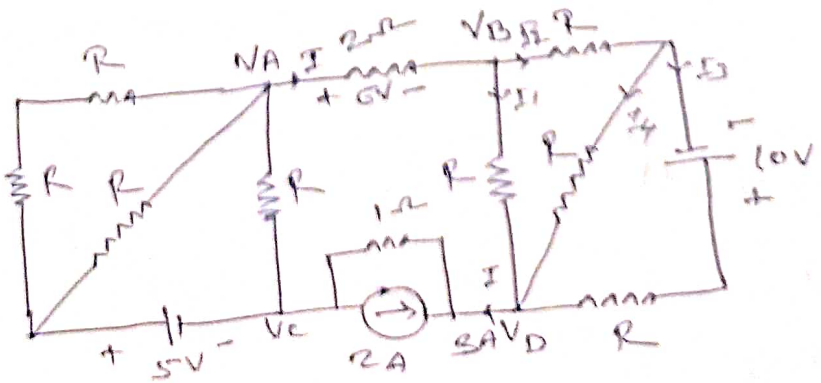
$I_{5V} = 4.167$

$P_{5V(D)} = 5 \times 4.167$ ✗ wrong

$= 20.835$

$\boxed{I_1 + I_2 = I_3}$ ✗ wrong

Q63)



If $V_A - V_B = 6V$

find value of $V_C - V_D$

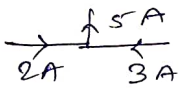
Note:- The potential of a node is generally defined ~~from~~ w.r.to ground potential as the ground potential is taken as '0'V.

Sol^n:- $V_C - V_D = V_{CD}$

$V_C = +$

$V_D = -$

* $I = \frac{6}{2} = 3A.$

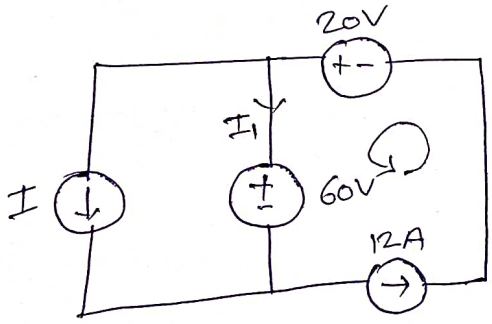
⇒ 

⇒ $2 + 3 = 5A$

$-5 \times 1 = 5V$

$\boxed{V_C - V_D = -5V}$

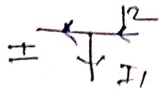
Q58)



* P_{60V} is absorbing power

P_{60V} absorbing $= 60 \times I_1$

* Applying KCL at node 'a'



$I + I_1 = 12A$

$\boxed{I = 12 - I_1}$

$I < 12A$

$\Rightarrow 10A$

$10 = 12 - I_1$

$I_1 = 12 - 10$

$\boxed{I_1 = 2A}$

verify

$P_I = 60 \times 10$

$= 600$ watt (A)

$P_{60V} = 60 \times 2$

$= 120W$ (A)

$P_{20V} = 20 \times 12$

$= 240W$ (D)

$= -240W$ (A)

$P_{12A} = 12 \times V$

Apply the KVL at loop

$-V + 20 - 60 = 0$

$V = -40V$

$P_{12A} = 12 \times 40$

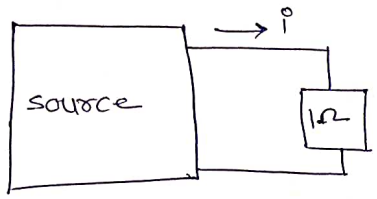
$= -480W$ (A)

$P_{Total} = 600 + 120 - 240 + -480$

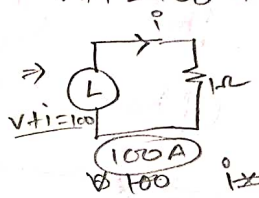
$= 0.$

Lect - 12

Q61) As shown in the below figure, a 1Ω resistance is connected across a source that has a load line $v + i = 100$. The current through the resistance is

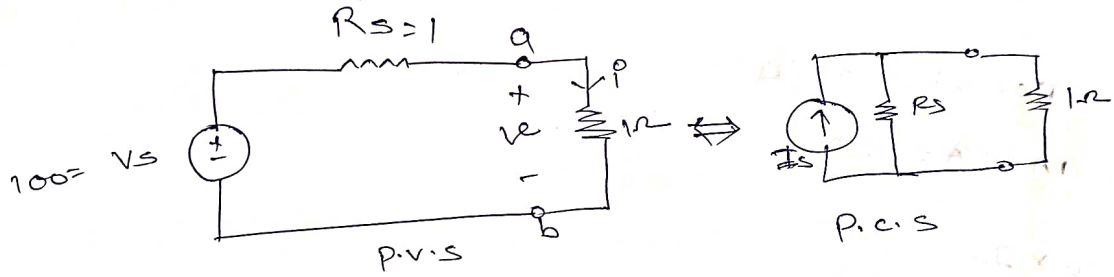


$v + i = 100$



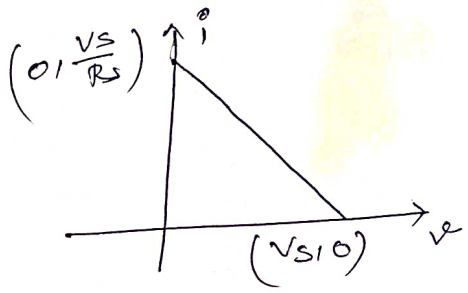
$V = 100 - i$

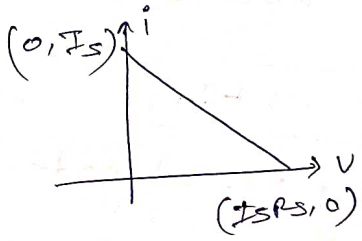
Sol^n:-



$v + i = 100$

$i = ?$





$i = 100 - V$

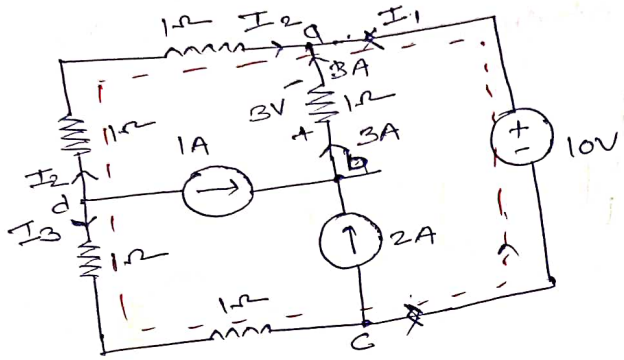
$i = (-1).V + 100$

$i = 100$ or $V = 100$

$i = \frac{100}{2}$

$\frac{V_S}{R_S} = 100$, $R_S = 1$

Q60) In the circuit shown, the power supplied by the voltage source is



Sol^n:- KCL at node 'b'

$1A + 2A = 3A$

$P_{10V} = 10 \times I_1$

* Applying KCL at node 'a'

$\boxed{I_2 = -3 + I_1}$

$-3 + I_2 + I_1 = 0$

$-3 - I_1 = I_2$

* Applying KCL at node 'd'

$-3 + I_1 = I_3 + 1$

$\boxed{I_3 = -2 + I_1}$

$I_2 + 1 + I_3 = 0$

$-3 - I_1 + 1 + I_3 = 0$

$-2 - I_1 = -I_3$

$2 + I_1 = I_3$

Apply KVL at whole loop

Solve again

$10 - (-3 - I_1) \cdot 1 + 1 \cdot (-3 - I_1) + 1 \times (2 + I_1) + 1 \times (2 + I_1) = 0$

$10 - [+3 - I_1 + 3 - I_1 + 2 + I_1 + 2 + I_1] = 0$

$10 - [+10 - 4I_1] = 0$

$\Rightarrow -10 + 10 + 4I_1 = 0$

$0 = -4I_1$

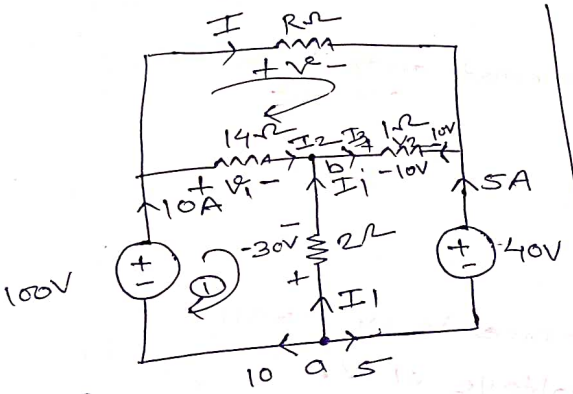
$\frac{0}{-4} = I_1$

$\boxed{-0 = I_1}$ $\boxed{I_1 = 0}$

$I = 0$

& ($P_{10V} = 0W$).

Q52) In figure, the value of R is



Sol^n:-

* $V = IR$

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

Apply KCL at node 'a'

$10 + 5 = -I_1$

$-15 = I_1$

$\therefore 2 \times I_1 = -30V$

Apply KVL at loop ①

$100 - V_1 - 30 = 0$

$\boxed{V_1 = 70V}$

$I_2 = \frac{V_1}{14} \Rightarrow \frac{70}{14} = 5A$

Apply KCL at node 'b'

$I_2 + I_1 = I_3$

$5 - 15 = I_3$

$-10 = I_3$

$\therefore \boxed{-10 \times 1 = -10V = V_2}$

$-V + 10 - 70 \Rightarrow -(-10)$ *

$\boxed{V = 60V}$

$I = 10 + I_2 \Rightarrow 10 + 5$

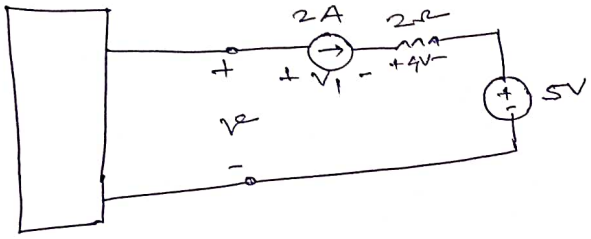
$I = 15A$

$R = \frac{V}{I} = \frac{60}{5} = 12\Omega$

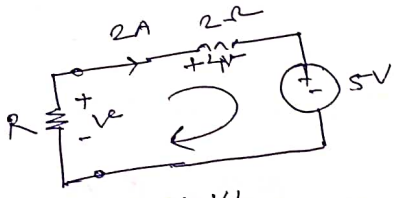
$\boxed{R = 12\Omega}$

Lect-13

Q44) The voltage V in figure is always equal to



Sol^n:-



Apply KVL

$V - 4 - 5 = 0$ × wrong method apply Total concept

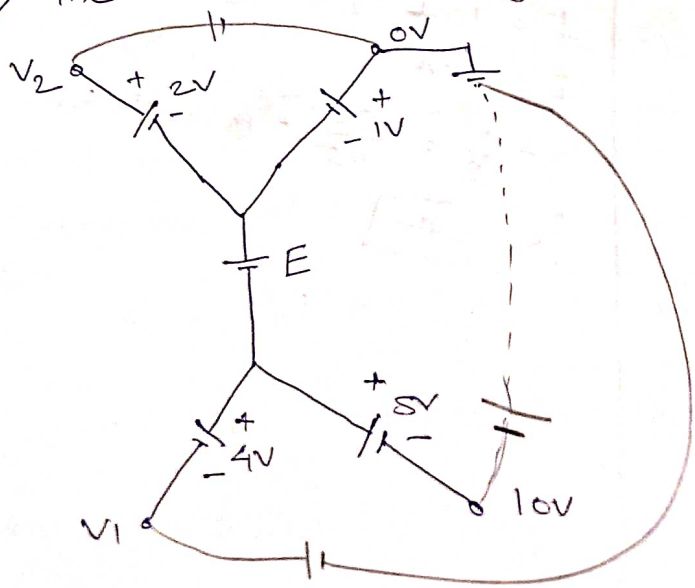
$\boxed{V = 10V}$

$V - V_1 - 4 - 5 = 0$

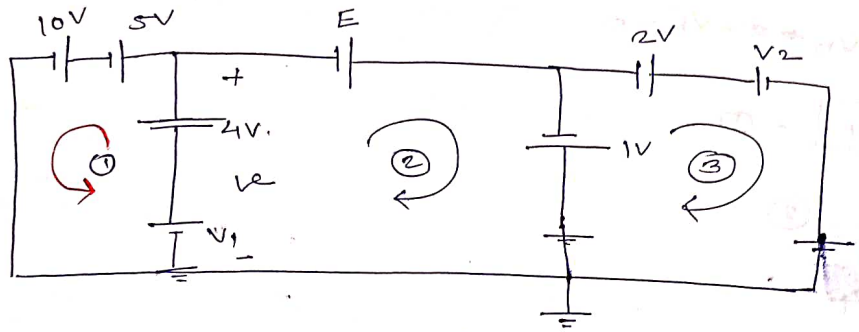
$\boxed{V = V_1 + 9}$

As the voltage across current source is unknown hence we can not calculate the voltage of V.

Q49) The value of the voltage source E is



* The voltage at a node is always with respect to ground potential / zero potential.



KVL in loop ①

$V - 5 - 10 = 0$

$\boxed{V = 15V}$

* KVL in loop ②

$E + 1 + 15 = 0$

$\boxed{E = -16V}$

KVL in loop ③

$-1 + 2 - V_2 = 0$

$\boxed{V_2 = -1}$

$V_1 = ?$

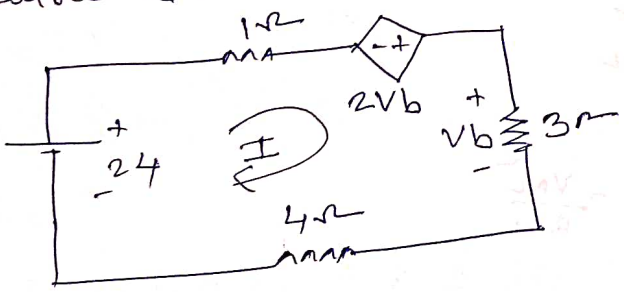
$E + 1 + V_1 + 4 = 0$

$-16 + 1 + V_1 + 4 = 0$

$-11 + V_1 = 0$

$\boxed{V_1 = 11V}$

Q33) The current in the ckt with a dependent voltage source is.



Sol^n:- Applying KVL in the loop shown

$24 - I \times 1 + 2V_b - V_b = 0$

$\boxed{I = V_b + 24}$ — ①

* $\boxed{V_b = 3 \times I}$ — ②

$I = 3 \times I + 24$

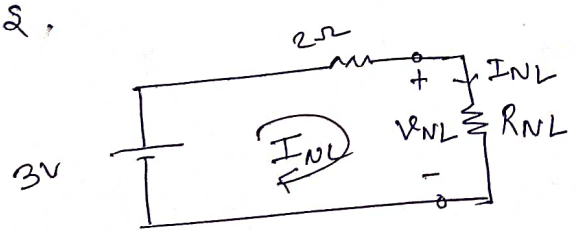
$-2I = 24$

$\boxed{I = -12\,A}$

$P_{d_{2V_b}} = 2V_b \times I = 2 \times 3I^2$
$= 6(-12)^2\ W$ (D)

practice Questions

① 78) A 3v dc supply with an internal resistance of 2Ω supplies a passive non-linear resistance characterized by the relation $V_{NL} = I_{NL}^2$. The power dissipated in the non linear resistance is.



* $P_{R_{NL}} = V_{NL} \cdot I_{NL} = I_{NL}^2 R_{NL} = \frac{V_{NL}^2}{R_{NL}}$
$= I_{NL}^2 \times I_{NL}$

$P_{R_{NL}} = (I_{NL})^3$

Apply KVL

$3 - 2 \times I_{NL} - V_{NL} = 0$

$\boxed{V_{NL} = 3 - 2 I_{NL}}$ — ②

* with the help of eqn ① & ②

$\boxed{V_{NL} = I_{NL}^2}$ — ①

$I_{NL}^2 = 3 - 2 I_{NL}$

$I_{NL}^2 + 2 I_{NL} = 3 \Rightarrow I_{NL}^2 + 2 I_{NL} - 3 = 0$

$I_{NL} = \dfrac{-2 \pm \sqrt{4 + 4 \times 3}}{2 \times 1}$

$I_{NL} = \dfrac{-2 \pm \sqrt{16}}{2}$

$= \dfrac{-2 \pm 4}{2}$

$I_{NL1} = 1\,A$

$(I_{NL2} = -3A)$ ✗ because Resistance R_{NL} is a passive element means it always absorb the energy.

$V_{NL} = (1)^3 = 1V$

$P_{RNL} = (I_{NL})^3 = 1W.$

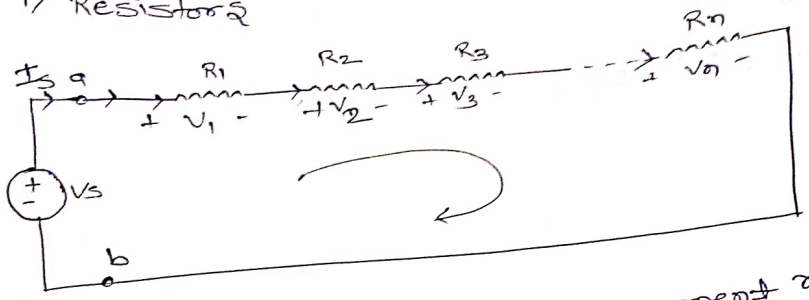
solve

⊕ ⇒ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 22, 21, 26, 31, 35, 39, 43, 46, 48, 64, 73, 81,

LEC# - 14

Series Interconnection

i) Resistors



* In series Interconnection the current remains same in all elements but voltages across elements may or may not remain same.

* $V_s = [V_1 + V_2 + V_3 + --- + V_n]$

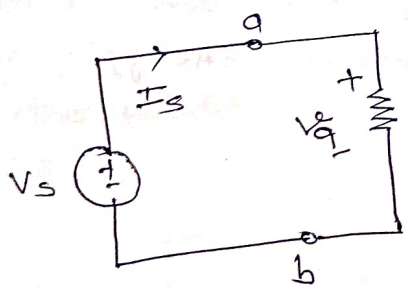
$= \cancel{\frac{I_s}{R_1}} + \cancel{\frac{I_s}{R_2}} + \cancel{\frac{I_s}{R_3}} + \cancel{---} + \cancel{\frac{I_s}{R_n}}$

$= I_s R_1 + I_s R_2 + I_s R_3 + --- + I_s R_n$

$V_s = I_s (R_1 + R_2 + R_3 + --- + R_n)$

$\frac{V_s}{I_s} = (R_1 + R_2 + R_3 + --- + R_n)$

*



$R_{eq} = \frac{V_s}{I_s}$

* $V_1 = I_s \times R_1 = \left(\frac{V_s}{R_1 + R_2 + R_3 + --- + R_n}\right) R_1$

* The voltage across any Resistor (R_x)

$$\boxed{V_x = \frac{V_s}{\sum_{i=1}^{n} R_i} \times R_x}$$

→ voltage Division Rule (VDR)

* If all Resistances are same

$$R_1 = R_2 = R_3 = \cdots = R_n = R$$

$$R_{eq} = R + R + R + R + R + \cdots + R$$

$$\boxed{R_{eq} = n \cdot R}$$

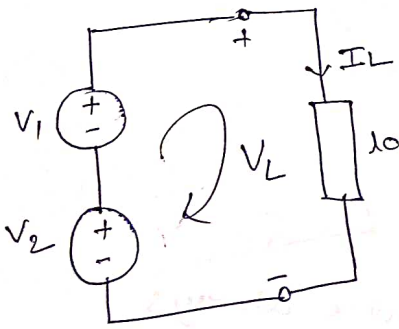
$$V_1 = V_2 = V_3 = V_n = \frac{V_s}{nR} \times R$$

$$\boxed{V_x = \frac{V_s}{n}}$$

* The Equivalent Resistance across any terminal is the ratio voltage across that terminal divide by the current passing through that terminal.

2) series connection of voltage sources. (use KVL only)

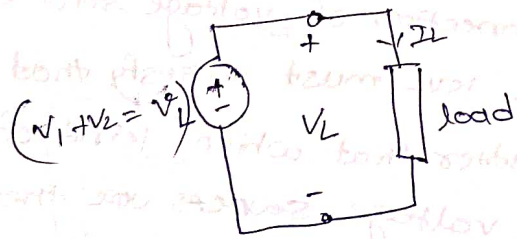
Case-I:- Two voltage sources of same polarity



$\Rightarrow V_1 + V_2 - V_L = 0$

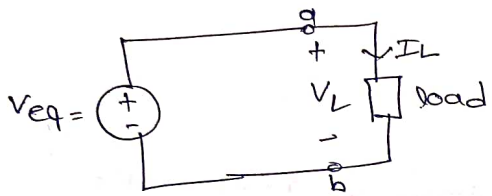
$$\boxed{V_L = V_1 + V_2}$$

→ (KVL satisfied)

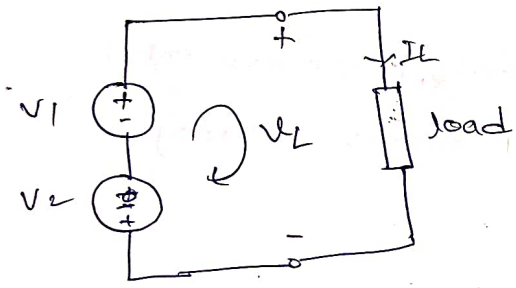


Note:- If n number of voltage sources of same polarity are connected in series then its equivalent V.S. will be

$$V_{eq} = V_1 + V_2 + V_3 + \cdots + V_n = V_L$$

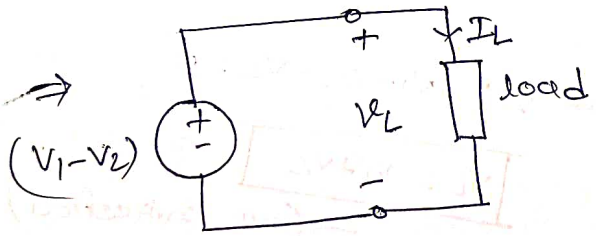


Case-II :- two voltage sources of different polarity.



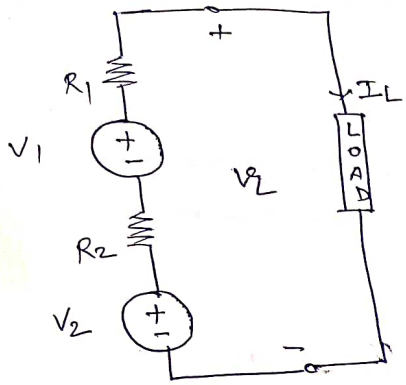
$$-V_2 + V_1 - V_L = 0$$

$$\Rightarrow V_L = V_1 - V_2$$

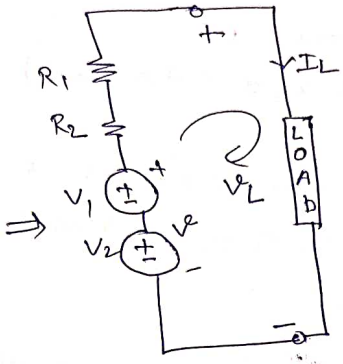


Note:- In ~~the~~ series connection of voltage source always apply KVL & KVL must satisfy that means it doesnt matter that which kind of polarity of individual voltage sources are there in the circuit.

Lect-15

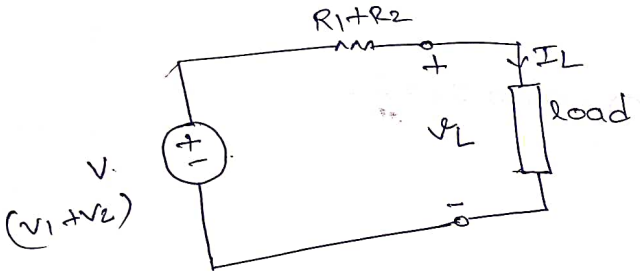


⇒

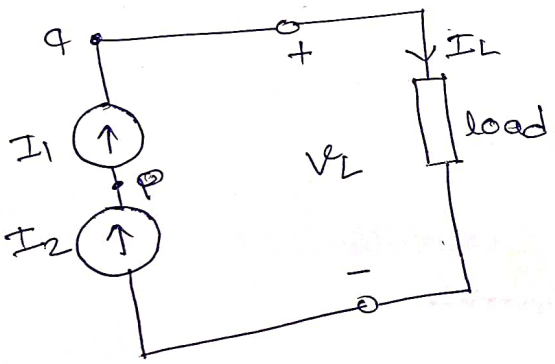


$\Rightarrow V_2 + V_1 - v = 0$

$v = V_1 + V_2$



iii) series connection of current sources (Apply KCL always)



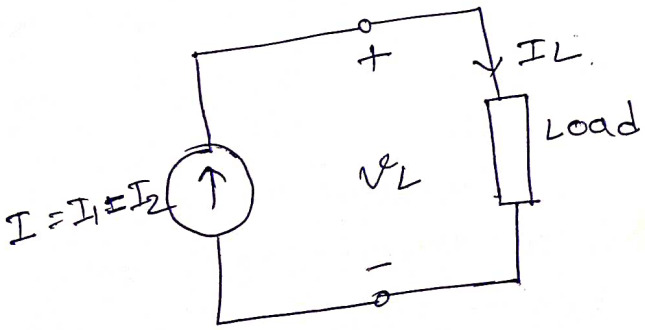
a) when $I_1 = I_2$

Apply KCL at node 'p'

$\boxed{I_1 = I_2}$ --- KCL satisfied

apply KCL at 'q' node

$I_1 = I_L$ --- KCL satisfied



b) $I_1 \neq I_2$

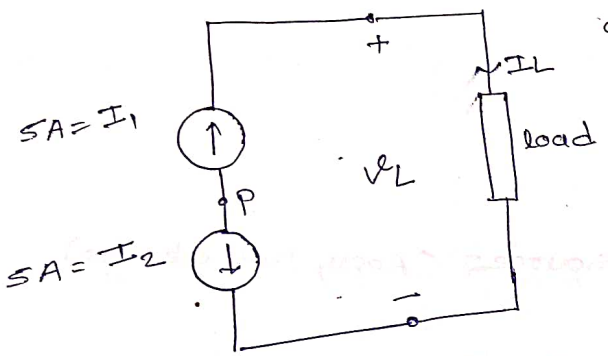
Apply KCL at node 'p'

$I_1 \neq I_2$ (KCL not satisfied)

Note:- Two current sources with different magnitude and same direction can not be connected in series.

Case-II :- Two current sources of diff. direction

a) when $I_1 = I_2$



Apply KCL at node 'p'

$I_2 + I_1 \neq 0$ } KCL is not satisfied

$5 + 5 \neq 0$

then the network is not a valid network.

b) $I_1 \neq I_2$ (~~mg~~ magnitude are different)

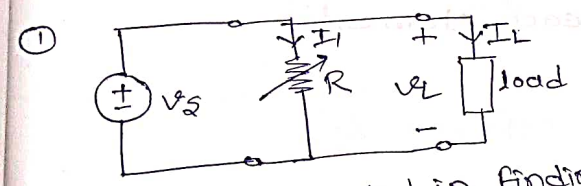
Apply KCL at node 'P'

$$\left.\begin{array}{l} I_1 + I_2 \neq 0 \\ 6 + 10 \neq 0 \end{array}\right\} \text{KCL is not satisfied}$$

Note:- Two or more than two current sources of same magnitude and same direction can only be connected in series because KCL will be satisfied and the network will be a valide Network.

Remember:-

case-I



we are interested in finding V_L, I_L, P_L (load parameters only)

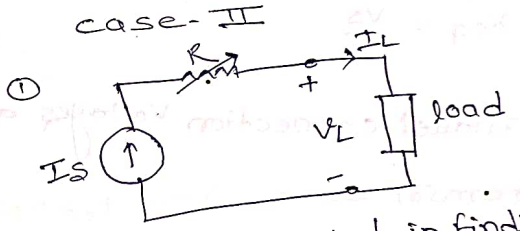
Then we can neglect the resistance are connected in parallel with the source voltage (V_s)

neglecting (R) means →

$\boxed{R \to \infty}$ → O.C.

* But if we are interested in finding the source parameters like (V_s, I_s, P_s) then you can not neglect R

case-II



if we are interested in finding the load parameters (V_L, I_L, P_L) then we can neglect the value of 'R', which in series with the current source.

* $R \to 0$ → S.C.

* But if we are interested in finding the source parameters then we can not neglect the value of 'R'.

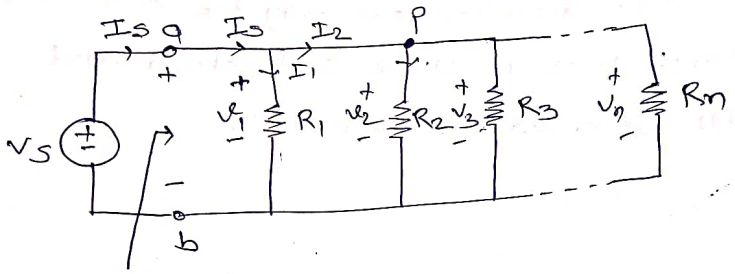
(Imp)

⇒ For the validity of the N/W KVL, KCL, energy conservation principle must be satisfied.

Lect-16

Parallel Interconnection.

i) Resistors.



$$R_{eq} = \frac{V_s}{I_s}$$

* In parallel connection voltages across each element will remain same

$$V_1 = V_2 = V_3 = \cdots = V_n = V_s.$$

* In parallel connection current in each element may not be same.

* Applying KCL at node 'p'.

Incoming current = outgoing

$$I_s = I_1 + I_2 + I_3 + \cdots + I_n$$

$$= \frac{V_s}{R_1} + \frac{V_s}{R_2} + \frac{V_s}{R_3} + \cdots + \frac{V_s}{R_n}$$

$$I_s = V_s\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}\right)$$

$$\frac{V_s}{I_s} = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}\right)} = R_{eq}$$

$$\boxed{\frac{1}{R_{eq}} = \frac{I_s}{V_s} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}}$$

* Conductance (G) $= \frac{1}{R}$ ℧ (mho)

$$\boxed{G_{eq} = G_1 + G_2 + G_3 + \cdots + G_n}$$

* If I want to find any individual current

* $I_1 = \frac{V_1}{R_1}$, $I_2 = \frac{V_2}{R_1}$, $I_n = \frac{V_n}{R_n}$ ie $V_n = V_s = V_1 = V_2 \cdots$

$= \frac{V_s}{R_1}$, $\frac{V_s}{R_2}$, $\frac{V_s}{R_n}$

$$\therefore \boxed{\frac{1}{R_{eq}} = \frac{I_s}{V_s}} \Rightarrow G_{eq} = G_1 + G_2 + G_3 + \cdots + G_n$$

$I_1 = \frac{I_s \cdot R_{eq}}{R_1}$, $I_2 = \frac{I_s R_{eq}}{R_2}$, $I_n = \frac{I_s R_{eq}}{R_n}$

$$\boxed{I_1 R_1 = I_s R_{eq}}$$

Generalize form

~~To form~~ to find the current in any Resistor connected in parallel,

$I_1 = \frac{V_1}{R_1} = V_1 \times G_1 = V_s \cdot G_1$

$I_1 = \frac{I_s}{G_{eq}} \times G_1 \Rightarrow \frac{I_1}{G_1} = \frac{I_s}{G_{eq}}$

$$\therefore I_1 = \left(\frac{I_s}{G_1 + G_2 + G_3 + G_n}\right) \times G_1$$

$$I_x = \left(\frac{I_s}{\sum_{i=1}^{n} G_i} \right) \times G_x \rightarrow \text{current Division Rule.}$$ (Imp)

* If all resistances are equal

$$R_1 = R_2 = R_3 = R_n = R.$$

$$I_1 = I_2 = I_3 = I_n = \frac{I_s}{G+G+G+\cdots+G} \times G$$

$$= \frac{I_s \times G}{nG}$$

$$\boxed{I_1 = \frac{I_s}{n}}$$

all resistance not equal, then.

$$= \frac{1}{R_1} + \frac{1}{R} + \frac{1}{R} + \cdots + \frac{1}{R} = \frac{1}{R_{eq}}$$

$$= \frac{n}{R}.$$

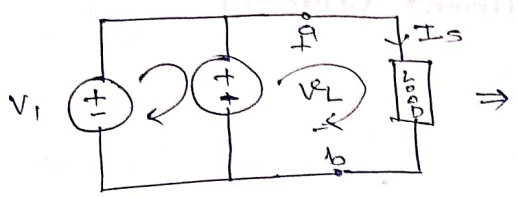
$$\therefore R_{eq} = \frac{R}{n}$$

Parallel Interconnection

i) parallel Interconnection of voltage sources

case I → {Two V.S. with same polarity}

* use always KVL



⇒

i) $V_1 = V_2 = 10V$.

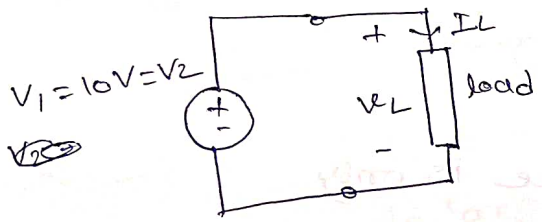
$V_1 - V_2 = 0$

$+10 - 10 = 0$ (KVL satiesfied)

$10 - V_L = 0$

$\boxed{V_L = 10V}$

equivalent ckt



ii) If $V_1 \neq V_2$ (In parallel condition)

$V_1 = 10V$, $V_2 = 20V$

apply KVL

$+10 - 20 = -10 \neq 0$ (KVL not satiesfied / fails)

$20 - V_L = 0$

$\boxed{V_L = 20V}$

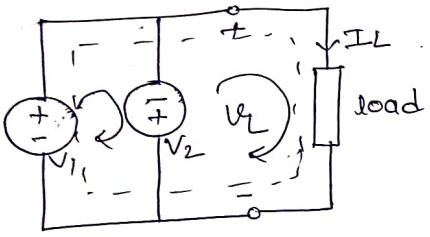
KVL in whole loop

$10 - V_L = 0$

$\boxed{10 = V_L}$ → KVL fails {

Network invalid.

Case-II {Two voltage source with different polarity}



i) $V_1 + V_2 = 0$

If $V_1 = V_2 = 10V$

$10 + 10 \neq 0$ (KVL fails)

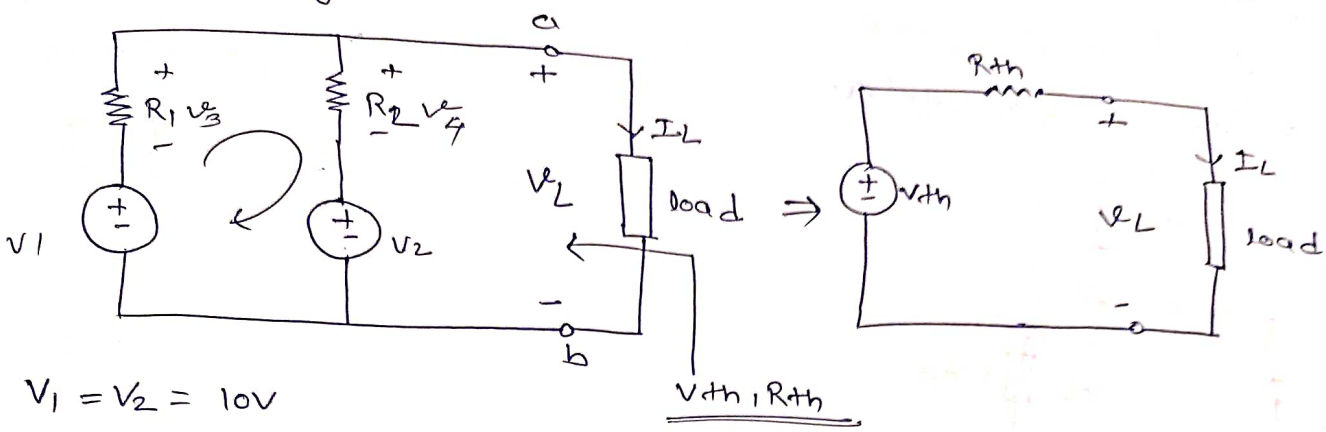
If $V_1 = 5$, $V_2 = 10V$

$5 + 10 \neq 0$ (KVL fails)

Lect - 17

* The parallel operation of voltage source is only possible if and if all the voltage source have same polarity & same magnitude.

practical voltage source

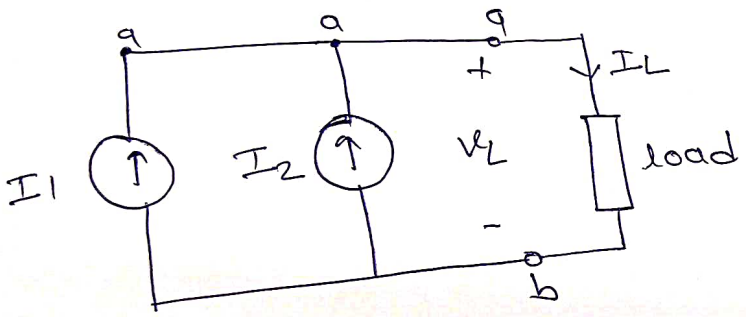


$V_1 = V_2 = 10V$

~~VL = 10V~~,

b) parallel interconnection of current sources.

Use KCL

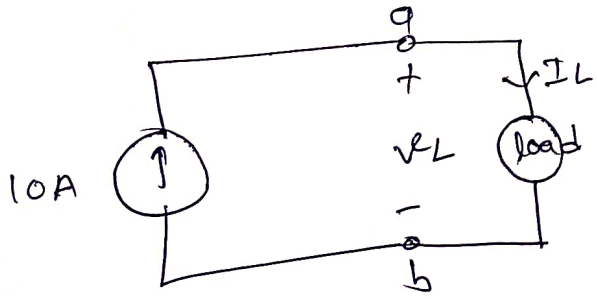


Case I :- If $I_1 = I_2 = 5A$

KCL apply at node 'a'.

$I_1 + I_2 = I_L$

$5 + 5 = 10A$

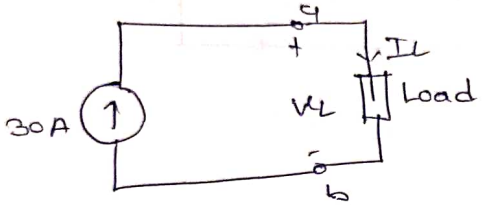


Case - II

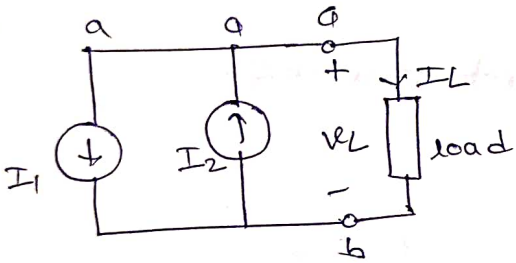
$I_1 = 10A$, $I_2 = 20A$

apply KCL at node 'a'

$$\boxed{30 = I_L}$$



ii)



Case - I If $I_1 = I_2 = 10A$

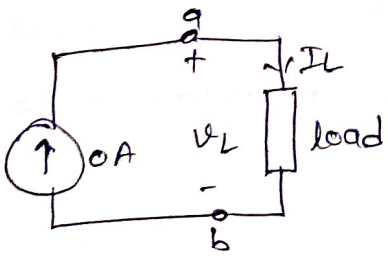
apply KCL at node 'a'

$I_1 + I_L = I_2$

$I_L = I_2 - I_1$

$I_L = 10 - 10$

$I_L = 0A$



case2:- $I_1 = 5A$
$I_2 = 10A$

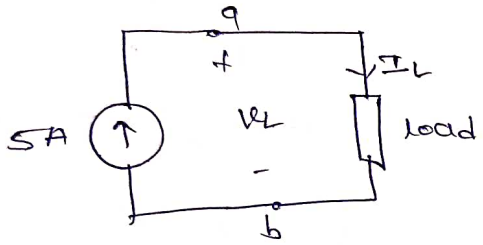
Applying KCL at node 'a'

$I_1 + I_L = I_2$

$I_2 = I_2 - I_1$

$= 10 - 5$

$\boxed{I_2 = 5A}$



case3-

$I_1 = 10A$, $I_2 = 5A$

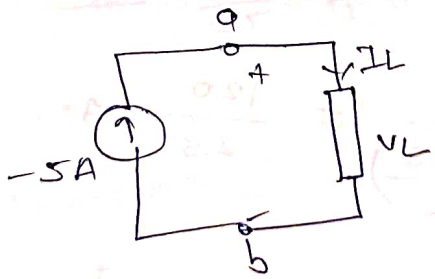
Applying KCL at node 'a'

$I_1 + I_L = I_2$

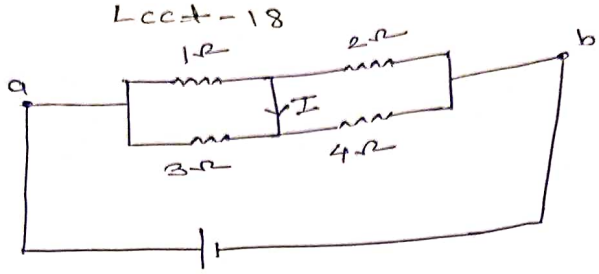
$I_L = I_2 - I_1$

$I_L = 5 - 10$

$\boxed{I_L = -5}$

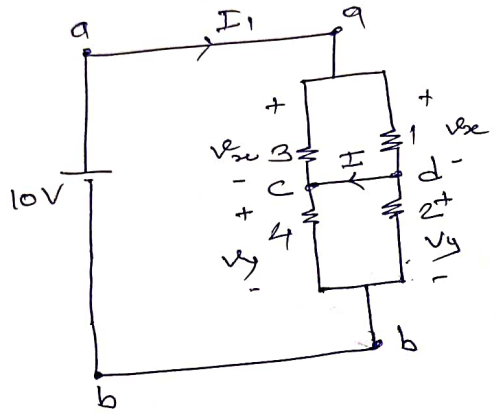


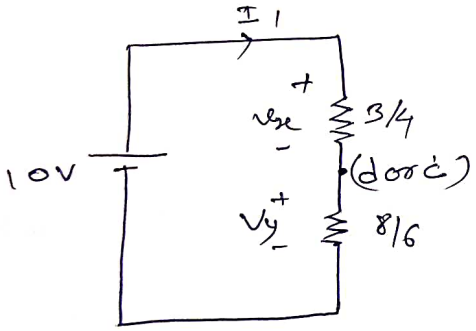
Q21) Lect-18



$I = ?$

Sol^n:-





$3 \| 1 = \frac{1 \times 3}{3+1} = \frac{3}{4}\Omega$

$4 \| 2 = \frac{4 \times 2}{4+2} = \frac{8}{6}\Omega$

$$\cdot\ I_1 = \frac{10}{3/4 + 8/6} = \frac{10}{\left(\frac{9+16}{12}\right)} = \frac{120}{25}\ A$$

$$V_x = \frac{120}{25} \times \frac{3}{4}$$

$$= \frac{30 \times 3}{25} = \left(\frac{90}{25}\right) V$$

$$\cdot\ V_y = \frac{20 \times 8}{25} = \left(\frac{160}{25}\right) V$$

→ By VDR

$$v_x = \frac{10 \times 3/4}{\frac{25}{12}}$$

$$= \left(10 \times 3/4\right) \times \frac{12}{25}$$

$$= \frac{10 \times 9}{25} = \frac{90}{25} \text{ V.}$$

$$v_y = \frac{160}{25} \text{ ''}$$

$$I_1 = \frac{120}{25} \text{ A}$$

$$V_x = \frac{90}{25} \text{ V}, \quad V_y = \frac{160}{25} \text{ V}$$

~~Ix1 = 30~~

finding the value of I_{x1} & I_{x2}

$$I_{x1} = \left(\frac{V_x}{3}\right) = \left(\frac{90}{25} \times \frac{1}{3}\right) = \frac{30}{25} \text{ A.}$$

$$I_{x2} = \frac{V_x}{1} = \frac{90}{25} \times \frac{1}{1} = \frac{90}{25} \text{ A.}$$

or $I_1 = I_{x1} + I_{x2}$.

finding the value of I_{y1} & I_{y2}

$$I_{y1} = \frac{160 \times 1}{25 \quad 4} = \frac{40}{25} \text{ A}$$

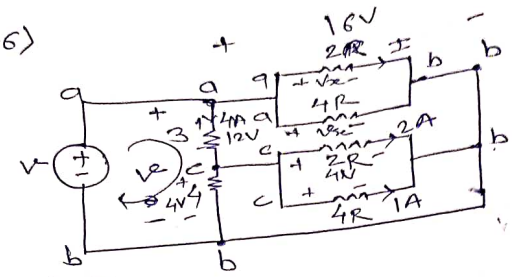
$$I_{y2} = \frac{V_y}{2} = \frac{160}{25} \times \frac{1}{2} = \frac{80}{25} \text{ A}$$

* Apply KCL at node 'c'

$$I_{x1} + I = I_{y1} \Rightarrow I = I_{y1} - I_{x1}$$

$$I = \frac{40}{25} - \frac{30}{25} = \frac{10}{25} \text{ A} = 2/5 \text{ A.}$$

Q26)



$\therefore R = 1$

soln

$$I = \frac{V}{R} = \frac{V_x}{2} = \frac{V}{2}$$

$V_x = V$

$\Rightarrow 4 \times 1 = 4\,\Omega$

$4 \times 1A = 4V$

Lect-19

$\Rightarrow \frac{4}{2} = 2A$

apply KCL at node 'c'

$2 + 1 = 3A$

$\Rightarrow \frac{4}{4} = 1A$ $\quad 3 + 1 = 4A$

$\Rightarrow 3 \times 4 = 12V$

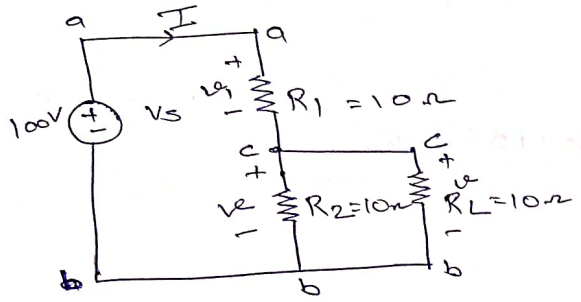
Apply KVL at loop

$V - 12 - 4 = 0$ $\quad \therefore \boxed{\frac{16}{2} = 8A = I}$

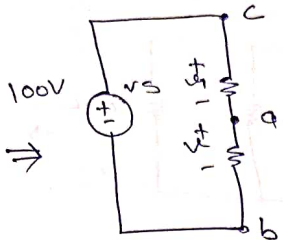
$\boxed{16 = V}$

find Total power of the ckt?

Q36) ~~vahad~~



$\Rightarrow$



$10 \| 10$

$R_{eq} = \frac{10 \times 10}{20}$

$= \frac{100}{20}$

$= 5$

$R_{eq} = \cancel{10+5}$

$= \cancel{5}$

$R = 10\Omega$

$\cancel{V_x = \frac{V \times R_{eq}}{R_{eq}+10}}$

$V_x = \frac{V \times R_L}{R_{total}}$

$= \frac{100 \times 5}{15}$

$= \cancel{\frac{100 \times 5}{15 \Rightarrow 5+10}}$

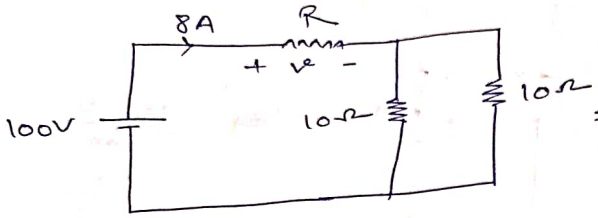
$\boxed{V_x = 33.33V}$

$V_1 = \frac{100 \times 10}{10+5}$

$V_1 = \frac{1000}{15} = 66.66$

$I = \frac{100}{10+5} = \left(\frac{100}{15}\right) A$

Q56)



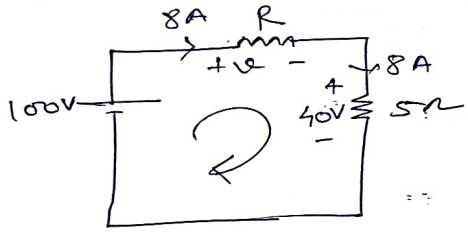
$\Rightarrow 10 \| 10 = 5\Omega$

And R

$V = IR$

$R = \frac{V}{I} = \frac{V}{8}$

Sol^n:-



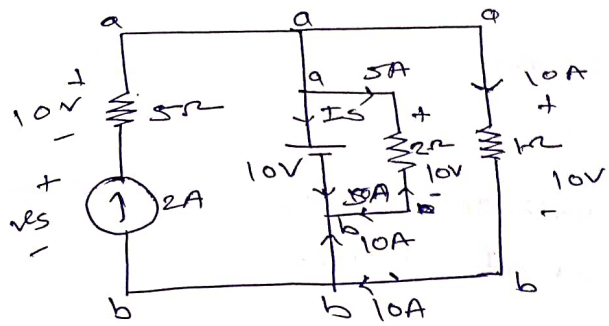
$100 - V - 40 = 0$

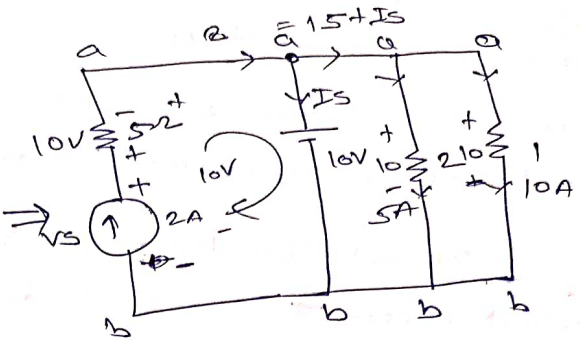
$100 - 40 = V$

$V = 60V$

$$\boxed{R = \frac{60}{8} = 7.5\Omega}$$

Q 64)





Sol^n:-

① $\frac{10}{2} = 5A$

② $\frac{10}{1} = 10A$

$= 15 + I_s = 2$

$\boxed{I_s = -13}$

$V_s - 10 - 10 = 0$

$\boxed{V_s = 20}$

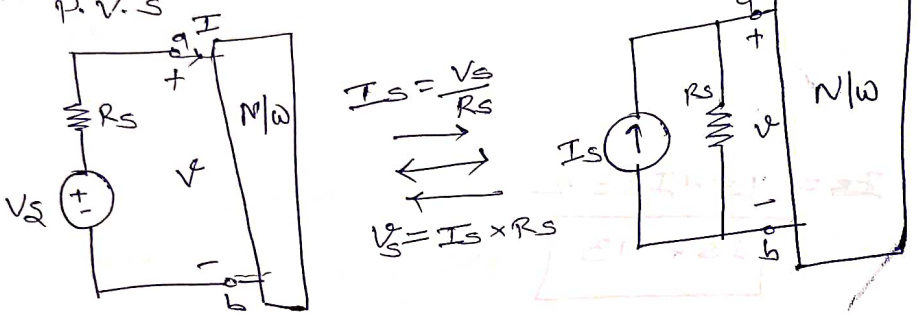
find Total Power in the ckt (Deliver)?

Lect-20

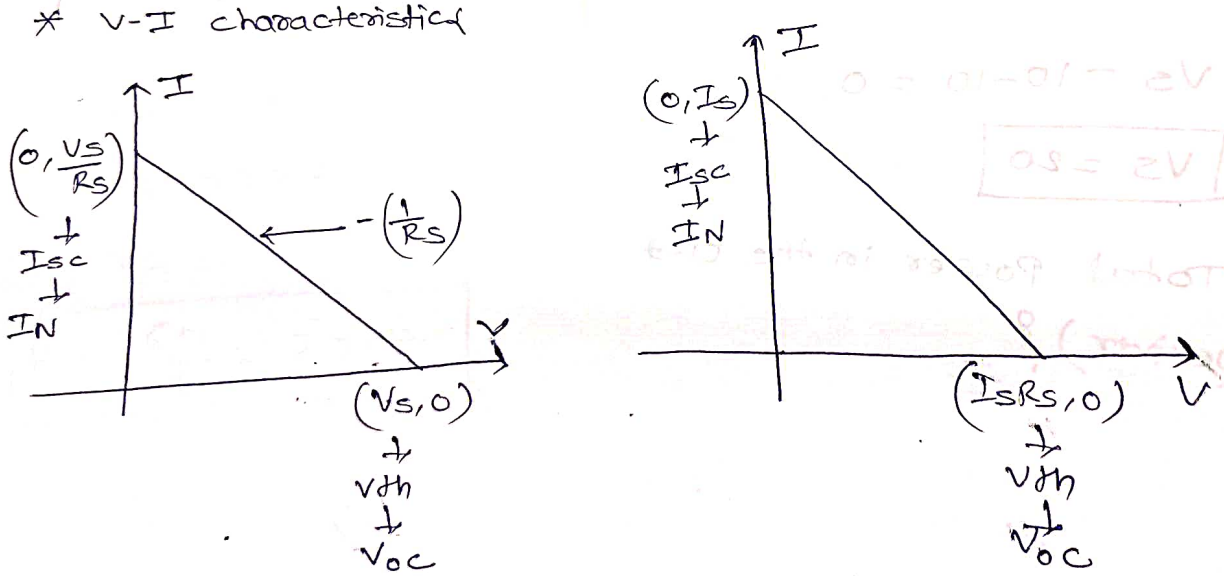
Source Transformation

* Source Transformation is not valid for Ideal voltage or current source.
* It is only applicable for practical voltage source, practical current source & dependent sources.

* P.V.S

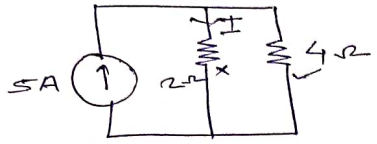


* V-I characteristics



* The element where source transformation is going to apply that must not be the part of asked response.

e.g:-



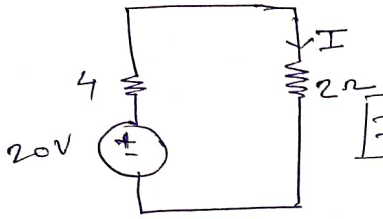
$2 \| 4 = \frac{2\times4}{2+6} = \frac{8}{6}$

$\cancel{I = \frac{5\times2}{8/6}}$

$I = \frac{5\times4}{4+2}$

$\boxed{I = \frac{20}{6}\ A}$ CDR

soln:-



$\boxed{I = \frac{20}{6}\ A.}$

* Ideal voltage source

$R_s \rightarrow 0\ \Omega$

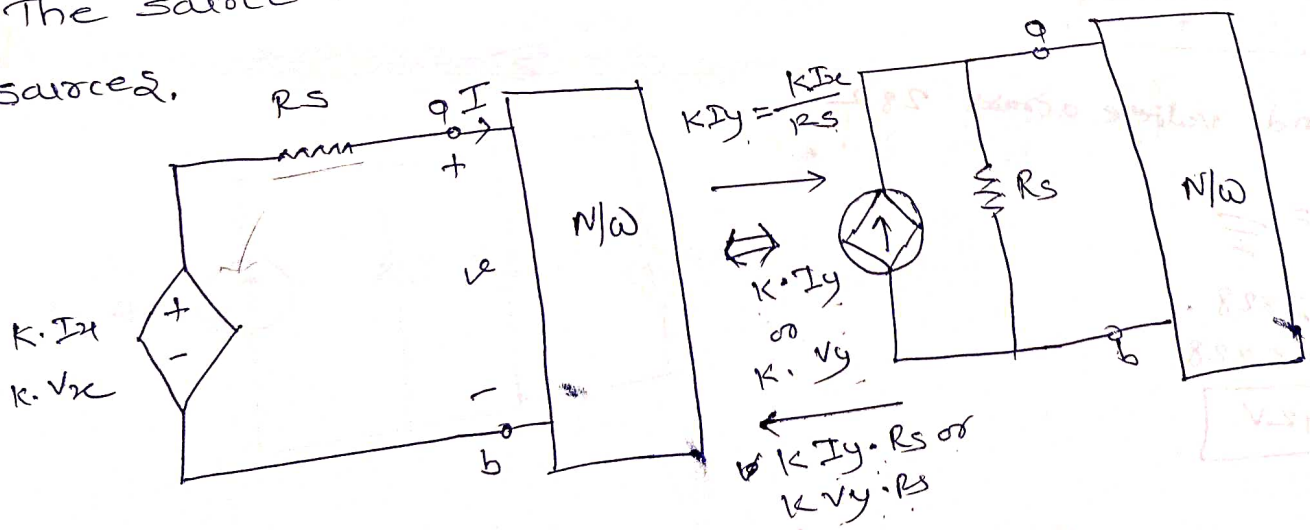
$I_s = \frac{V_s}{R_s} = \frac{V_s}{0} = \infty$

Ideal current source

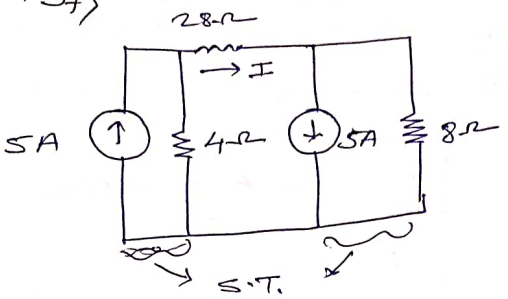
$R_s \rightarrow \infty$

$\cancel{I_s =}\ V_s = I_s R_s = I_s \times \infty$
$= \infty$

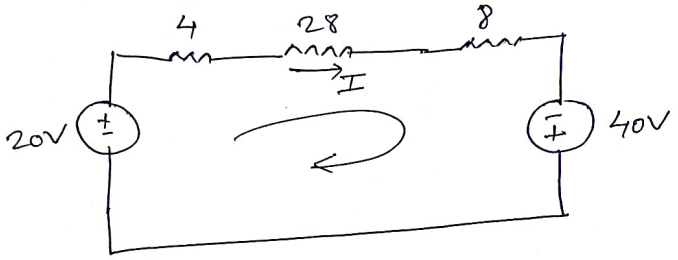
* The source Transformation is equally valid for dependent sources.



Q 37)



$I = \frac{V}{28}$



$20 - (I \times (4+28+8)) + 40 = 0$

$60 = 40I$

$I = \frac{60}{40}$ A.

$I = \frac{6}{4} = \frac{3}{2}$

$\boxed{I = 1.5A}$

find voltage across 28Ω

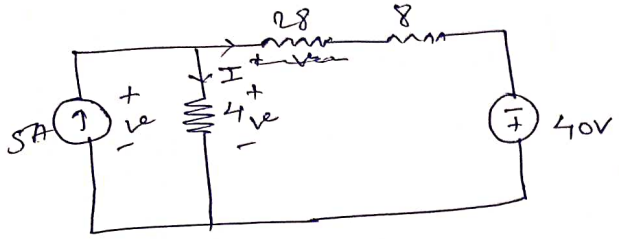
$28 = \frac{V}{I}$

$V = I \times 28$

$= 1.5 \times 28$

$\boxed{V = 42V}$

Find voltage across 5A



apply Nodal.

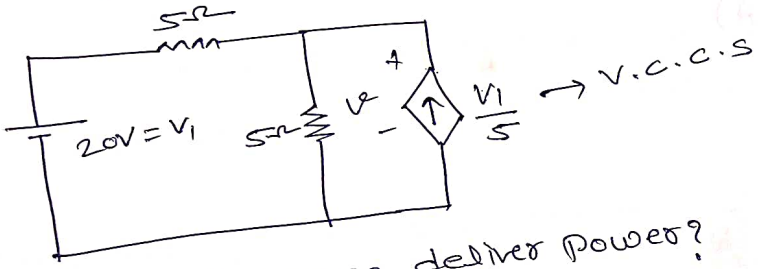
$$I = \frac{40}{36} = 1.11$$

$$5 - 1.11 = I$$

$$\cancel{V = 36 \times 1.11 = 8.88}$$

$$\boxed{I = 3.89 \text{ or } 3.90}$$

Q5-1)

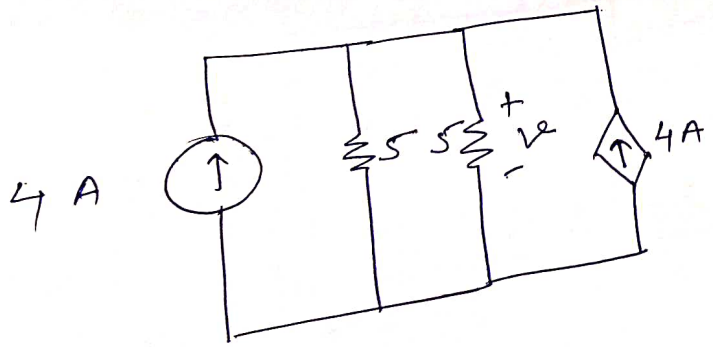


The dependent source deliver power?

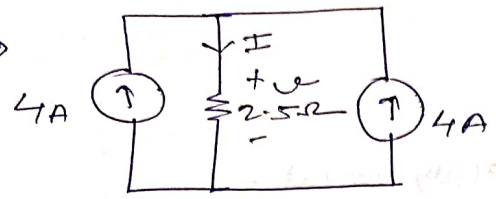
$$P_{dependent} = \frac{V_1}{5} \times v \quad (D)$$

$$= \frac{20}{5} \times V = 4 \times V$$

$$5 \| 5 \quad \frac{5 \times 5}{5+5} = \frac{25}{10} = 2.5\,\Omega$$



$\Rightarrow$



$I = 4+4 = 8A$

$V = 8 \times \frac{5}{2} = 4 \times 5$

$\boxed{V = 20V}$

$P_{delivered} = 4 \times 20$

$= 80W$ (D) ✓

or $80W$ (A)

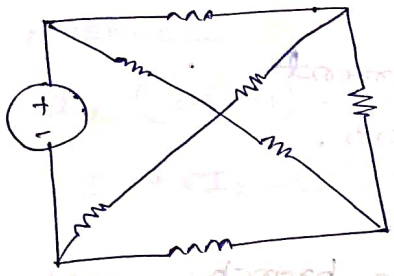
Lect - 21

Mesh analysis

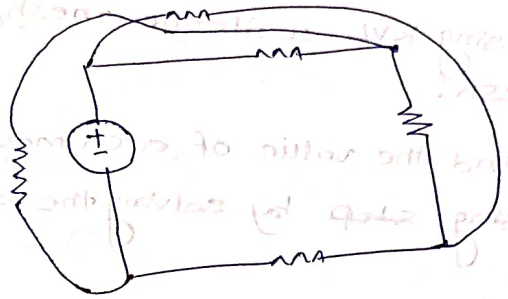
* Mesh analyis → KVL + ohms law

* It is applicable to planner circuit

e.g.:-



(planner circuit)



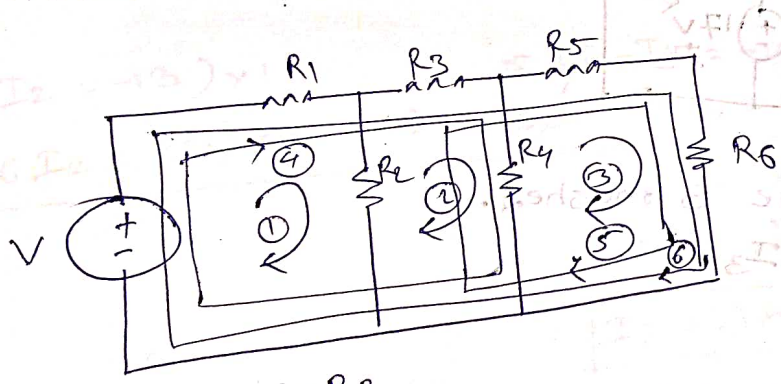
(Non-planner circuit)

* mesh → It is a closed path which does not have any further closed path.

* loop → It is a also closed path which may or may not have any further closed path.

* ~~All~~ all meshes are loop but vice versa is not always true.

e.g.:-



mesh 1 = V → R1-R2

mesh 2 = R2 - R3 - R4

mesh 3 = R4 - R5 - R6

Step 1:- Assign the number of meshes

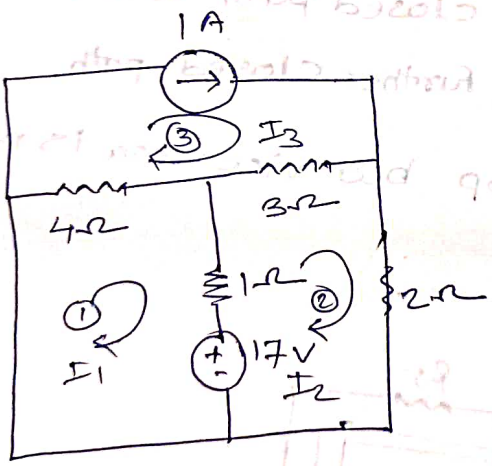
Step2:- Assign the current to individual meshes in clockwise direction.

Step 3:- Using KVL write the mesh eqn for each mesh.

Step 4:- Find the value of each mesh current using ~~step~~ by solving the step 03.

Note:- mesh currents may or may not be branch current.

Q 82) Using mesh analysis verify the power balance eqn in the circuit shown below.



Step 1&2:- There are 3 meshes.

I_1, I_2, I_3

Step 3:- writing the mesh eqn.

Mesh - 01

$I_1(4+1) - I_2 \times 1 - 4 \times I_3 = -17$

$5I_1 - I_2 - 4I_3 = -17$ --- (1)

mesh-02

$I_2(3+2+1) - 1 \times I_1 - 3I_3 = 17$

$-I_1 + 6I_2 - 3I_3 = 17$ - (2)

mesh-03

$I_3 = 1A$ --- (3)

from eqn (1) & (2)

$5I_1 - I_2 - 4 = -17$

$5I_1 - I_2 = -13$ --- (4)

$-I_1 + 6I_2 - 3 = 17$

$-I_1 + 6I_2 = 20$ --- (5)

$(5I_1 - I_2 = -13) \times 1$

$(-I_1 + 6I_2 = 20) \times 5$ $\Rightarrow$

$\cancel{5I_1} - I_2 = -13$

$-\cancel{5I_1} + 30I_2 = 100$

$29I_2 = 87$

$I_2 = \frac{87}{29}$

$\boxed{I_2 = 3A}$

put this value in eqn (4)

$5I_1 - 3 = -13$

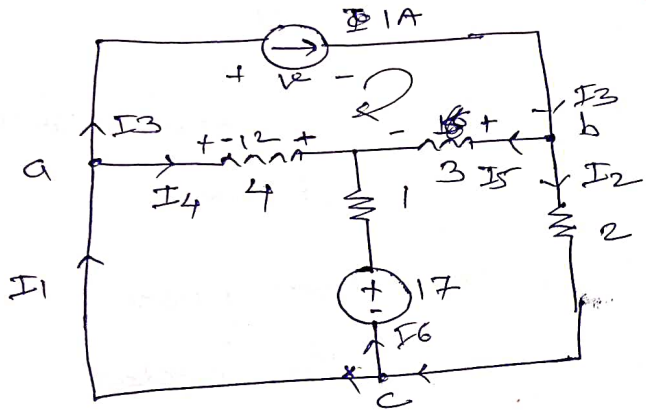
$5I_1 = -10$

$I_1 = \frac{-10}{5}$

$\boxed{I_1 = -2}$

Ans. $I_1 = -2A$, $I_2 = 3A$, $I_3 = 1A$

Satisfy power ballance eqn.



Apply KCL at node 'a'

$I_1 + I_3 = I_4$

$-2 + 1 = -3 = I_4$

$I_4 = -3$

$4 \times 3 = -12$

$P_4 = -12 \times -3 = 36W$ (A)

Apply KCL at node 'b'

$I_3 - I_2 = I_5$

$3 - 1 = I_5$

$\boxed{3 - 1 = 2 = I_5}$

$V_3 = 3 \times 2 = 6V$

$P_3 = 2 \times 5 = 10W(A)$

Apply KVL at loop I_3

$+12 - V - 6 = 0$ $\quad P_{17} = -6 \times +1 = -6W(A)$

$\boxed{V = -6V}$ $\quad \therefore P_{17V} = +17 \times -1 = -17W(A)$

Apply KCL at node 'c'

$I_1 - I_6 = I_2$

$I_1 - I_2 = I_6$

$-2 - 3 = I_6$

$\boxed{-5 = I_6}$

$P_{17V} = 17 \times -5 = -85W(A)$

$P_{1\Omega} = -5 \times -5 = +25W(A)$

$P_{2\Omega} = 6 \times 3 = 18W(A)$

~~$P_{Total} = 12 + 10 - 17 - 85 - 5 + 12$~~

~~$P_{Total} = 36 + 10 - 17 - 85 + 25 + 18$~~

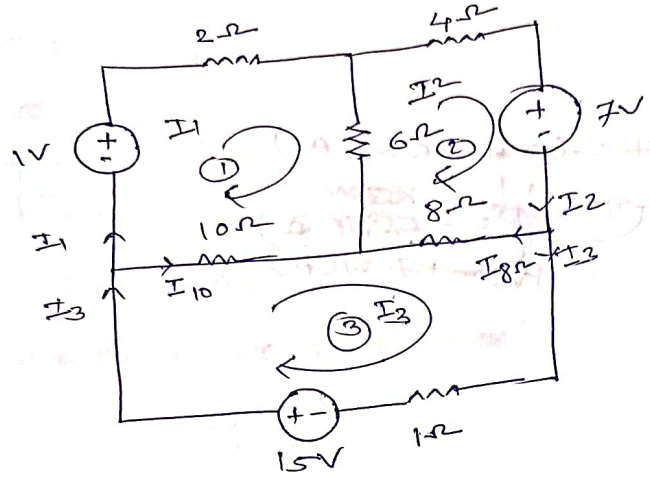
~~Lect-22~~

$P_{Total} = -85 + 18 + 12 + 25 + 36 - 6$

$= 0$

Hence circuit is valid.

Q 83)



writing the mesh eqn.

Mesh 01:-

$I_1 (18) - I_2 6 - I_3 10 = 1$

mesh 02:-

$I_2 (18) - 10 I_1 - 8 I_3 = -7$

Mesh 03:-

$I_3 (19) - I_1 10 - I_2 8 = 15$

using matrix form

$$\begin{bmatrix} 18 & -6 & -10 \\ -10 & 18 & -8 \\ -10 & -8 & 19 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 1 \\ -7 \\ 15 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 18 & -6 & -10 \\ -10 & 18 & -8 \\ -10 & -8 & 19 \end{bmatrix} \qquad \Delta_1 = \begin{bmatrix} 1 & -6 & -10 \\ -7 & 18 & -8 \\ 15 & -8 & 19 \end{bmatrix}$$

$$\Delta_2 = \begin{bmatrix} 18 & 1 & -10 \\ -10 & -7 & -8 \\ -10 & 15 & 19 \end{bmatrix}, \quad \Delta_3 = \begin{bmatrix} 18 & -6 & 1 \\ -10 & 18 & -7 \\ -10 & -8 & 15 \end{bmatrix}$$

$$I_1 = \frac{|\Delta|}{|\Delta_1|} = \frac{784}{2340}$$

$I_1 = -1.5\,A$

$I_2 = -1\,A$

$I_3 = -2\,A.$

Find the current in 6Ω & 8Ω in the circuit?

$I_{10} + I_3 = I_1$

$I_{10} = I_1 - I_3 \Rightarrow I_3 - I_1$

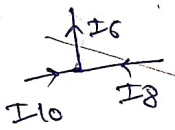
$= -1.5 + 2 = -2 + 1.5$
$= +0.5$

$= \cancel{-3.5A}\ 0.5\,A$

$I_{8\Omega} = +I_2 - I_3$

$= -1 + 2 = 1\,A$

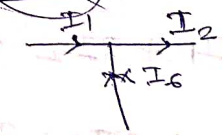
$\therefore \boxed{I_{8\Omega} = 1A}$



$\cancel{I_6 = I_{10} + I_8}$

$\cancel{= +0.5 + 1}$

$\cancel{\boxed{I_{6\Omega} = +0.5 + 1.5A}}$

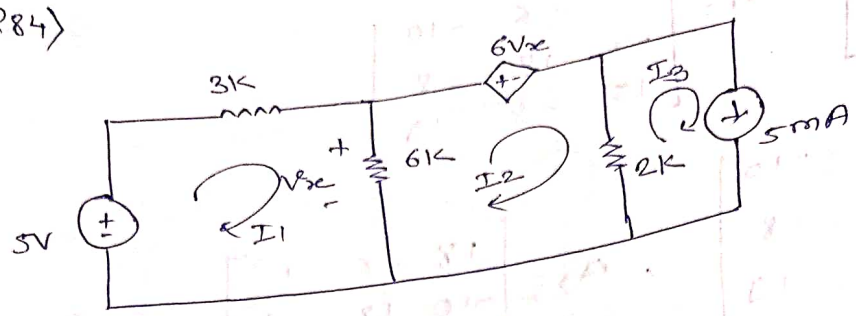


$I_{6\Omega} = I_1 - I_2$

$= -1.5 + 1$

$= -0.5\,A.$

Q84)



$I_1(9) - I_2(6) = 5$ — ①

$I_2(8) - I_1(6) - I_3(2) = -6V_x$ — ②

$-6I_1 + 8I_2 - 2I_3 = -6V_x$

$I_3 = 5mA.$

$V_x = 6(I_1 - I_2)$ — ④

$I_{6K} + I_2 = I_1$

$I_{6K} = I_1 - I_2$

from eqn

$-6I_1 + 8I_2 - 2I_3 = -6 \times V_x$

$-6I_1 + 8I_2 - 2I_3 = -6 \times 6(I_1 - I_2)$

$-6I_1 + 8I_2 - 2I_3 = -36I_1 + 36I_2$

$30I_1 - 28I_2 - 2I_3 = 0$ — ⑤

I_3 put in eqn (5)

$$30I_1 - 28I_2 = 10 \quad \text{---} (6)$$

eqn (1)

$$9I_1 - 6I_2 = 5 \quad \text{---} (1)$$

$$\Rightarrow (30I_1 - 28I_2 = 10) \times 3$$
$$(9I_1 - 6I_2 = 5) \times 10$$

$$90I_1 - 84I_2 = 30$$
$$- \; 90I_1 + 60I_2 = -50$$
$$-24I_2 = -20$$

$$I_2 = \frac{-20}{-24} = 0.833$$

put in eqn (1)

$$9I_1 - 6(0.833) = 5$$
$$9I_1 - 4.998 = 5$$

$$I_1 = \frac{10}{9} = 1.11 \text{ A}$$

put I_1 & I_2 in eqn (4)

$$V_{ze} = 6(I_1 - I_2)$$
$$= 6(1.11 - 0.833)$$

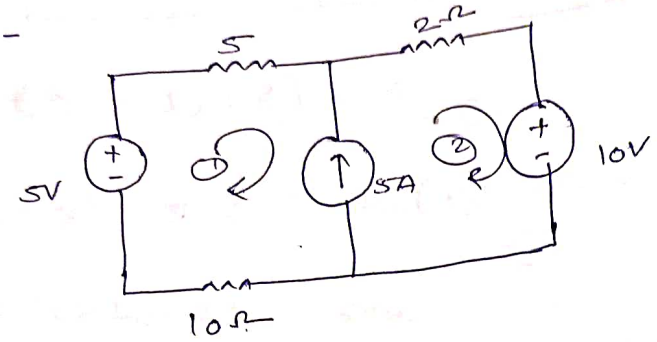
$$\boxed{V_{ze} = 1.662 \text{ V}}$$

Lect - 23

Concept of supermesh

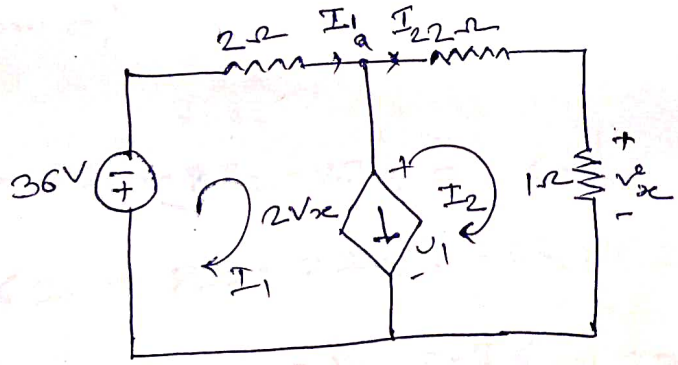
* Supermesh :- whenever a independent or dependent current source is present in between two meshes.

e.g:-



* Supermesh does not have its own current
* we have to apply KVL and KCL at the same time.
* Supermesh provide a constraint eqn for the solution of mesh current or branch current.

Q86) In the ckt of figure, mesh current I_2 will be,



Soln :- The ckt is planner ckt.

* mesh 01 & mesh 02 is forming a supermesh.

$I_1(2) + I_2(3) = -36$ — ①

applying KCL at node 'a'

$2V_x + I_2 = I_1$

$I_1 - I_2 = 2V_x$ — ②

$V_x = I_2 \times 1$

$= I_2$ — ③

Put eq^n ③ in eq^n ②

$I_1 - V_x = +2V_x$

$\boxed{I_1 = 3V_x}$ — ④

put eq^n ④ in eq^n ② ①

$3V_x(2) + V_x(3) = -36$

$6V_x + 3V_x = -36$

$9V_x = -36$

$V_x = \frac{-36}{9} = -4A$

$\boxed{V_x = -4 = I_2}$

$I_1 - (-4) = 2(-4)$

$I_1 + 4 = -8$

$\boxed{I_1 = -12A}$

Power across 36V

$P = 36 \times I_1$

$= 36 \times -12$

$= -432W$ (A)

Power across Dependent current source

$P_D = 2 \times V_x \times V_1$

Apply KVL in loop ①

$-36 - (-12 \times 2) - V_1 = 0$

$-36 + 24 - V_1 = 0$

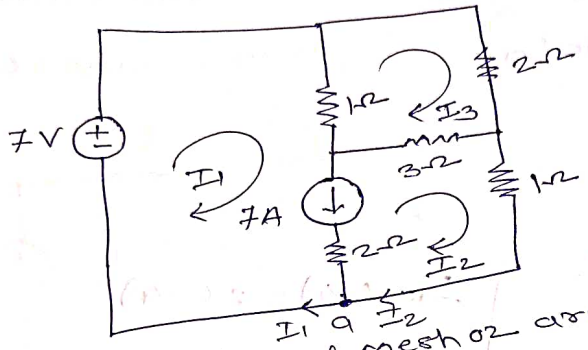
$\boxed{-12V = V_1}$

$\therefore P_D = 2 \times -4 \times -12$

$= 96W$ (A)

Q87) Determine the power delivered by 7V source by mesh analysis.

* Don't use Resistance of supermesh.



∴ mesh 01 & mesh 02 are forming a supermesh

* mesh 01 & mesh 02

$$I_1(1) - I_3 \times 1 + I_2(1+3) - I_3(3) = 7$$

$$I_1 + 4I_2 - 4I_3 = 7 \quad \text{--- (1)}$$

* mesh 03

$$I_3(6) - I \times 1 - 3(I_2) = 0$$

$$-I_1 - 3I_2 + 6I_3 = 0 \quad \text{--- (2)}$$

applying KCL at node 'a'.

$$I_2 + 7 = I_1 \quad \text{--- (3)}$$

Eqn (2) & (3)

$$\boxed{I_1 - I_2 = 7}$$

$$-I_1 - 3(I_1 - 7) + 6I_3 = 0$$

$$-I_1 - 3I_1 + 21 + 6I_3 = 0$$

$$-4I_1 + 6I_3 = -21 \quad \text{— (4)}$$

eqn (1) & (3)

$$I_1 + 4(I_1 - 7) - 4I_3 = 7$$

$$I_1 + 4I_1 - 28 - 4I_3 = 7$$

$$5I_1 - 4I_3 = 7 + 28$$

$$5I_1 - 4I_3 = 35 \quad \text{— (5)}$$

from eqn (4) & (5)

$$(-4I_1 + 6I_3 = -21) \times 5$$
$$+ (5I_1 - 4I_3 = 35) \times 4$$

$$-20I_1 + 30I_3 = -105$$
$$+ 20I_1 - 16I_3 = 140$$

$$14I_3 = 35$$

$$\boxed{I_3 = 2.5\,A}$$

Lec 9-24

Put I_3 in eqn (4)

$$-4I_1 + 6(2.5) = -21$$

$$-4I_1 + 15 = -21$$

$$-4I_1 = -36$$

$$I_1 = \frac{-36}{-4}$$

$I_1 = 9$ put in eqn (3)

$$I_2 = -7 + 9$$

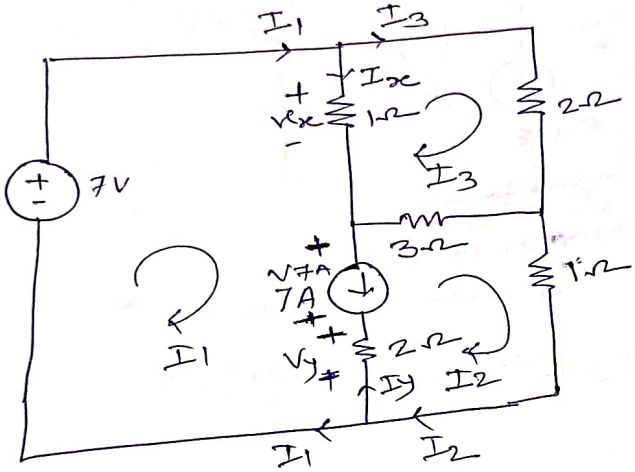
$$\boxed{I_2 = 2\,A}$$

$P_{7V} = 7 \times I_1$

$= 7 \times 9$

$= 63W$ (D)

Power delivered by 7A ?



$I_x + I_3 = I_1$

$I_x = I_1 - I_3$

$= 9 - 2.5$

$I_x = 6.5\,A$

$V_x = I_x \times 1$

$= 6.5 \times 1$

$\boxed{V_x = 6.5V}$

$I_y + I_1 = I_2$

$I_y = I_2 - I_1$

$= 2 - 9$

$\boxed{I_y = -7A}$

$V_y = 2 \times +7$

$\boxed{V_y = +14V}$

Apply KVL in loop 1

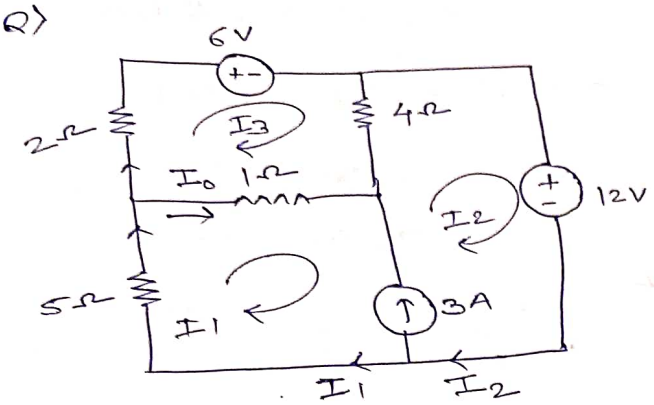
$7 - 6.5 + V_{7A} + 14 = 0$

$+V_{7A} = -13.5V$

$\boxed{V_{7A} = -13.5V}$

$\boxed{V_{7A} = -13.5V}$

Q)



find I_0

* ~~mes~~ There are 3 meshes

* Mesh 01 & Mesh 02 ~~are~~ is forming a supermesh
(it will creat only one eqn.)

* $I_1(6) - I_3(1) + I_2(4) - I_3(4) = -12$

$6I_1 - I_3 + 4I_2 - 4I_3 = -12$

$6I_1 + 4I_2 - 5I_3 = -12$ --- (1)

* mesh 03 :-

$I_3(7) - I_1(1) - I_2(4) = -6V$

$-I_1 - 4I_2 + 7I_3 = -6V$ -- (2)

$I_1 + 3 = I_2$

$\boxed{3 = I_2 - I_1}$ — (3)

from eqⁿ ① & ③

$$6I_1 + 4I_2 - 5I_3 = -12$$

$$\therefore I_2 = I_1 + 3$$

$$6I_1 + 4(I_1 + 3) - 5I_3 = -12$$

$$6I_1 + 4I_1 + 12 - 5I_3 = -12$$

$$10I_1 - 5I_3 = 0 \quad \text{--- ④}$$

from eqⁿ ② & ③

$$-I_1 - 4I_2 + 7I_3 = -6$$

$$-I_1 - 4(I_1 + 3) + 7I_3 = -6$$

$$-I_1 - 4I_1 - 12 + 7I_3 = -6$$

$$-5I_1 + 7I_3 = -6 \quad \text{--- ⑤}$$

from eqⁿ ④ & ⑤

$$(10I_1 - 5I_3 = 0) \times 5$$

$$+(-5I_1 + 7I_3 = -6) \times 10$$

$$\cancel{50I_1} - 25I_3 = 0$$

$$\cancel{-50I_1} + 70I_3 = -60$$

$$45I_3 = -60$$

$$\boxed{I_3 = \frac{60}{45} = -1.33\,A}$$

put I_3 in eq^n (4)

$$10I_1 - 5(-1.33) = 0$$

$$10I_1 = -6.65$$

$$I_1 = \frac{-6.65}{10}$$

$$\boxed{I_1 = +0.665\ A}$$

$$I_2 = I_1 + 3$$

$$\therefore\ I_2 = +0.665 + 3 \qquad \boxed{I_2 = 2.335\ A}$$

$$\boxed{I_2 = 3.665}$$

$$I_0 = I_1 - I_3 \qquad \Rightarrow I_0 = -0.665 + 1.33$$

$$= 0.665 - 1.33 \qquad \boxed{I_0 = 0.67\ A}$$

$$\boxed{I_0 = -0.665\ A}$$

$$P_{12} = 12 \times I_2 \qquad = 12 \times 2.335$$

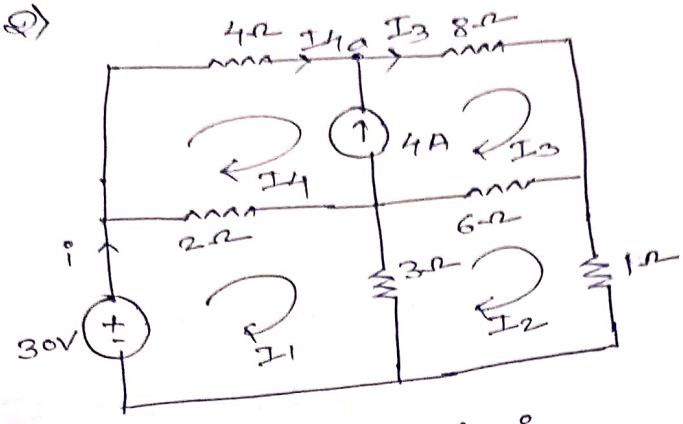
$$= 12 \times (3.665) \qquad = 28.02\ W(A)$$

$$= 43.98\ W(A)$$

Check again this question.

Lect - 25

Q)



Find the value of i.

mesh 01 :-

$I_1(5) - I_2(3) - I_4(2) = 30$

$5I_1 - 3I_2 - 2I_4 = 30$ — (1)

Mesh 02:-

$I_2(10) - I_1(3) - I_3(6) = 0$

$-3I_1 + 10I_2 - 6I_3 = 0$ — (2)

mesh 03 & 04

$I_4(6) - 2(I_1) + I_3(14) - 6(I_2) = 0$

$6I_4 - 2I_1 + 14I_3 - 6I_2 = 0$

$-2I_1 - 6I_2 + 14I_3 + 6I_4 = 0$ — (3)

apply KCL at node 'a'

$I_4 + 4 = I_3$ --- (4)

put eqn (4) in eqn (2)

$-3I_1 + 10I_2 - 6(I_4+4) = 0$

$-3I_1 + 10I_2 - 6I_4 - 10 = 0$

$-3I_1 + 10I_2 - 6I_4 = 10$ — (5)

~~from eqn (1) & (5)~~

~~$5I_1 - 3I_2 - 2I_4$~~

put eqn (4) in eqn (3)

$-2I_1 - 6I_2 + 14(I_4+4) + 6I_4 = 0$

$-2I_1 - 6I_2 + 14I_4 + 56 + 6I_4 = 0$

$-2I_1 - 6I_2 + 20I_4 = -56$ --- (6)

from eqn (1), (5) & (6)

$\boxed{I_1 = i = 6.65}$

$I_1 = 6.65$, $I_2 = 2.09$

$I_4 = -1.50$

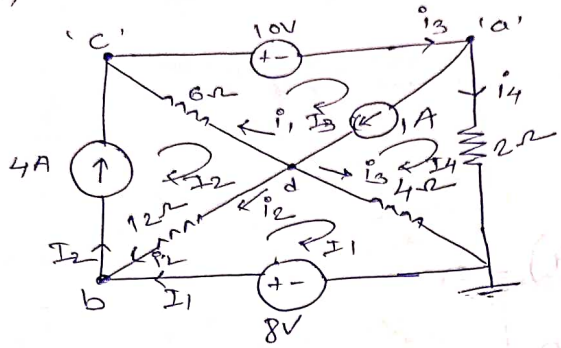
put I_1 & I_2 in eqn (2)

$-3(6.65) + 10(2.09) - 6I_3 = 0$

$-19.95 + 20.9 - 6I_3 = 0$

$I_3 = \frac{0.95}{-6} = -0.158\,A.$

Q)



Find i_1, i_2 & i_3

Sol^n:-

* mesh - 01

$$I_1(16) - I_2 \times 12 - 4 \times I_4 = 8$$

$$16I_1 - 12I_2 - 4I_4 = 8 \quad \text{--- (1)}$$

* mesh 02

$$I_2 = 4A$$

* mesh 03 & 04 forming a supermesh

$$I_3(6) - I_2(6) + I_4(6) - 4I_1 = -10$$

$$-4I_1 - 6I_2 + 6I_3 + 6I_4 = -10 \quad \text{--- (3)}$$

Applying KCL at node 'a'

$$[I_3 = I_4 + 1] \quad \text{--- (4)}$$

* from eqⁿ ①, ② & ④

$$16I_1 - 12(4) - 4I_4 = 8$$

$$16I_1 - 4I_4 = 56 \quad \text{— ⑤}$$

* from eqⁿ (2) (3) & (4)

$$-4I_1 - 6\times4 + 6(I_4+1) + 6I_4 = -10$$

$$-4I_1 - 12I_4 = -10+24-6$$

$$-4I_1 - 12I_4 = 8 \quad \text{— ⑥}$$

from eqⁿ ⑤ & ⑥

$$(16I_1 - 4I_4 = 56)\times1$$
$$(-4I_1 - 12I_4 = 8)\times4$$

$$16I_1 - 4I_4 = 56$$
$$+\ -16I_1 - 48I_4 = 32$$
$$-52I_4 = 88$$

$$I_4 = \frac{88}{-52}$$

$$I_4 = -1.69 \approx -1.7A.$$

from eqⁿ ⑤ & ⑥

$$I_4 = 2A$$

* $4I_1 - 2 = 14$

$$I_1 = \frac{14+2}{4}$$

$$\boxed{I_1 = 4A}$$

$$I_3 = I_4 + 1$$

$$I_3 = 2+1$$

$$\boxed{I_3 = 3A}$$

Lect - 26

Applying KCL at node 'b'

$i_2 + I_1 = I_2$

$i_2 = I_2 + I_1$

$i_2 = 4 - 4 = 0\,A$

$\boxed{i_2 = 0\,A}$

Applying KCL at node 'c'

$4 + i_1 = I_3$

$i_1 = I_3 - 4$

$= 3 - 4$

$\boxed{i = -1}$

Applying KCL at node 'd'

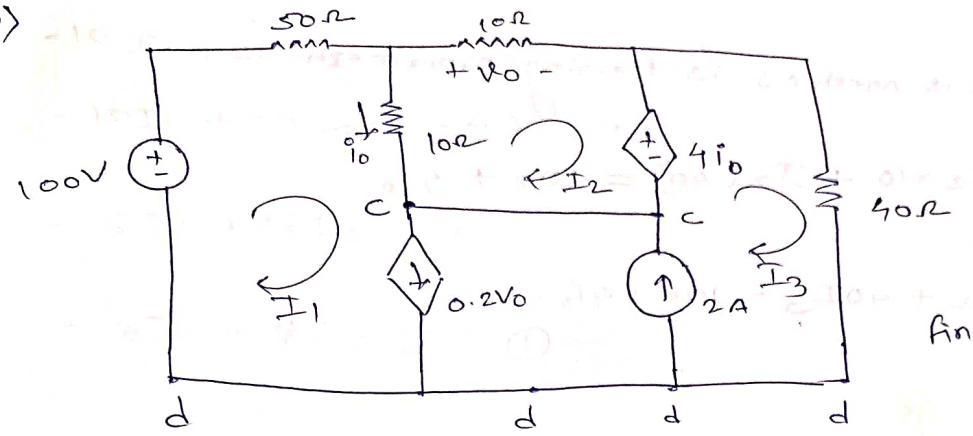
$i_1 + i_2 + i_3 = 1$

$i_3 = 1 - i_1 - i_2$

$= 1 + 1 + 0$

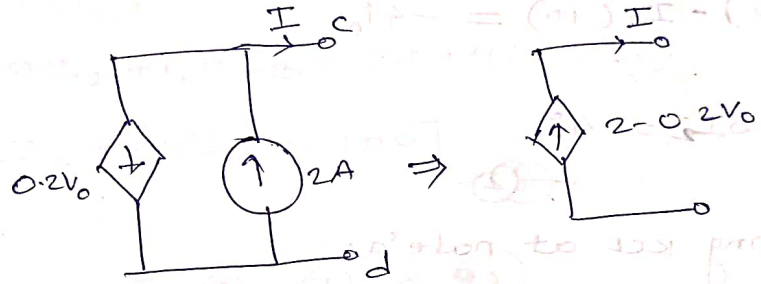
$\boxed{i_3 = 2A}$

Q)



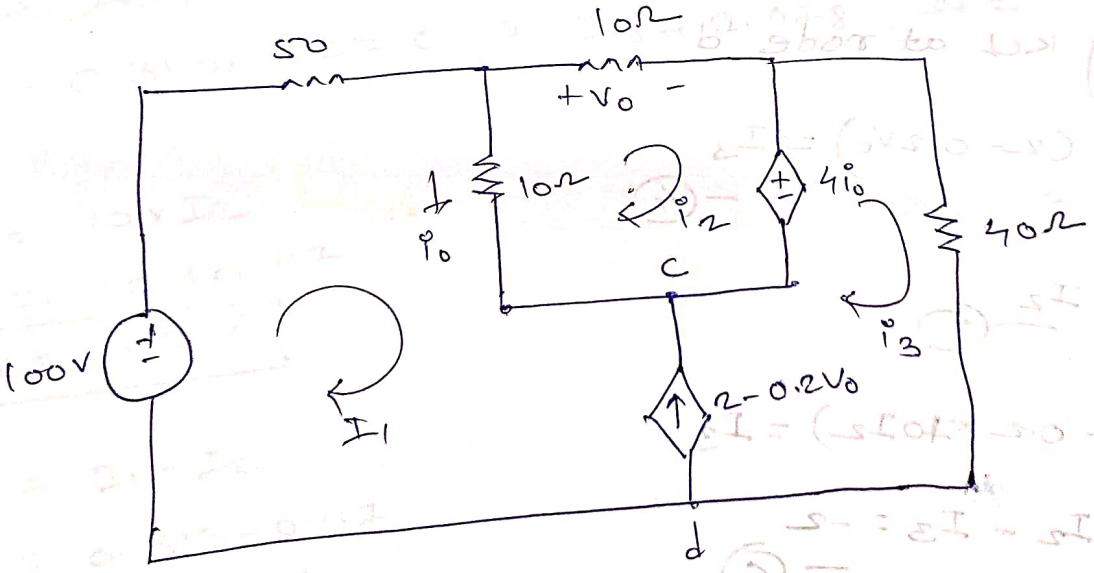
Find i_o & V_o

Soln:-



$$I + 0.2V_o = 2$$

$$\boxed{I = 2 - 0.2V_o}$$



Fin

sol^n:-

* mesh 01 & mesh 03 is forming supermesh

$I_1(60) - I_2 \times 10 + I_3(40) = 100 + 4i_o$

$60I_1 - 10I_2 + 40I_3 = 100 + 4i_o$ — (1)

* mesh 02

$I_2(20) - I_1(10) = -4i_o$

$-10I_1 + 20I_2 = -4i_o$ — (2)

applying KCL at node 'a'

$i_o + I_2 = I_1$

$\boxed{i_o = I_1 - I_2}$ — (3)

* Applying KCL at node 'd'

$I_1 + (2 - 0.2V_o) = I_3$ — (4)

$V_o = 10 \times I_2$ — (5)

$I_1 + (2 - 0.2 \times 10 I_2) = I_3$

$I_1 - 2I_2 - I_3 = -2$ — (6)

$$-10I_1 + 20I_2 = -4 \times (I_1 - I_2)$$

$$-10I_1 + 20I_2 = -4I_1 + 4I_2$$

$$-6I_1 + 16I_2 = 0$$

$$-3I_1 + 8I_2 = 0 \quad \text{---} (7)$$

From eq (1)

$$60I_1 - 10I_2 + 40I_3 = 100 + 4(I_1 - I_2)$$

$$\boxed{56I_1 - 6I_2 + 40I_3 = 100} \quad - (8)$$

From eqn (6), (7) & (8)

~~$I_1 = 0.155$, $I_2 = 0.058$~~

~~$I_3 = 2.272$~~

$I_1 = 0.313$, $I_2 = 0.117$, $I_3 = 2.078$,

$$V_o = 10 \times I_2$$
$$= 10 \times 0.117$$
$$\boxed{V_o = 1.17\ V}$$

$$i_o = I_1 - I_2$$
$$= 0.313 - 0.117$$
$$\boxed{i_o = 0.196\ A}$$

Nodal Analysis

* This is the most general approch for solving the N/w.
* This is valid for planner as well as non planner ckt.
* It uses KCL + ohm's law.

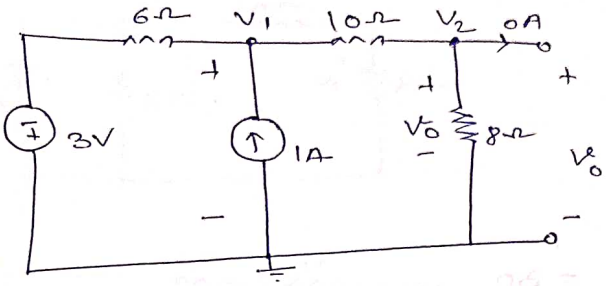
Step:01 Assign the nodes and give the node voltages

Step 02:- write the KCL at the nodes (nodal eqn)
at that time consider the node voltage at
higher potential at which your writing the
KCL eqn than other node voltages.

Step 03:- Solve the above set of eqn found in step 02.
to get the node voltages.

* The node voltage may or maynot be the branch voltage

Q88)



$V_o = ?$

sol^n:-

Step 01:- Assign the nodes V_1 & V_2

Step 02:- At node 01

$$V_1\left(\frac{1}{6}+\frac{1}{10}\right)-V_2\left(\frac{1}{10}\right)=1-\frac{3}{6}$$

$$V_1\left(\frac{10+6}{60}\right)-V_2\left(\frac{1}{10}\right)=\frac{6-3}{6}$$

$$V_1\left(\frac{16}{60}\right)-V_2\left(\frac{1}{10}\right)=\frac{3}{6}=\frac{1}{2}$$

$$\frac{16V_1-V_2\times 6}{60}=\frac{1}{2}$$

$$\boxed{16V_1-6V_2=30} \quad \text{— (1)}$$

* node 2 :-

$$V_2\left(\frac{1}{8}+\frac{1}{10}\right)-\frac{V_1}{10}=0$$

$$V_2\left(\frac{10+8}{80}\right)-\frac{V_1}{10}=0$$

$$\frac{V_2\times 18}{\cancel{80}\,8}=\frac{V_1}{\cancel{10}}$$

$V_2 \times 18 = V_1 \times 8$

$V_2 \times 9 = V_1 \times 4$

$$\boxed{V_2 = \frac{V_1}{9} \times 4}$$

— (2)

from eqn (1) & (2)

$$16 \times V_1 - 6 \times \frac{4}{9} \times V_1 = 30$$

$$V_1\left(16 - \frac{24}{9}\right) = 30$$

$$V_1\left(\frac{16 \times 9 - 24}{9}\right) = 30$$

$$V_1 = \frac{30 \times 9}{16 \times 9 - 24}$$

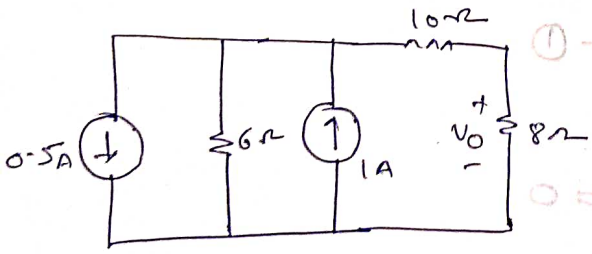
$$\boxed{V_1 = 2.25\,V}$$

put V_1 in V_2

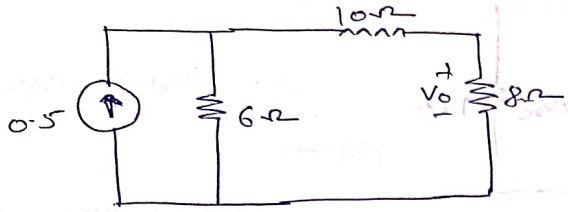
$$V_2 = \frac{2.25}{9} \times 4$$

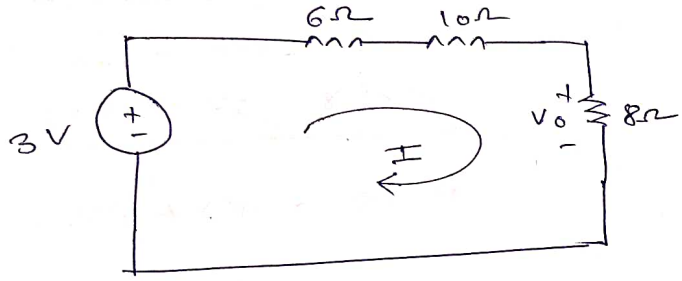
$$\boxed{V_2 = V_o = 1\,V}$$

By Source Transformation



$-0.5 + 1 = 0.5A$





$3 - I(6+10+8) = 0$

$3 - 24I = 0$

$-24I = -3$

$I = \frac{-3}{-24}$

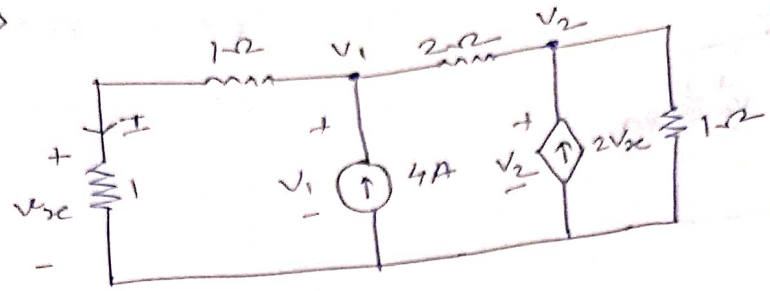
$I = 0.125$

$V_o = 8 \times I$

$= 8 \times 0.125$

$\boxed{V_o = 1V}$

Q89)



find V_x ?

Sol:-

Node-01

$$V_1\left(\frac{1}{2}+\frac{1}{2}\right)-\frac{V_2}{2}=4$$

$$V_1-\frac{V_2}{2}=4$$

$$2V_1-V_2=8 \quad -(1)$$

Node.02

$$V_2\left(\frac{1}{2}+\frac{1}{1}\right)-V_1\left(\frac{1}{2}\right)=2V_x$$

$$V_2\left(3/2\right)-\frac{V_1}{2}=2V_x$$

$$3V_2-V_1=4V_x \quad -(2)$$

$$V_x=1\times\frac{V_1}{2}=\frac{V_1}{2} \quad \ldots(3)$$

$-V_1 + 3V_2 = 4 \times \frac{V_1}{2} = 2V_1$

$-3V_1 + 3V_2 = 0$

— (4)

from eqn (1) & (4)

~~$2V_1 - V_2 = 8$~~

$(-3V_1 + 3V_2 = 0)$

$(2V_1 - V_2 = 8) \times 3$

$-3V_1 + 6V_1 = 0 + 24$

$V_1 = \frac{24}{3} = 8V$

$\boxed{V_1 = 8V}$

put in eqn (1)

$2 \times 8 - V_2 = 8$

$16 - V_2 = 8$

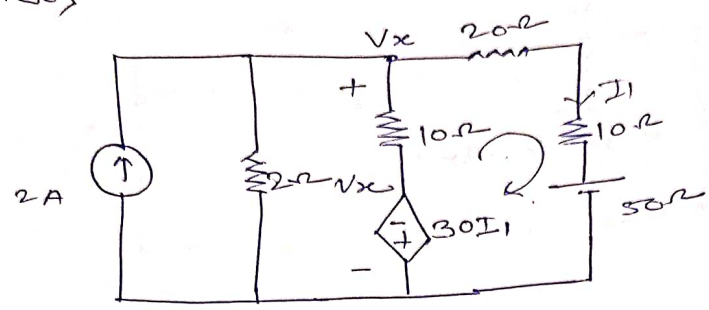
$-V_2 = 8 - 16$

$\boxed{V_2 = 8}$

$V_x = \frac{V_1}{2} = \frac{8}{2} = 4V.$

Lect-28

Q90) Lect-28



V_x & I_1 = ?

Soln:-

$$V_x\left(\frac{1}{2}+\frac{1}{10}+\frac{1}{30}\right) = 2-\frac{30I_1}{10}+\frac{50}{30}$$

$$V_x\left(\frac{19}{30}\right) = \frac{60-30I_1\times 3+50}{30}$$

$$19V_x = 60-90I_1+50$$

$$\boxed{19V_x = 110-90I_1} \quad \text{--- (1)}$$

* $V_x - I_1\times 30 - 50 = 0$

$$I_1\times 30 = V_x - 50$$

$$\boxed{I_1 = \frac{V_x-50}{30}} \quad \text{--- (2)}$$

put I_1 in eqn (1)

$$19V_x = 110-90\left(\frac{V_x-50}{30}\right)$$

$19V_x = 110 - 3V_x + 150$

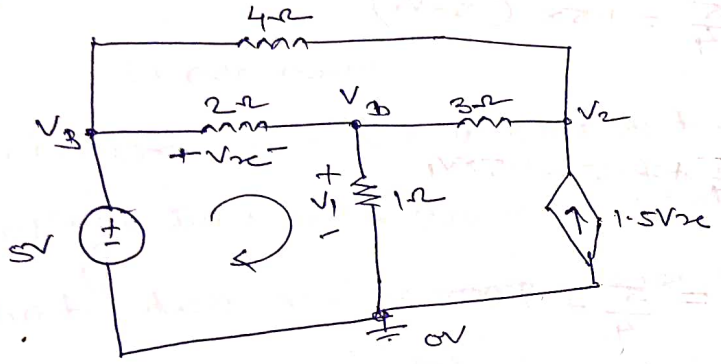
$22V_x = 260$

$V_x = \frac{260}{22}$

$\boxed{V_x = 11.81V}$

$I_1 = \frac{11.81 - 50}{30} = (-1.273A)$.

Q 91)



$* \; V_1\left(\frac{1}{1} + \frac{1}{2} + \frac{1}{3}\right) - V_2\left(\frac{1}{3}\right) - V_3\left(\frac{1}{2}\right) = 0$ — (1)

$* \; V_2\left(\frac{1}{4} + \frac{1}{3}\right) - \frac{V_1}{3} - \frac{V_3}{4} = 1.5V_x$ — (2)

$* \; V_3 = 5V$ — (3)

Apply KVL in loop

$5 - V_x - V_1 = 0$

$\boxed{V_x = 5 - V_1}$ — (4)

Rearrange

$$* \; V_1\left(\frac{6+2+3}{6}\right) - \frac{V_2}{3} - \frac{5}{2} = 0$$

$$V_1\left(\frac{11}{6}\right) - \frac{V_2}{3} = \frac{5}{2}$$

$$11V_1 - 2V_2 = \frac{5}{2}\times 6 = 15$$

$$\boxed{11V_1 - 2V_2 = 15} \quad -①$$

$$* \; -\frac{V_1}{3} + V_2\left(\frac{3+4}{12}\right) - \frac{5}{4} = 1.5\times(5-V_1)$$

$$-\frac{V_1}{3} + \frac{7}{12}\times V_2 = \frac{5}{4} = \frac{5}{4} + 7.5 - 1.5\times V_1$$

$$V_1\left(1.5 - \frac{1}{3}\right) + \frac{7}{12}V_2 = \frac{5}{4} + 7.5$$

$$V_1\left(\frac{4.5-1}{3}\right) + \frac{7}{12}V_2 = \frac{5+7.5\times 4}{4}$$

$$\frac{3.5V_1}{3} + \frac{V_2\times 7}{12} = \frac{5+30}{4}$$

$$3.5\times V_1 4 + 7V_2 = \frac{35\times 12}{4}$$

$$* \; (14V_1 + 7V_2 = 105)\times 2$$
$$(11V_1 - 2V_2 = 15)\times 7$$

$$28V_1 + 77V_1 = 105\times 2 + 15\times 7$$

$$V_1 = \frac{105\times 2 + 15\times 7}{28+77}$$

$$\boxed{V_1 = 3V}$$

$*2V_2 = 33 - 15$

$[V_2 = 9V.]$

$V_3 = 5V.$

$1.5 \times V_{2e} \times V_2 \Rightarrow 1.5 \times 9 \times 2$

$= 18 \times 1.5$

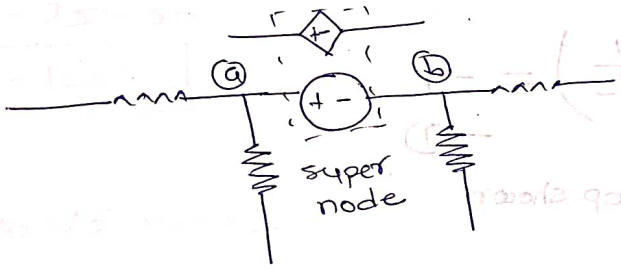
$= 27W$ (D)

$= -27W$ (A)

Lect - 29

Super node

* whenever there is a independent voltage or dependent voltage source is present between two nodes then that two nodes form a supernode.



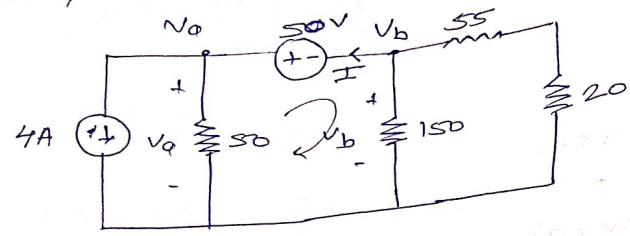
* supernode provides the constraint eqn for the calculation of node voltages (V_a & V_b)

$V_a - 10 - V_b = 0$

$\boxed{V_a - V_b = 10V}$ constraint eqn

* supernode uses both KVL & KCL at the same time
* supernode doesnot have its own voltage.

Q92)



$P_{50V} = 50 \times I$

To find the value of I, we have to get the value of Va & Vb.

* Va & Vb is forming a supernode and now we will see how to write nodal eqn for supernode.

$$V_a\left(\frac{1}{50}\right) + V_b\left(\frac{1}{150} + \frac{1}{75}\right) = -4 \quad -(1)$$

writing KVL in the loop shown

$$V_a - 50 - V_b = 0$$

$$\boxed{V_a - V_b = 50} \quad -(2)$$

$$* \quad \frac{V_a}{50} + V_b\left(\frac{75+150}{150 \times 75}\right) = -4$$

$$V_a \times 150 \times 75 + V_b \times 50 \times 225 = -4 \times 150 \times 75 \times 50$$

$$3 \times 75\, V_a + V_b\,(225) = -4 \times 150 \times 75$$

$[V_b = V_a - 50]$

$225 V_a + 225 \times (V_a - 50) = -4 \times 150 \times 75$

$225 V_a + 225 V_a - 11250 = -45000$

$450 V_a = -33750$

$V_a = \frac{-33750}{450}$

$[V_a = -75]$

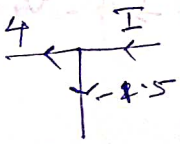
$V_b = -75 - 50$

$\boxed{V_b = -125}$

$\therefore V = 50 \times I$

$\frac{N}{50} = I$

$\frac{-75}{50} = I$



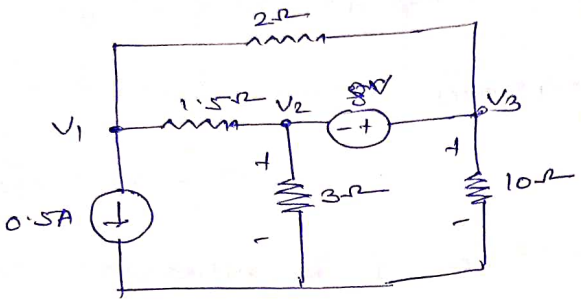
$-1.5 = I$

$4 + (-1.5) = I$

$2.5 = I$

$\therefore 50 \times 2.5 = 125W$ (D)

Q93) Find the node voltages V_1, V_2 & V_3 in the ckt shown.



~~$V_1\left(\frac{1}{1.5}\right) - V_3$~~ at node V_1

$$V_1\left(\frac{1}{2}+\frac{1}{1.5}\right) - V_2\left(\frac{1}{1.5}\right) - V_3\left(\frac{1}{2}\right) = -0.5$$

$$V_1(1.16) - V_2(0.66) - V_3(0.5) = -0.5 \quad -(1)$$

at node V_2 & V_3 are forming a super node

$$V_2\left(\frac{1}{3}+\frac{1}{1.5}\right) - V_1\left(\frac{1}{1.5}\right) + V_3\left(\frac{1}{10}+\frac{1}{2}\right) - V_1\left(\frac{1}{2}\right) = 0$$

$$-0.16V_1 + V_2 + 0.6V_3 = 0 \quad -(2)$$

$$V_2 + 8V - V_3 = 0$$

$$V_2 - V_3 = -8V \quad -(3)$$

$V_1 = -3.23\times10^{-3} \approx 0$

$V_2 = -3$

$V_3 = 4.99 \approx 5$

Lect-30

Chapter-02 → Network Theorem (2 Marks)

(1) Superposition theorem ✓
(2) Thevenin & Norton theorem ✓
(3) Maximum power Transfer Theorem ✓
(4) Reciprocity Theorem ✓
(5) Tellegence Theorem
(6) millimon's Theorem

* Superposition theorem *

* It is applicable to linear & Bilateral network.
* This Theorem is used to find the voltage & current Response in a branch of a network.
* That means it is not applicable for power calculation.
* It is applicable in the Network when the independent sources present in the network are more than '1'.

Statement :- To find the response i.e. voltage or current in any element or branch can be calculated by superposition theorem.

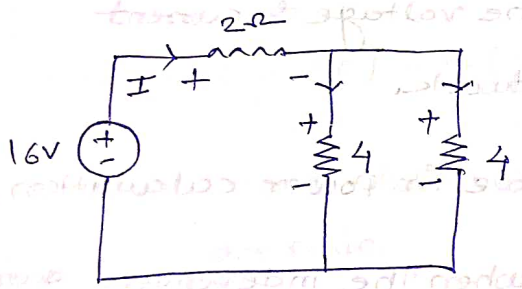
* The Response is the summation of individual Responses caused by individual independent Sources and at that time all the remaining Independent source has been deactivated.

$$\left\{\begin{array}{l} I.V.S \longrightarrow S.C. \\ I.C.S \longrightarrow O.C. \end{array}\right\}$$

Note:- while finding the Response Do not touch the Dependent sources.

Superposition follows two principles.

1) Homogenity principle



* The Network must have single independent source.

$\Rightarrow$

$$I = \frac{16}{4} = 4A$$

$$V = 4 \times 2 = 8V$$

Response In 2Ω Resistor.

$\Rightarrow I_1 = 2A$

$I_2 = 2A$

$V_1 = V_2 = 8V$

* If the I.s. has been scaled by a factor (K), then the response (V & I) will also be scaled by same factor.

* $(I.S.)_{new} = 16 \times K \rightarrow$ if
* $V_{new} = KV$ ← then

$V_{1\,new} = KV_1$

$V_{2\,new} = KV_2$

$I_{new} = KI$

$I_{1\,new} = KI_1$

$I_{2\,new} = KI_2$

Let take $K = 2$

$(I.S)_{new} = 16 \times 2 = 32$

$V_{new} = 2 \times 8 = 16V$

$V_{1\,new} = 2 \times 8 = 16V$

$V_{2\,new} = 2 \times 8 = 16V$

$I_{new} = 2 \times 4 = 8A$

$I_{1\,new} = 2 \times 2 = 4A$

$I_{2\,new} = 2 \times 2 = 4A$.

Note:- according to homogenity priciple if we scale the I.S. by a factor K then the Responses in any branch of the ckt will be scaled like given below.

Remember :- if (I.S) scaled by factor K

$V_{new} = K V_{old}$

$I_{new} = K \cdot I_{old}$

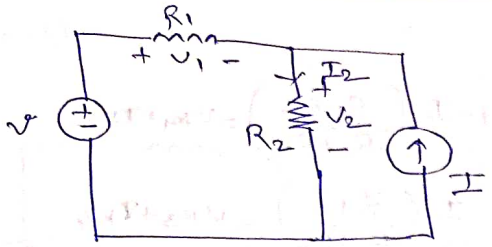
$P_{new} = K^2 P_{old}$.

2) Additivity principle.

If a network having more than one I.S. then the response in any branch i.e (V&I) is the summation of Individual responses due to one source acting alone while other I.S. has been deactivated.

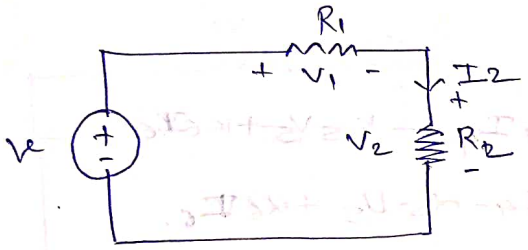
$$\left\{ \begin{array}{l} I.V.S \longrightarrow S.C. \\ I.C.S \longrightarrow O.C. \end{array} \right\}$$

*



Step 01 :- Independent voltage sources activated

Independent current sources deactivated - (o.c)



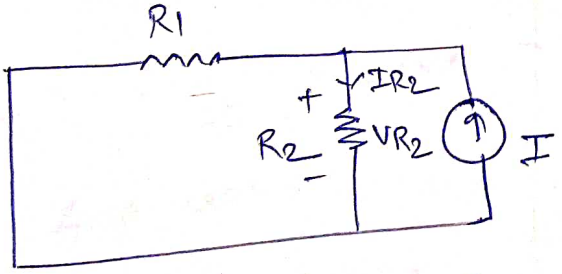
Lect - 31

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

$$V_{R_2} = \frac{V \times R_2}{R + R_2} \quad \text{— VDR}$$

Step 02 :- I.C.S → Active

I.V.S → Deactive → S.C.



$$I_{R_2} = \frac{I \times \frac{1}{R_1}}{\frac{1}{R_1} + R_2}, \quad \left[V_{R_2} = R_2 \times I_{R_2} = \frac{R_2 \cdot R_1 \times I}{R_1 + R_2} \right]$$

$$\boxed{I_{R_2} = \frac{I \times G_1}{G_{eq}}}$$

Step 3 :- Total Response

$$V = V_{R_1} + V_{R_2} = V\left(\frac{R_2}{R_1+R_2}\right) + I\left(\frac{R_1 R_2}{R_1+R_2}\right) = VK_1 + IK_2$$

$$I = I_{R_1} + I_{R_2} = V\left(\frac{R_1}{R_1+R_2}\right) + I\left(\frac{R_1}{R_1+R_2}\right) = VK_3 + IK_4$$

* all the voltage & current Responses are the function of (I.V.S & I.C.S)

The Response,

$$V = K_1 V_1 + K_2 V_2 + K_3 I_3 + K_4 I_4 - K_5 V_5 + K_6 I_6$$

$$I = \alpha_1 V_1 + \alpha_2 V_2 + \alpha_3 I_3 + \alpha_4 I_4 - \alpha_5 V_5 + \alpha_6 I_6.$$

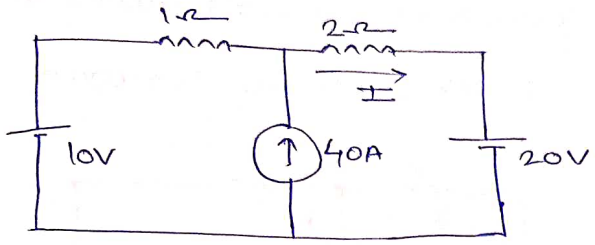
* K_i = const
  where $i = 1, 2, 3, 4 ---$

α_i = const
  where $i = 1, 2, 3, 4, ---$

V_i = I.V.S.
  where $i = 1, 2, 3, 4 ----$

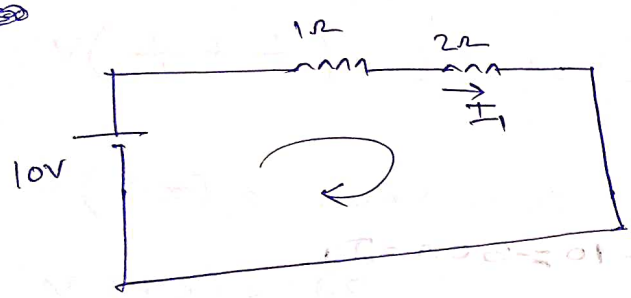
I_i = I.C.S
  where $i = 1, 2, 3, 4 ---$

2.1)



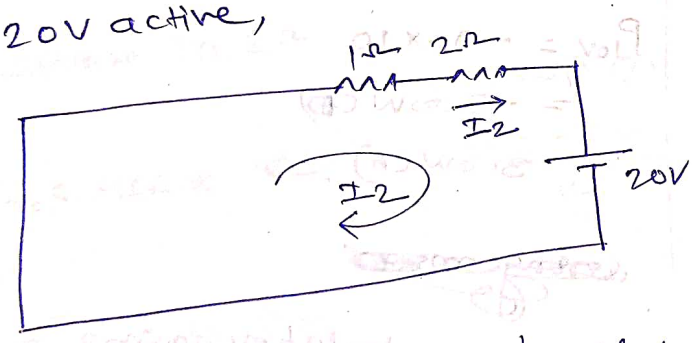
sol^n

10V active, other are deactive



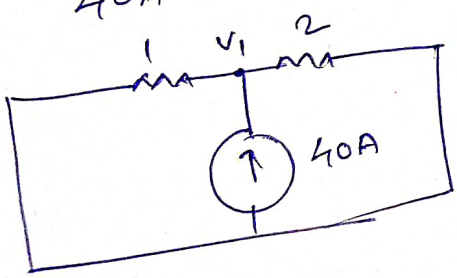
$$I_1 = \frac{10}{3} = 3.33\ A$$

20V active,



$$I_2 = \frac{-20}{3} = -6.66\ A$$

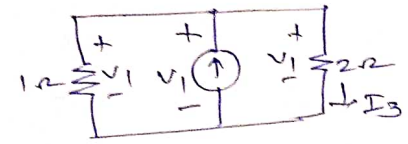
40A active



$$V_1\left(\frac{1}{2} + \frac{1}{1}\right) = 40$$

$$V_1 = \frac{40}{1.5}$$

$$V_1 = 26.66V$$



$V_1 = 26.66$

$I_3 = \frac{26.66}{2}$

$I_3 = 13.33$

$\therefore I = 3.33 - 6.66 + 13.33$

$I = 10A$

$P_{2\Omega} = 2 \times I^2$

$= 2 \times 10^2 = 200W(A)$

$P_{20V} = 20 \times I$

$= 20 \times 10$

$= 200W(A)$

$P_{40A} = V \times 40$

$\therefore V - 20 - 20$

$V = -40V$

$\therefore P_{40A} = -40 \times 40$

$= -1600W(D)$

$= 1600W(A)$

$\therefore P_{1\Omega} = 1 \times I_1$

$\therefore 40 + I_1 = I$

$40 - I = -I_1$

$40 - 10 = -30A = I_1$

$P_{1\Omega} = 1 \times -30$

$= -30W(A)$

$P_{10V} = -30 \times 10$

$= -300W(D)$

$= 300W(A)$.

~~wrong answer~~

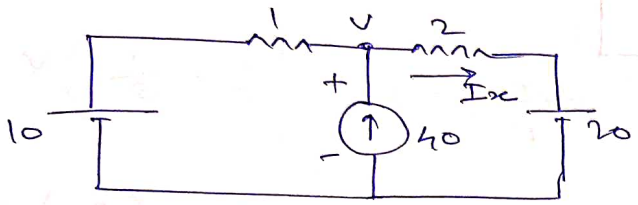
check calculation again

if correct then

ckt is invalid.

Superposition not applied for power but if ask in exam find power through 2Ω.

applied Nodal analysis.



$$V\left(\frac{1}{1}+\frac{1}{2}\right) = \frac{10}{1}+40+\frac{20}{2}$$

$$V(1.5) = 10+40+10$$

$$V(1.5) = 60$$

$$V = \frac{60}{1.5} = 40V$$

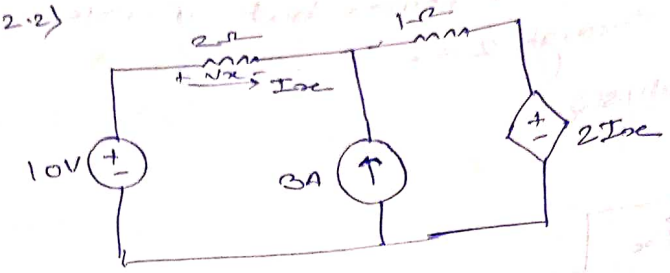
Response in 2Ω

KVL in loop ②

$$I = \frac{40-20}{2} = \frac{20}{2} = 10A.$$

$$P = I^2R = (10)^2 \times 2$$
$$= 200W.$$

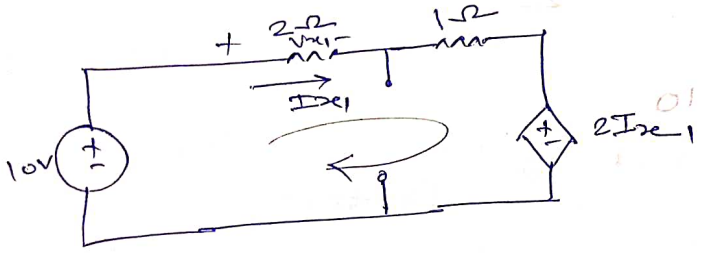
2.2)



Step 1:- 10V → active

3A → o.c.

Do not touch dependent sources



$$10 - (2+1)\, I_{x1} - 2I_{x1} = 0$$

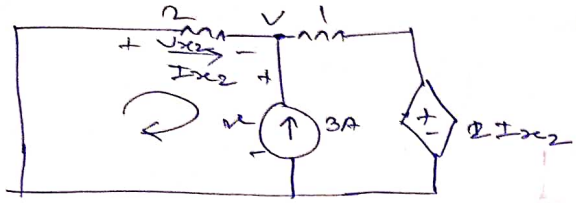
$$5I_{x1} = 10$$

$$I_{x1} = \frac{10}{5} = 2A$$

$$V_{x1} = 2 \times 2 = 4V$$

Step 2:- 3A → active

10V → S.C.



$$V\left(\frac{1}{2}+\frac{1}{1}\right) = 3 + \frac{2I_{x2}}{1}$$

$$V\left(\frac{3}{2}\right) = 3 + 2I_{x2} \quad -(1)$$

$$* \; -I_{x2}\times 2 - V = 0$$

$$V = 2I_{x2} \quad -(2)$$

$$\therefore \; V\left(\frac{3}{2}\right) = 3 + 2\times V$$

or

$$-2I_{x2}\left(\frac{3}{2}\right) = 3 + 2I_{x2}$$

$$-2I_{x2}\left(\frac{3}{2}\right) - 2I_{x2} = 3$$

$$-5I_{x2} = 3$$

$$I_{x2} = \frac{3}{-5} = -0.6\,A$$

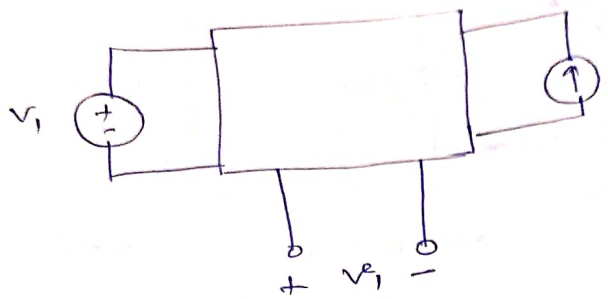
$$V_{x2} = I_{x2}\times 2$$
$$= -1.2V$$

$$I_x = I_{x1} + I_{x2} = 2 + 0.6$$
$$= 1.4A$$

$$V_x = V_{x1} + V_{x2} = 4 - 1.2$$
$$= 2.8V.$$

LOCA-32

2.3)



Sol:-

V & I are the function of I.V.S & I.C.S.

$V_x = f(V_1 \& I_1)$

$V_x = K_1 V_1 + K_2 I_1$

$80 = K_1 8 + K_2 12$ — ①

$0 = K_1 \times -8 + K_2 4$ — ②

$\rightarrow V_x = K_1 \times 10 + K_2 \times 10$ — ③

adding ① & ②

$K_1 = 2.5$

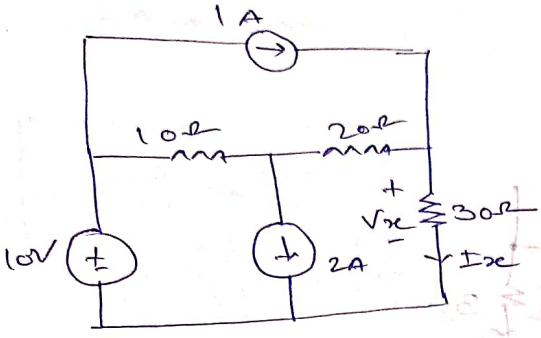
$K_2 = 5$

$V_x = 2.5 \times 10 + 5 \times 10$

$= 25 + 50$

$\boxed{V_x = 75V}$

2.4)

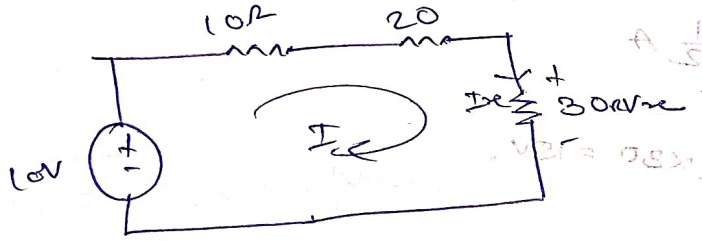


Step 01

active 10V

2A → O.C

1A → O.C



$$10-(10+20+30)I=0$$

$$I_{x1}=\frac{10}{60}=0.167A$$

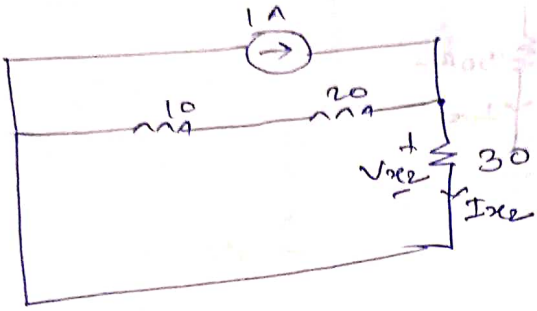
$$\boxed{I_{x1}=0.167A}$$

$$V_{x1}=30\times0.16$$

$$\boxed{V_{x1}=5V}$$

Step (2)

1 A → active



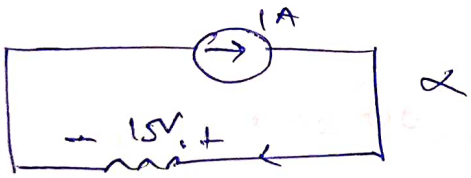
$30 \parallel 30 = 15$

CDR

$$I_{x2} = \frac{1 \times 30}{60} = \frac{1}{2} A$$

$$V_{x2} = I_{x2} \times 30 = \frac{1}{2} \times 30 = 15V.$$

or

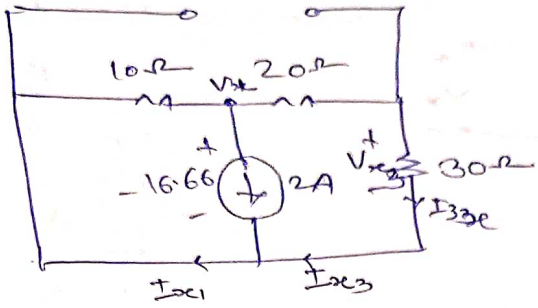


wrong

Because Never do source transform in finding response element.

Step ③ :-

2A → active



$$V_1\left(\frac{1}{10}+\frac{1}{30}\right)=-2$$

$$V_1(0.12)=-2$$

$$V_1=\frac{-2}{0.12}$$

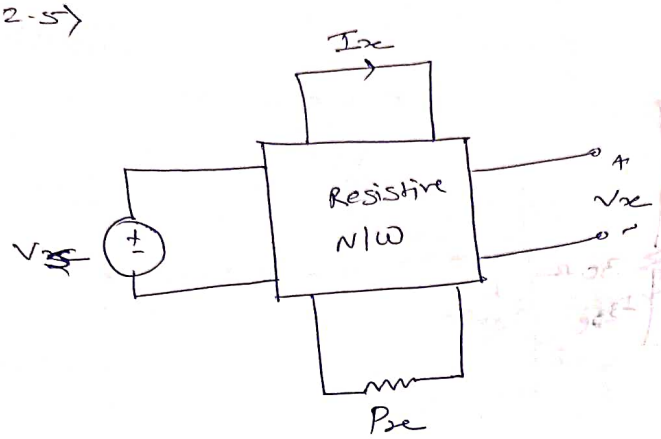
$$\boxed{V_1=-16.66V}=V_{x3}$$

$$I_{x3}=\frac{-2\times 10}{60}\quad \text{— CDR}$$

$$I_{x3}=-0.33\,A$$

$$\boxed{V_{x3}=-10V}$$

Q 2.5)



if $V_s = 10V$ then $I_{xe} = 6A$, $V_{xe} = 4V$ and $P_{xe} = 5W$

Now if $V_s = 25$, then the value I_{xe}, V_{xe} & P_{xe} will be ?

$V_{s\,new} = K \times V_{s\,old} = 2.5 \times 10 = 25$

$I_{xe\,new} = K \times I_{xe\,old} = 2.5 \times 6 = 15A$

$V_{xe\,New} = K \times V_{xe\,old} = 2.5 \times 4 = 10V$

$P_{xe\,New} = K^2 \times P_{xe\,old} = (2.5)^2 \times 5 = 31.25W$

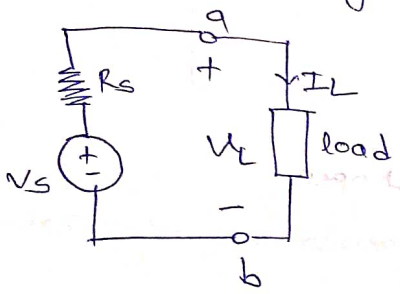
$\frac{V_s}{V_s} \quad \frac{25}{10} = K = 2.5$

Lect# - 3

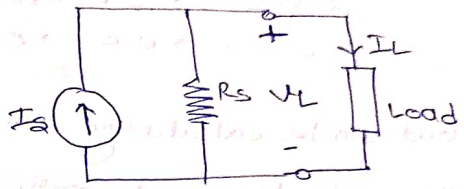
(2marks)

Thevenin & Norton Theorem

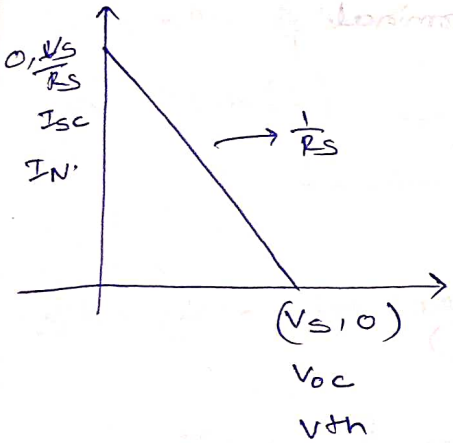
Practical voltage source

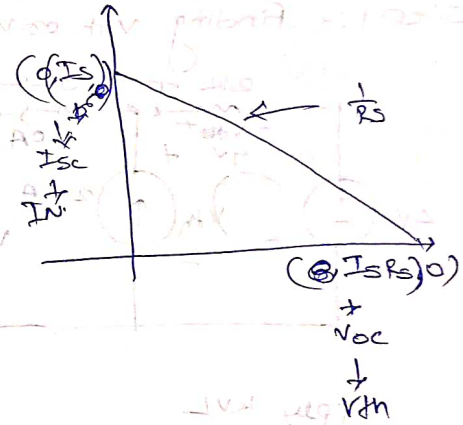


Practical current source

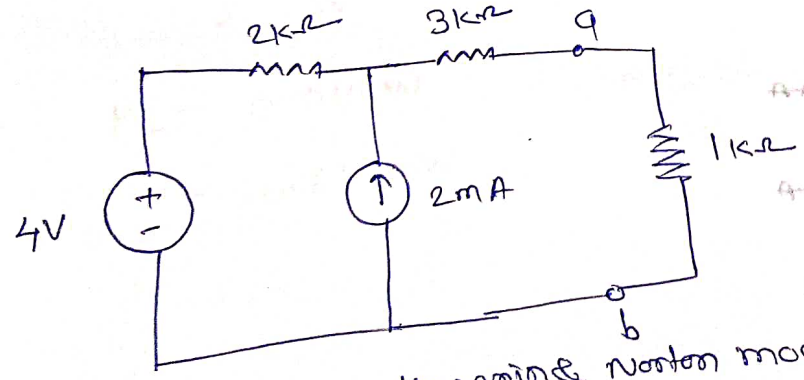


Source Transformation





Case -I :- The Network having I.s. & Resistances.



Develop the thevenin & Norton model acros the ab terminal.

* In this case while finding Rth or Req always Rth

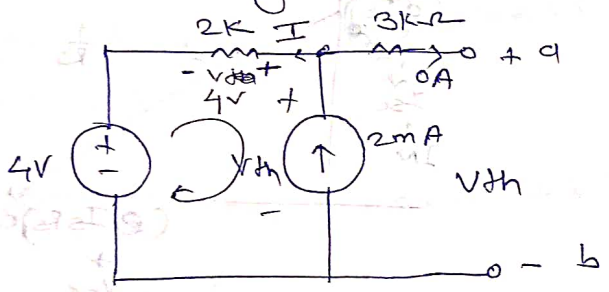
Remember that all the independent sources must be deactivated.

I.V.S → S.C → 0V

I.C.S → O.C → 0A

* But while calculating Vth or Voc → just open the ab terminal only.

* Step 1:- finding Vth or Voc across ab terminal



apply KVL

$4 + 4 = V_{th}$

$\boxed{8 = V_{th}}$

Nodal

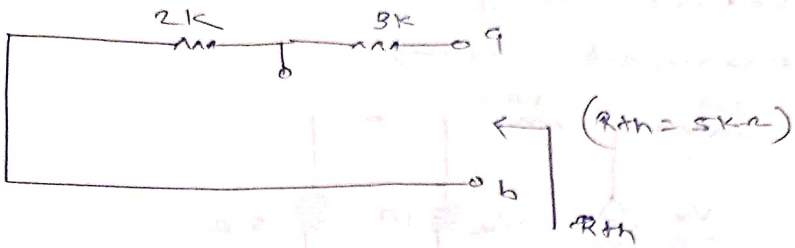
* $V_{th}\left(\frac{1}{2}\right) = \frac{4}{2K} + 2mA$

$= 2mA + 2mA$

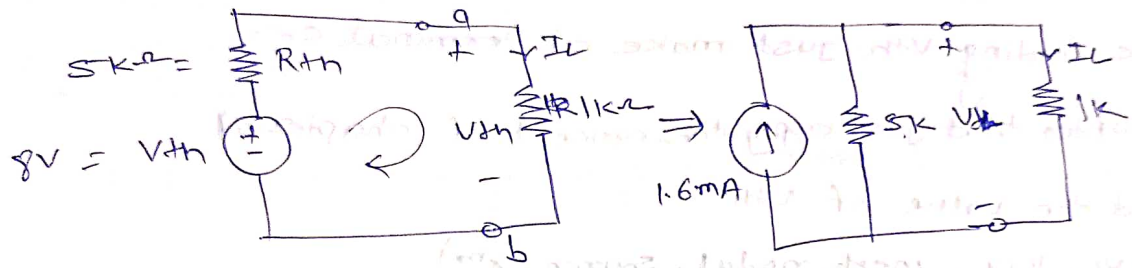
$V_{th} = 4mA \times 2$

$\boxed{V_{th} = 8V}$

Step 02:- Finding the value of Rth or RN or Req or Rab



Step 03:- Developing Thevenin & Norton model



Step 04:- Finding VL, IL & PL

$$I_L = \frac{8}{6K} = 1.33 \times 10^{-3} A$$

$$V_L = 1.6 \times 10^{-3} \times 5000$$

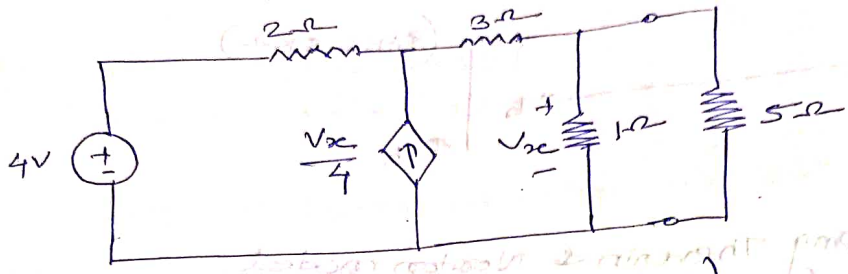
$$= 8V$$

$$P_L = 0.010 W$$

$$= 10.64 mW$$

Lect-34

Case 2:- (Network having I. source, Resistor, Dependent source)

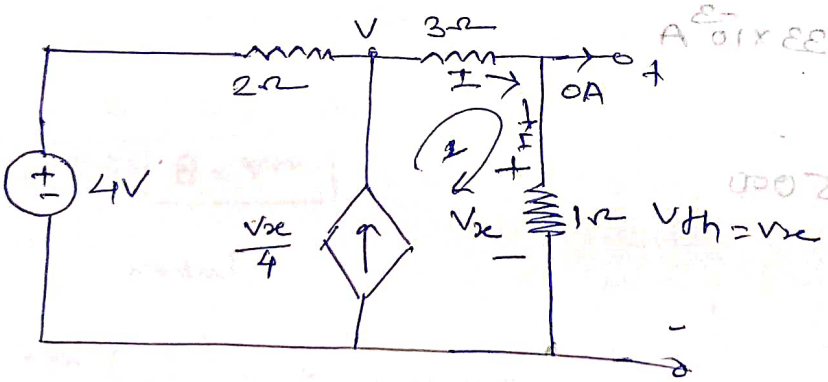


(Develope thevenin & Norton)

*while finding Vth just make ab terminal o.c. and after that just apply the concept of chapter-01 to find the value of Vth

(KVL, KCL, mesh, nodal, source xm)

*Step 01:- finding the value of Vth;



Nodal

Apply Nodal Analysis

$$V\left(\frac{1}{2}+\frac{1}{4}\right) = \frac{V_x}{4} + \frac{4}{2}$$

$$v\left(\frac{3}{4}\right) = \frac{V_{th}+2}{4}$$

$$v\left(\frac{3}{\cancel{4}}\right) = \frac{V_{th}+8}{\cancel{4}}$$

$$3V = V_{th}+8 \quad \text{—(1)}$$

$\therefore V_{th} = V_{oc}$

* $v = (3+1)I$

$$\frac{v}{4} = I$$

* $I \times 1 = V_{th}$

$$\frac{v}{4} \times 1 = V_{th} = V_{oc} \quad \text{—(2)} \quad \Rightarrow \boxed{v = 4 \times V_{th}}$$

from eqn (1) & (2)

$$3 \times 4 \times V_{th} = V_{th} + 8$$

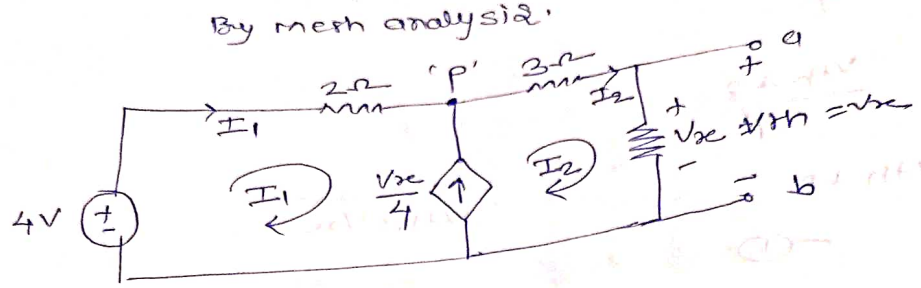
$$12 V_{th} = V_{th} + 8$$

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

$$11 V_{th} = 8$$

$$\boxed{V_{th} = \frac{8}{11} V}$$

By mesh analysis:



Mesh 01 & 02

$I_1(2) + I_2(4) = 4$ ---①

applying KCL at 'P'

$I_1 + \frac{V_{th}}{4} = I_2$ ---②

$V_{th} = V_x = I_2 \times 1$ --③

solving eqⁿ ① ② & ③

$2I_1 + 4I_2 = 4$

$I_1 - I_2 = -\frac{V_{th}}{4}$

$\boxed{I_2 = V_{th}}$

Put in eq ②

$I_1 + \frac{I_2}{4} = I_2$

$I_1 = I_2 - \frac{I_2}{4}$

$I_1 = \frac{3I_2}{4}$ → put this in eqⁿ ①

$$\frac{\cancel{2}\times 3 I_2}{4} + I_2 \times 4 = 4$$

$$\frac{6 I_2}{4} + I_2 \times 4 = 4$$

$$\frac{6 I_2 + 4 I_2 \times 4}{4} = 4$$

$$22 I_2 = 4 \times 4$$

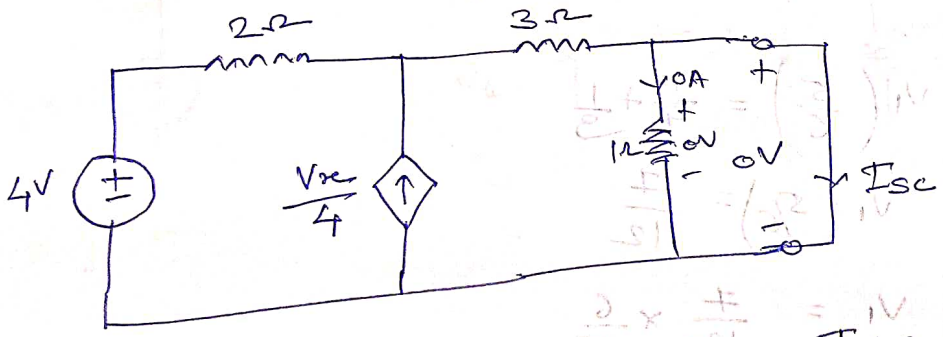
$$I_2 = \frac{16}{22} A = \frac{8}{11} A$$

$$\boxed{V_{th} = I_2 = \frac{8}{11} A}$$

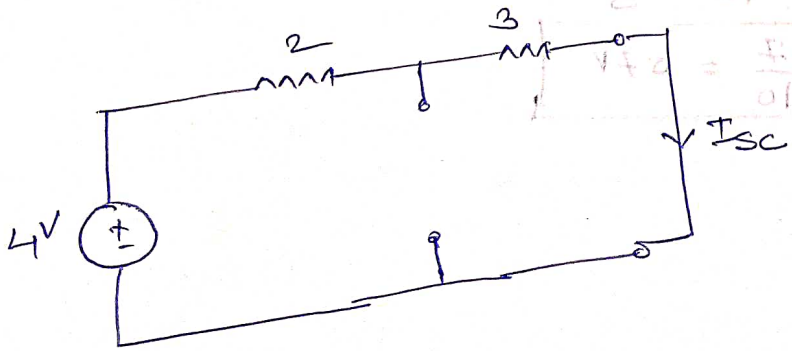
* In such cases there are two methods to <u>find Rth</u>

Method 1:- By finding the s.c. ~~terminal~~ current Isc through ab terminal then $R_{th} = R_N = R_{eq} = \frac{V_{th}}{I_{sc}}$.

* Do not touch any source (I.S. or D.S.)



$$I_{sc} = \frac{4}{5} A$$



$$R_{th} = \frac{V_{th}}{I_s} = \frac{8/11}{4/5} = \frac{40}{44}\Omega$$

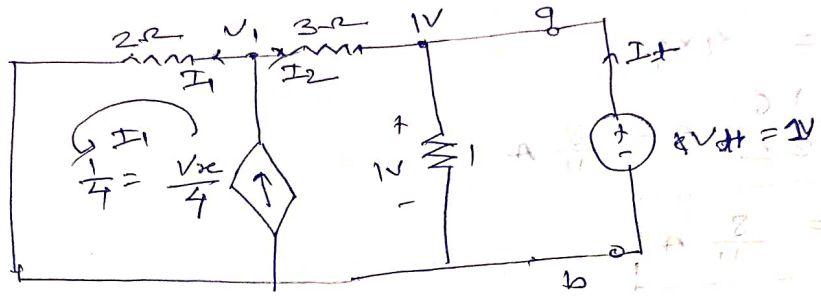
$$= 0.909\Omega.$$

Method 2:- test voltage approch (universal method)

universal method valide for all cases

I.V.S — deactivate = 0V = S.C

I C S — deactivate = OC = 0A



$$R_{th} = R_N = \frac{V_t}{I_t} = \frac{1}{I_t}$$

Apply Nodal analysis

$$V_1\left(\frac{1}{2}+\frac{1}{3}\right) - \frac{1}{3} = \frac{1}{4}$$

$$\cancel{V_1\left(\frac{1}{2}\right) = \frac{1}{4}}$$

$$\cancel{V_1 = \frac{2}{4}}$$

$$\cancel{V_1 =}$$

$$V_1\left(\frac{5}{6}\right) = \frac{1}{4}+\frac{1}{3}$$

$$V_1\left(5/6\right) = \frac{7}{12}$$

$$V_1 = \frac{7}{12} \times \frac{6}{5}$$

$$\boxed{V_1 = \frac{7}{10} = 0.7V}$$

$$I_1 = \frac{V_1}{2} = \left(\frac{0.7}{2}\right) A$$

$$I_2 = \frac{V_1 - 1}{3} = \frac{0.7 - 1}{3} = \frac{-0.3}{3} = -0.1\,A.$$

Apply KCL at node 'p'

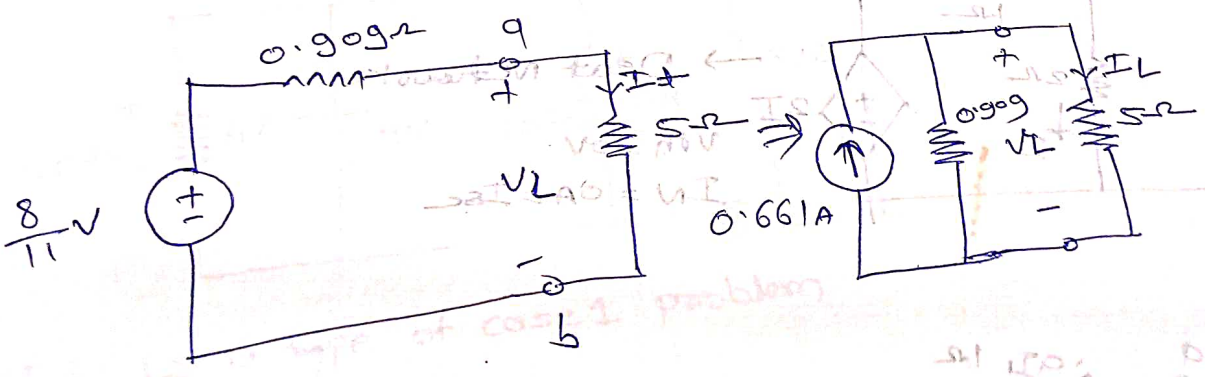
$$I_2 + I_t = 1$$

$$I_t = 1 + I_2$$

$$I_t = 1 + 0.1 = 1.1\,A$$

$$R_{th} = \frac{V_t}{I_t} = \frac{1}{1.1}$$

$$\boxed{R_{th} = 0.909\,\Omega}$$



Lect - 35

Case 03:- (Network having Resistor & Dependent source)

--- Dead Network

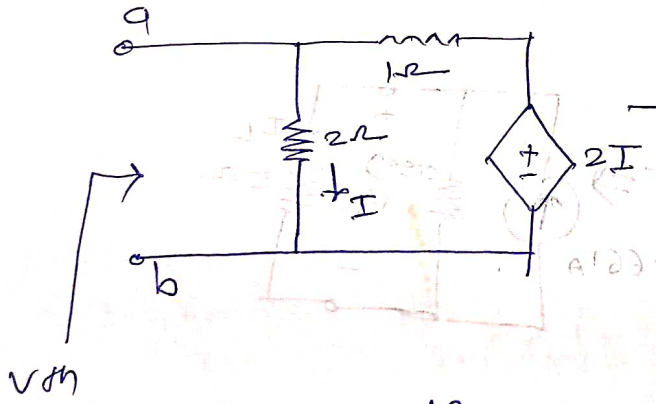
$V_{th} = 0V$, $I_N = I_{sc} = \frac{V_{th}}{R_{th}} = \frac{0}{R_{th}} = 0A.$

$R_{th} = R_N = R_{eq}$ will only exist.

we will apply only test voltage approach.

$R_{th} = \frac{V_t}{I_t} = \frac{1}{I_t}$

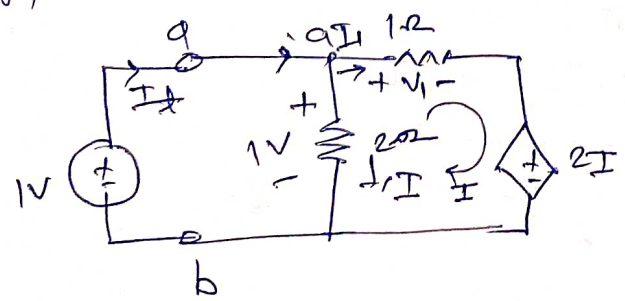
e.g:-



→ Dead Network

$V_{th} = 0V$.

$I_N = 0A = I_{sc}$



Sol^n:- $I = \frac{1}{2} = 0.5A$

$\therefore 2I = 2 \times 0.5$

$= 1V$

$1 - I_1 - 2I = 0$

$I_1 = 1 - 2I$

$I_1 = 1 - 1$

$\boxed{I_1 = 0A}$

KCL at node a

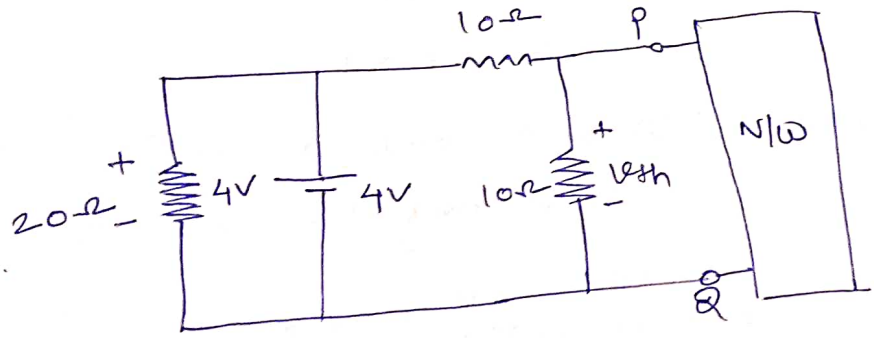
$I_t = I_1 + I$

$= 0 + 0.5$

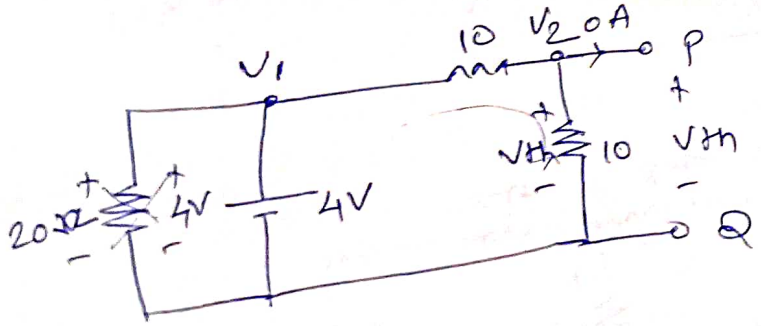
$I_t = 0.5$

$$\boxed{R_{th} = \frac{1}{I_t} = 2\Omega}$$

Q6) Find the thevenin equivalent across PQ terminal in the given network.



I_t is a type of case 1 problem



- $V_1 = 4V$
- $V_{th} = V_2$
- Apply Nodal
- $V_1 = 4V$ — ①
- $V_2\left(\frac{1}{10} + \frac{1}{10}\right) - V_1\left(\frac{1}{10}\right) = 0$ — ②
- $V_2 = V_{th}$

$$V_{th}\left(\frac{1}{10} + \frac{1}{10}\right) - \frac{4}{10} = 0$$

$$V_{th}\left(\frac{2}{10}\right) - \frac{4}{10} = 0$$

$$V_{th} = \frac{4}{10} \times \frac{10}{2} = 2V.$$

Method ②

$$* \quad I = \frac{4 - V_{th}}{10} \quad — ①$$

$$I = \frac{V_{th}}{10} \quad — ②$$

$$\frac{V_{th}}{10} = \frac{4 - V_{th}}{10}$$

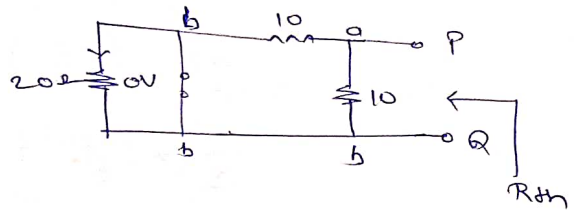
$$\frac{V_{th}}{10} = \frac{4}{10} - \frac{V_{th}}{10}$$

$$\boxed{V_{th} = 2V}$$

Step 02:- Finding Rth

I.V.S → S.C

I.C.S → O.C.



$10 \| 10 = 5\Omega = R_{th}$

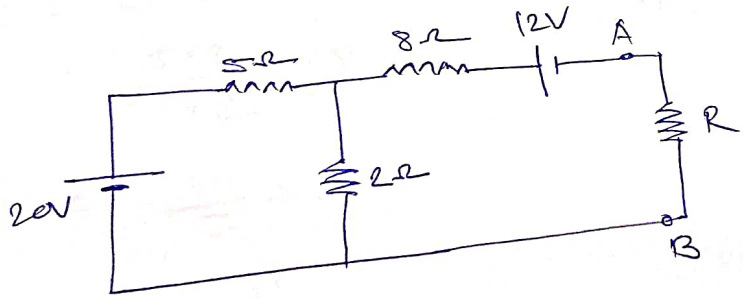
$R_{th} = \frac{10}{2} = 5\Omega$

$V_{th} = 2V$

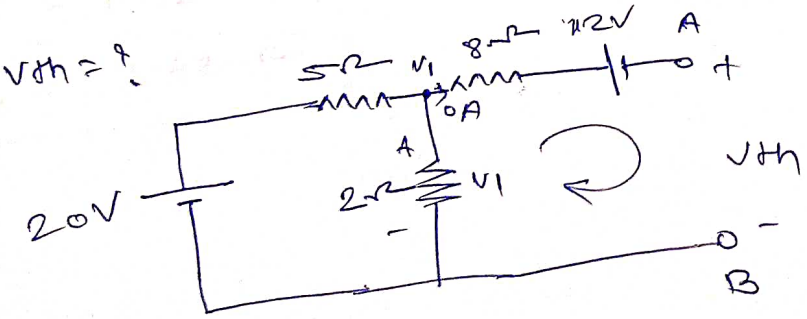
$I_{sc} = I_N = \frac{V_{th}}{R_{th}} = \left(\frac{2}{5}\right) A.$

Lect- 36

Q7) Find the value of Vth & Rth across 'ab' terminal of the ckt given below.



Soln Vth = ?



Apply KVL in loop

$$20 - I(5+2) = 0$$

$$20 - I(7) = 0$$

$$\frac{20}{7} = I$$

$$\boxed{2.85 = I}$$

$$V_{5\Omega} = I \times 5$$

$$= 2.85 \times 5$$

$$= 14.28$$

5.71

$$20 - 14.28 - V_1 = 0$$

UDR

$$\boxed{V_1 = \frac{20 \times 2}{7} = \frac{40}{7} V}$$

Applying KVL

$$V_1 - 12 - V_{th} = 0$$

$$\frac{40}{7} - 12 = V_{th}$$

$$\boxed{-6.28 = V_{th}}$$

also ~~by~~ Nodal

$$V_1\left(\frac{1}{5}+\frac{1}{2}\right)=\frac{20}{5}$$

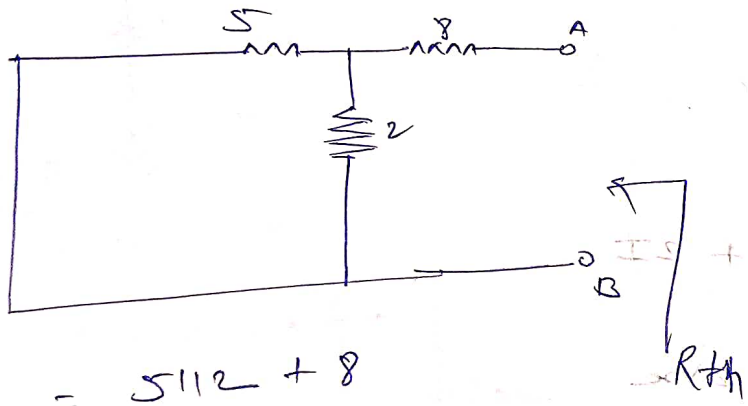
$$V_1\left(\frac{2+5}{10}\right)=\frac{20}{5}$$

$$V_1\left(\frac{7}{10}\right)=\frac{20}{5}$$

$$V_1=\frac{20}{5}\times\frac{10}{7}$$

$$\boxed{V_1=\frac{200}{45}=\frac{40}{7}V}$$

find R_{th} ?



$$R_{th}=5\|2+8$$

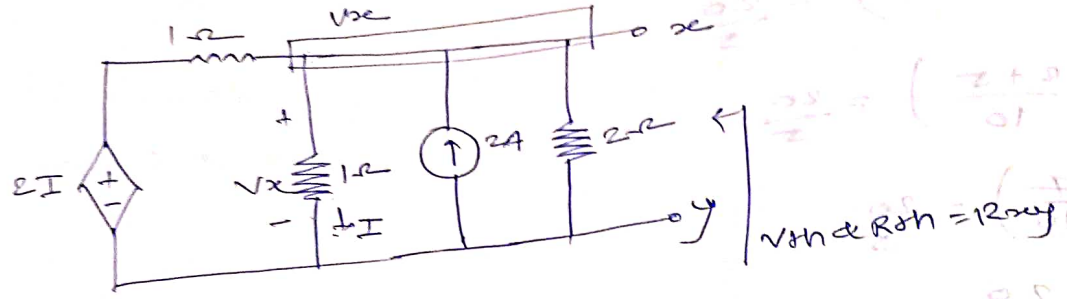
$$=\frac{5\times2}{5+2}+8$$

$$=\frac{10}{7}+8$$

$$=1.42+8$$

$$\boxed{R_{th}=9.42\,\Omega}$$

2.8) Find the value of R_{xy} in the N/W shown below.



Sol^n:→

$$I_{sc} = \frac{V_{th}}{R_{th}}$$

$$I \times 1 = V_x$$

$$\boxed{I = V_x}$$

$$2 \times I = 2 \times V_x$$

Nodal Analysis

$$V_x\left(\frac{1}{1} + \frac{1}{2} + \frac{1}{1}\right) = 2 + 2I$$

$$V_x\left(\frac{1}{1} + \frac{1}{2} + \frac{1}{1}\right) = 2 + 2V_x$$

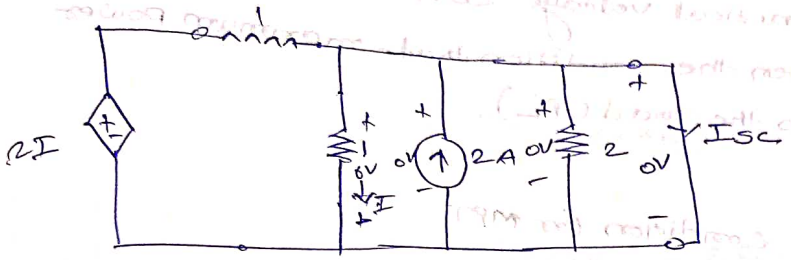
$$V_x(2.5) = 2 + 2V_x$$

$$V_x(2.5 - 2) = 2$$

$$\boxed{V_x = \frac{2}{0.5} = 4V}$$

$R_{th} = \frac{V_{th}}{I_{sc}}$

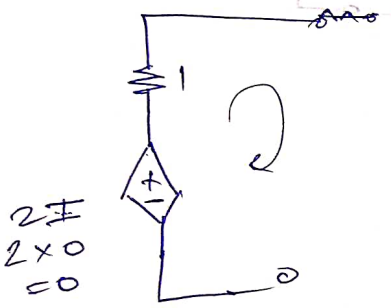
$I_{sc} = ?$



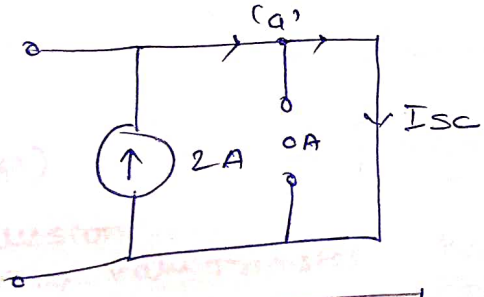
Short ckt = voltage = 0V

open ckt = current = 0 A

$\frac{0V}{1} = 0A$



$= I = \frac{0}{1} = 0$



$\boxed{I_{sc} = 2A}$

$\boxed{R_{th} = \frac{4}{2} = 2\Omega}$

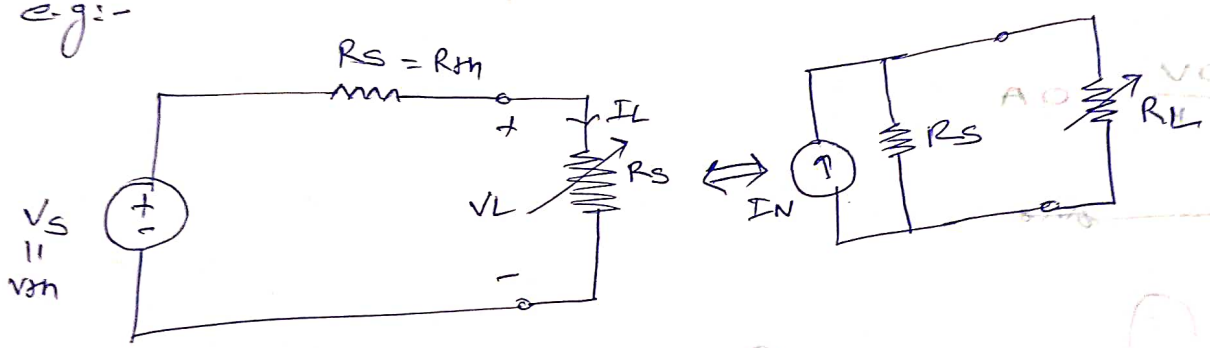
Lect- 37

Maximum power Transfer theorem (MPT)

* Lets assume a practical voltage source is feeding a variable load R_L then the condition that maximum power will be transfered to the load (R_L).

$\boxed{\text{when } R_L = R_S}$ --- condition for MPT

e.g:-



* $P_L = V_L * I_L = (I_L \cdot R_L) \times I_L$

$V_L = I_L \cdot R_L$

$$\boxed{P_L = I_L^2 \times R_L} \quad \text{---} (1)$$

* $I_L = \dfrac{V_S}{(R_S + R_L)}$ --- (2)

* from eqn (1) & (2)

$$P_L = \frac{V_S^2}{(R_S + R_L)^2} \times R_L \quad \text{---} (3)$$

For maxima,

$$\frac{dP_L}{dR_L} = 0 \Rightarrow \frac{(R_S+R_L)^2 \times V_S^2 - V_S^2 R_L \frac{d}{dR_L}(R_S^2+R_L^2+2R_SR_L)}{(R_S+R_L)^4}$$

$$= V_S^2\left[(R_S+R_L)^2 - R_L(0+2R_L+2R_S)\right] = 0$$

$$= \left[(R_S+R_L)^2 - 2R_L^2 - 2R_SR_L\right] = 0$$

$$= R_S^2 + R_L + 2R_SR_L - 2R_L^2 - 2R_SR_L =$$

$$= R_S^2 + R_L^2 - 2R_S^2$$

$$= R_L - R_S \qquad \therefore R_S = R_L$$

$$= R_S^2 + R_L^2 + 2R_SR_S - 2R_L^2 - 2R_S^2 = 0$$

$$= -R_S^2 - R_L^2 + 2R_SR_L = 0$$

$$= (R_S - R_L)^2 = 0$$

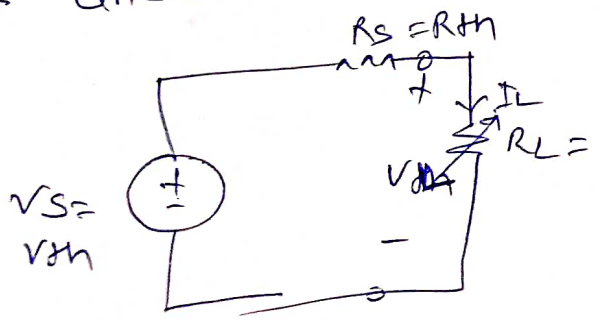
$$= \boxed{R_S = R_L}$$

(vvv Imp)

Conclusion

for max. value transfer $R_S = R_L$ when R_L is variable.

* Load must be variable
* under MPT ($R_L \neq R_S$)



* under MPT condition → $P_{L\,max} = \frac{V_s^2}{(R_s+R_L)^2} \times R_L$

$$= \frac{V_s^2}{(2R_s)^2} \times R_s$$

$$= \frac{V_s^2}{4R_s}$$

* under MPT condition

$$P_{source} = V_s * I_L$$

$$= V_s \times \frac{V_s}{2R_s}$$

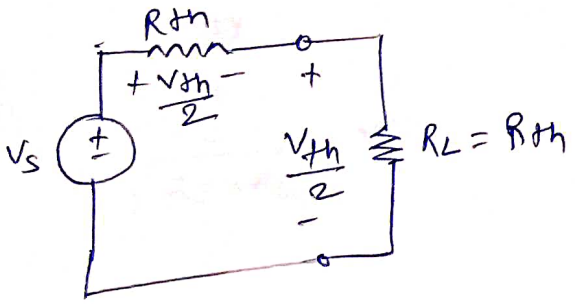
$$P_{source} = \frac{V_s^2}{2R_s}$$

* under MPT condition efficiency

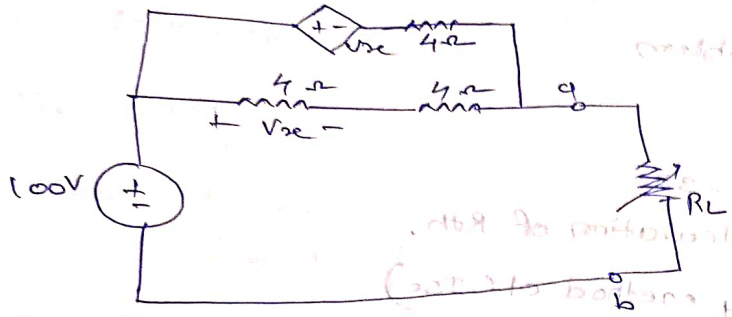
$$\eta = \frac{P_{Load}}{P_{source}} = \frac{V_s^2}{4R_s} \times \frac{2R_s}{V_s^2} = \frac{2}{4} = \frac{1}{2} = 0.5$$

$$= 0.5 \times 100 = 50\%.$$

* under MPT condition



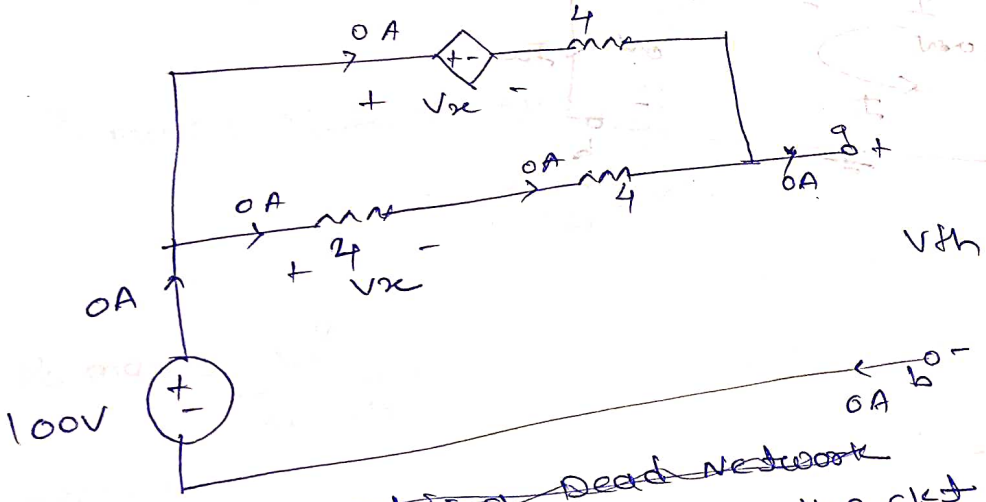
Q.9) Find the value R_L for ~~RD~~ $P_{L\,max}$.



* first of all find the thevenin model across the terminal where maximum power has been asked.

Sol:-

Step 01:- $V_{th} = ?$



~~(This is a Dead Network~~

current will not flow in the ckt even though I.V.S is present.

$\therefore$ $\boxed{V_{th} = 100V}$

Step 2 :- $R_{th} = ?$

case:-2 problem

$$R_{th} = \frac{V_{th}}{I_{sc}}$$

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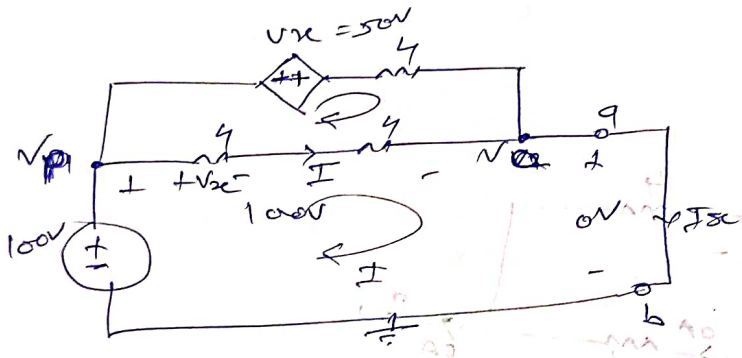
* To find for the calculation of R_{th}, we are going to apply method 01 (I_{sc})

$$R_{th} = \frac{100}{I_{sc}}$$



$V_p = 100V$

$V_a = 0V$

$$I = \frac{100-0}{8}$$

$$I = \frac{100}{8} A$$

$$* V_x = I \times 4$$

$$= \frac{100}{8} \times 4$$

$$\boxed{V_x = 50V}$$

150

$* \; 50 - I_2 \times 4 + 100 = 0$

$I_2 = \frac{150}{4} \; A$

$I_{sc} = I + I_2$

$= \frac{100}{8} + \frac{150}{4}$

$\boxed{I_{sc} = 50A}$

$R_{th} = \frac{100}{50} = 2\Omega$

$\boxed{R_L = R_{th} = 2\Omega}$

$P_{L\,max} = V_L I_L = 50 \times \frac{100}{4}$

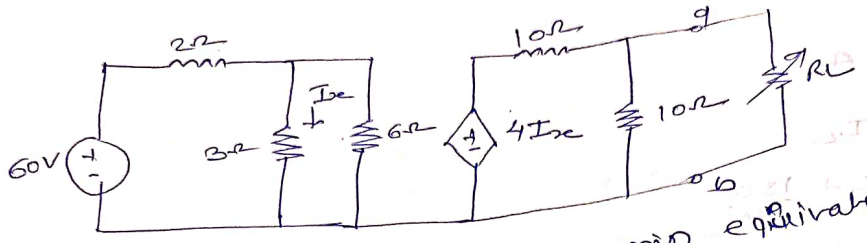
$= \frac{5000}{4} \; W.$

$\therefore \; P_{L\,max} = \frac{V_s^2}{4 \cdot R_{th}}$

$= \frac{100 \times 100}{4 \times 2}$

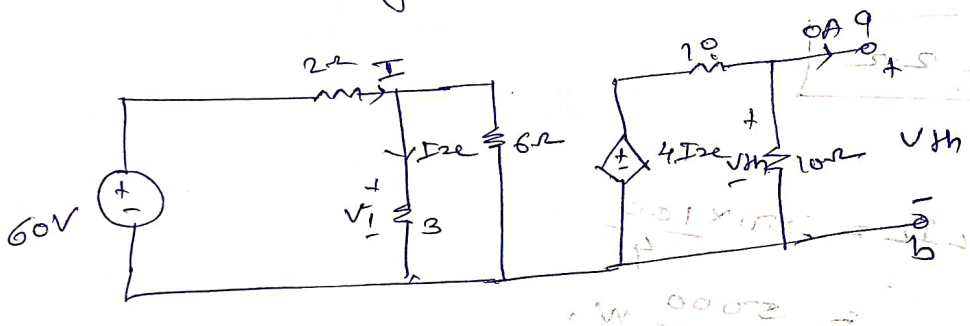
$= 1250 \; W. = \frac{5000}{4} \; W.$

2.10)



* for MPT first find thevenin equivalent across a b terminal.

Step 01:- finding the Vth



~~VDR~~

$$V_1 = \frac{V \times 3}{R_{eq}}$$

$$= \frac{60 \times 3}{4}$$

$$V_1 = 45$$

Sol^n:- $V_{th} = \frac{4I_x}{2}$

$$6 \| 3 = \frac{6 \times 3}{6+3} = 2\Omega$$

$$I = 10/6 = 1.5A$$

* CDR

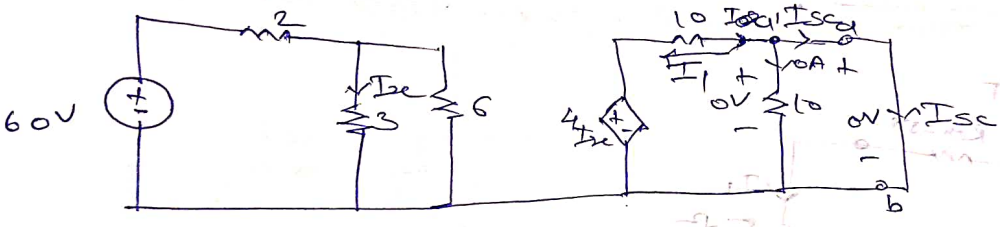
$$I_x = \frac{I \times 6}{9} = \frac{15 \times 6}{9} = \frac{90}{9} = 10A$$

--- CDR.

$$\therefore V_{th} = \frac{4 I_x}{2} = \frac{40 \times 10}{2} = \frac{40}{2} = 20V.$$

step 2 ⇒ $R_{th} = ?$

(It is a case 2 problem)

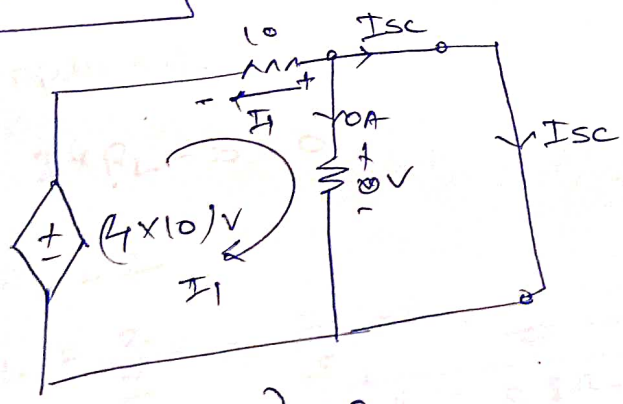


writing KCL at node 'a'

$$I_1 + I_{sc} = 0$$

$$\boxed{I_{sc} = -I_1}$$

$$\boxed{I_x = 10A.}$$



$$40 + (I_1 \times 10) = 0$$

$$I_1 = \frac{40}{10} = -4A =$$

$$I_{sc} = -I_1 = -(-4) = 4A = I_{sc}.$$

$R_{th} = \frac{20}{4}$

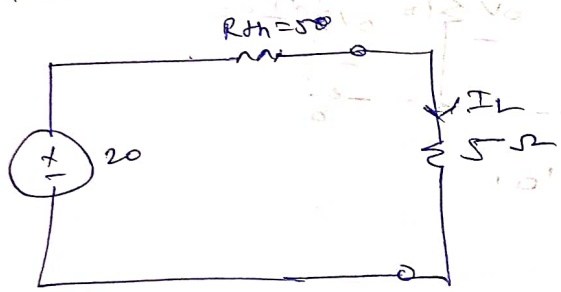
$\boxed{R_{th} = 5\Omega}$

$P_{Lmax} = \frac{(V_{th})^2}{4R_{th}}$

$= \frac{(20)^2}{4 \times 5}$

$\boxed{P_{Lmax} = 20W}$

under MPT



$P_{Lmax} = I_L^2 R_L$

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

$= \frac{(20 \times 20) \times 5}{4 \times 5}$

$\boxed{P_{Lmax} = 20W}$

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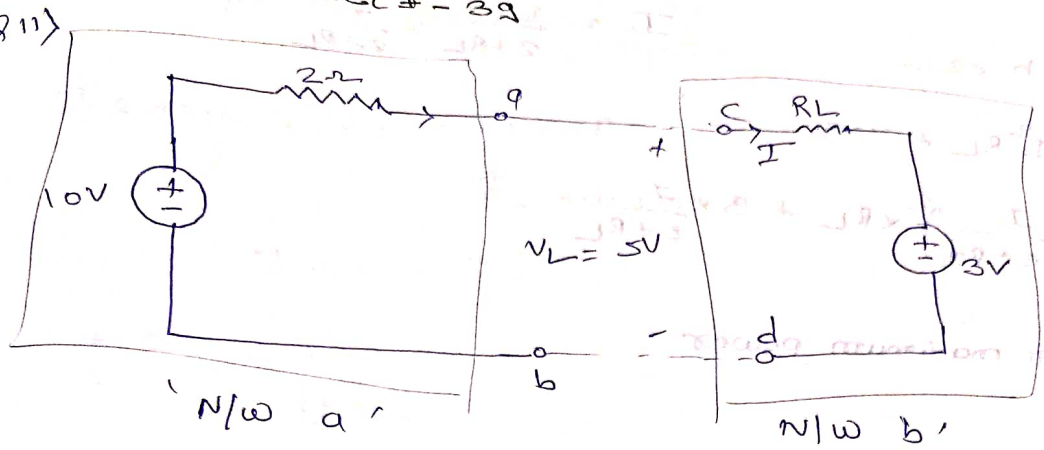
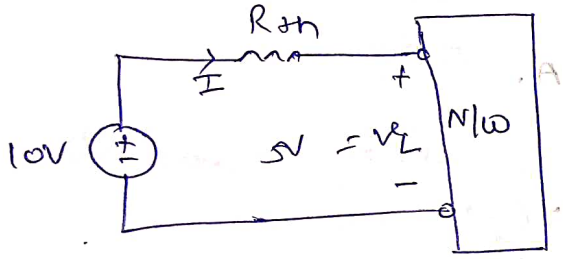
Q11)



$R_L \rightarrow$ variable $\rightarrow R_L = ? \rightarrow$ under MPT



$$V_L = \frac{V_{th}}{2} = \frac{10}{2} = 5V$$

Approach 01:- $\frac{5}{2}$ A = I_{R_L} = I_{3V} = I = $I_{2\Omega}$

Apply KVL

$$5 - I \times R_L - 3 = 0$$

$$I \times R_L = 2$$

$$R_L = \frac{2}{I} = \frac{2}{5} \times 2 = \frac{4}{5}\Omega$$

$$\boxed{R_L = 0.8\Omega}$$

$$I = \frac{10-3}{2+R_L} = \frac{7}{2+R_L}$$

Approch 02:-

$$P_B = I^2 R_L + 3 \times I$$

$$P_B = \left(\frac{7}{2+R_L}\right)^2 \times R_L + 3 \times \frac{7}{2+R_L}$$

for maximum power

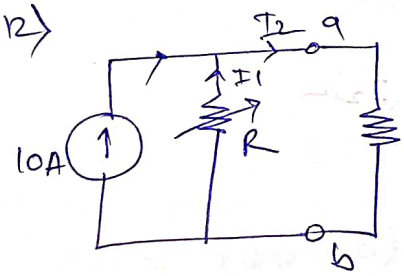
$$\frac{dP_B}{dR_L} = 0$$

$\therefore R_L = \frac{4}{5}\,\Omega$ go for shortest approch (1)

$$I = \frac{10-3}{2+4/5} = \frac{7\times 5}{10+4} = \frac{35}{14}\,A.$$

$$I \times 10 = \frac{10 \times 35}{14} = \frac{350}{14}\,W.$$

Q12)



$2\,\Omega$ = load

load is not variable

$\therefore R_L \neq R_{th} \neq R_s$

$R = ?$

$\boxed{R = 2}$ X

* To get max. power in $2\,\Omega$ resistor.

$I = (I_1 + I_2) \Rightarrow I_2 = I - I_1$

$= 10 - I_1$

I_{2max} when $= I_1 = 0A$

$\frac{1}{R} \to \infty \ (\infty)$

$I_2 = 10 - I_1$

* $I_1 = \frac{I \times 2}{(R+2)}$

$I_1 = \frac{2 \times 10}{2+R}$ I_1 is minimum when ~~power~~ is max.

$R + 2 = \infty$

$R = \infty$

$I_{2max} = \frac{10 \times 2}{R(1+2/R)} = \frac{10}{1+2/R} \Rightarrow \frac{2}{\infty} = 0$

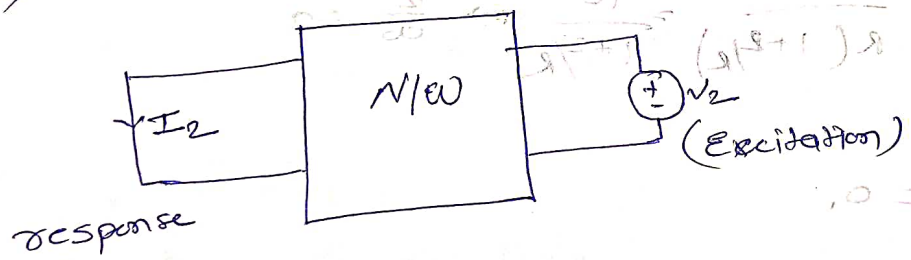
$\frac{d I_2}{dR} = 0.$

(V.V.Imp)

Reciprocity theorem (Black Box)

* ~~Thi~~ - It is applicable to linear & Bilateral network
* It is only valid with Independent sources
* It is <u>not valid</u> in dependent source.
*

⇒



* $\left[\frac{I_1}{V_1} = \frac{I_2}{V_2}\right]$ — reciprocal N/W

* N/W structure must remain same

Imp

* It is valid with single Independent source.

* if Network having more than one independent source then apply reciprocity along with the superposition theorem.

Lect-40

Q 2.13)

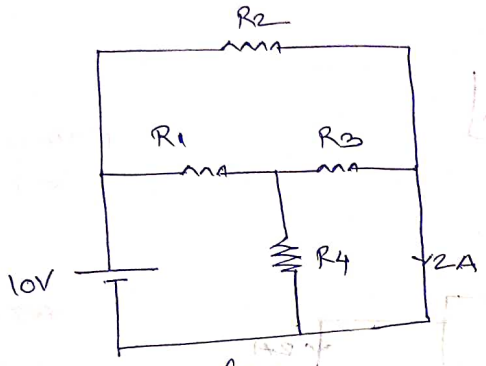


fig.a

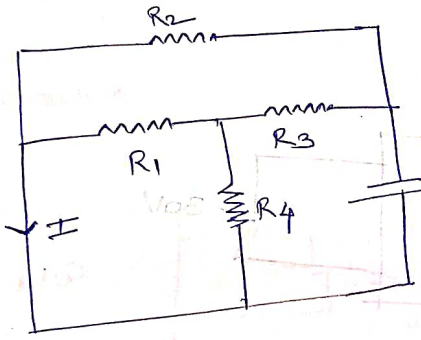
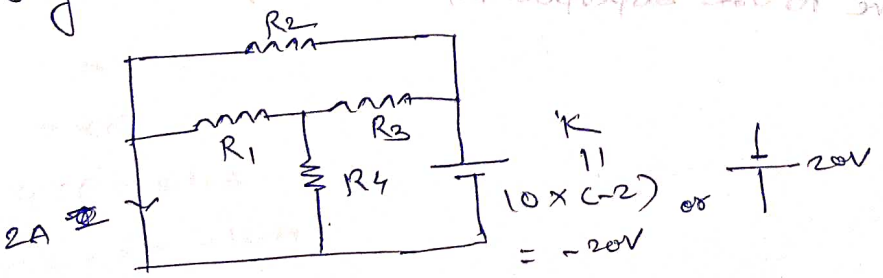


fig.b

Sol:- Network structure is same

* Applying reciprocity theorem in fig a



$[I = -4A]$

$\times \quad \frac{2}{10} = \frac{I}{-20} \Rightarrow \frac{I_1}{V_1} = \frac{I_2}{V_1}.$

$= I = \frac{-20 \times 2}{10}$

$\boxed{I = \frac{-40}{10} = -4A.}$

2.14)

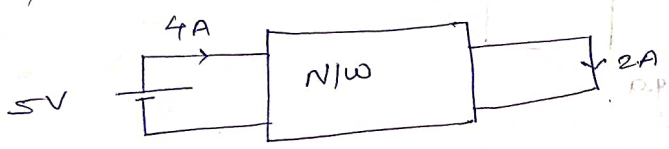


Fig.a

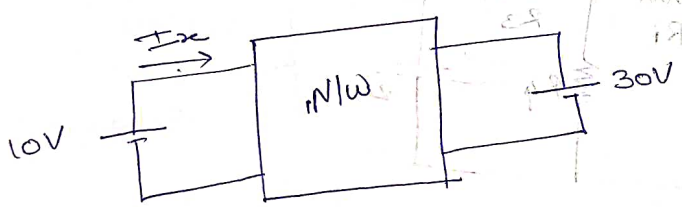


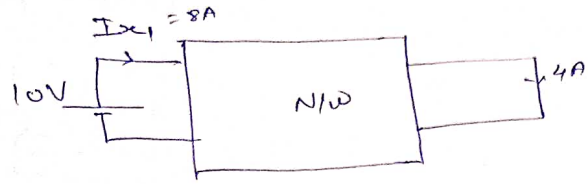
Fig.b

$I_x = ?$

sol:- I_x (response) $\rightarrow f(10V, 30V)$

i.e. we have to use superposition theorem

Step01 10V → active
30V → deactive (S.C)



compare with fig.a

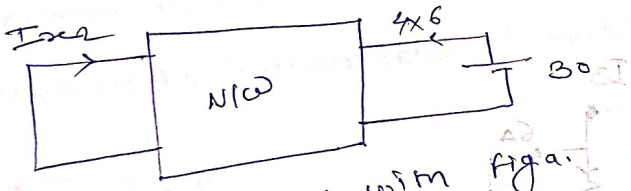
Scalling

~~V = 10V~~ K = scalling
5V × 2 = 10V

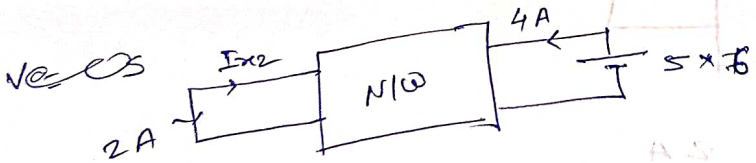
K = 2

∴ 4×2 = I_{x1} = 8A
∴ 2×2 = 4A.

Step02 :- 30V active
10V deactive



compare with fig.a.



K = 6

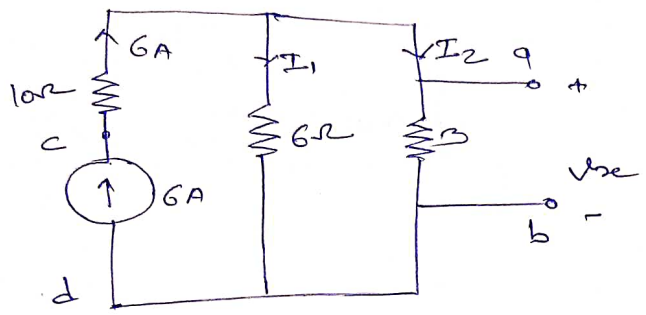
V = 5×6
I = 4×6 = 24A
I_{x2} = −2×6 = −12A.

$I_x = I_{x1} + I_{x2}$

$= 8 - 12$

$\boxed{I_x = -4A}$

Q

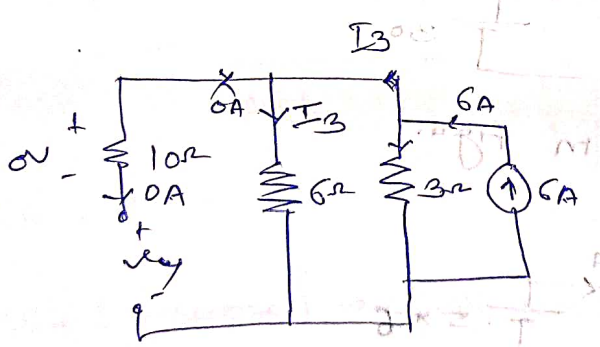


* $I_2 = \frac{6 \times 6}{9}$ — CDR

$\boxed{I_2 = 4A}$

$V_x = I_2 \times 3 = 4 \times 3 = 12V$

*



$I_3 = \frac{6 \times 3}{9} = 2A$

$I_4 = 6 - 2$

$= 4A.$

* Applying KVL in the loop shown

$v_y - I_3 \times 6 = 0$

$v_y = I_3 \times 6$

$v_y = 2 \times 6$

$\boxed{v_y = 12V}$

Hence $V_x = V_y = 12V$.

Tellegence Theorem

* This is nothing but power conservation principle.

$$\boxed{\sum_{i=1}^{n} P_i = 0}$$

— Tellegence theorem

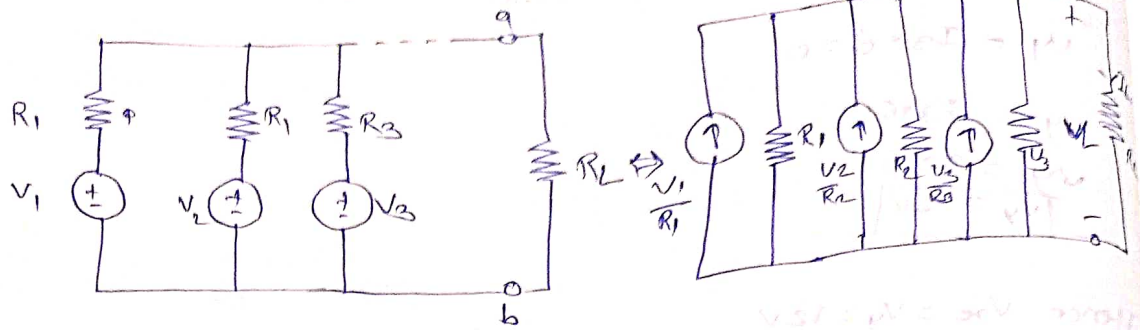
Lect-41

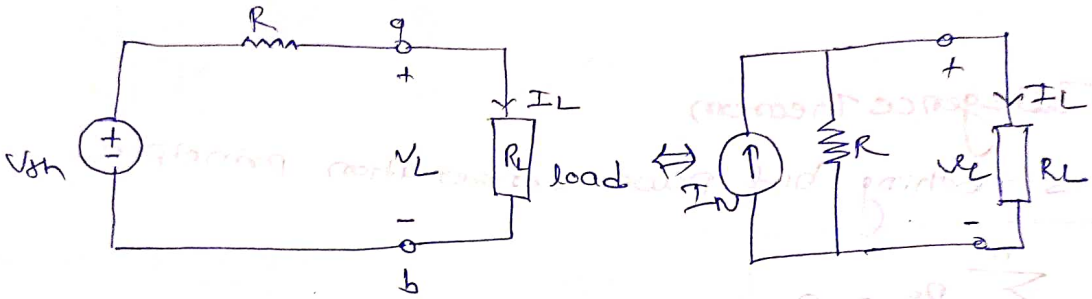
* This theorem is valid for any kind of element or network.
* This theorem is independent of nature of element.

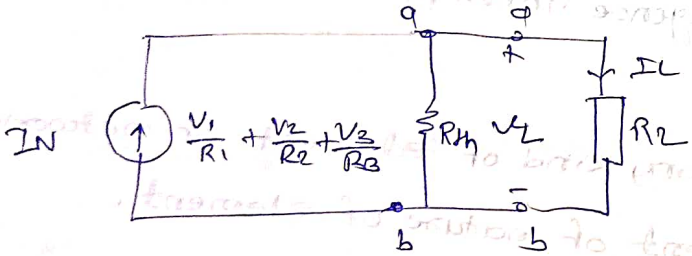
$$\sum V \cdot I = 0$$

Millman's Theorem

*

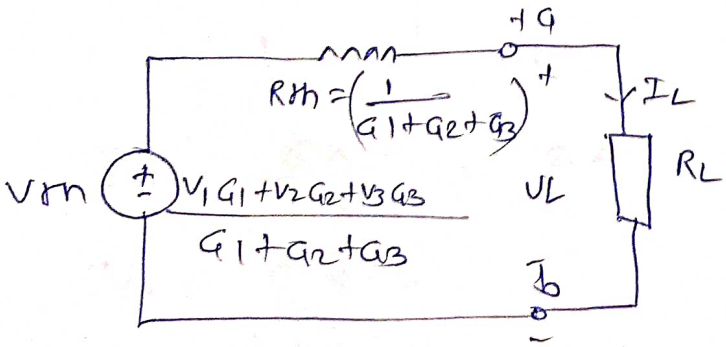






$$R_{th} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} = \left(\frac{1}{G_1}+\frac{1}{G_2}+\frac{1}{G_3}\right) = R_1+R_2+R_3$$

$$I_N = V_1G_1 + V_2G_2 + V_3G_3$$

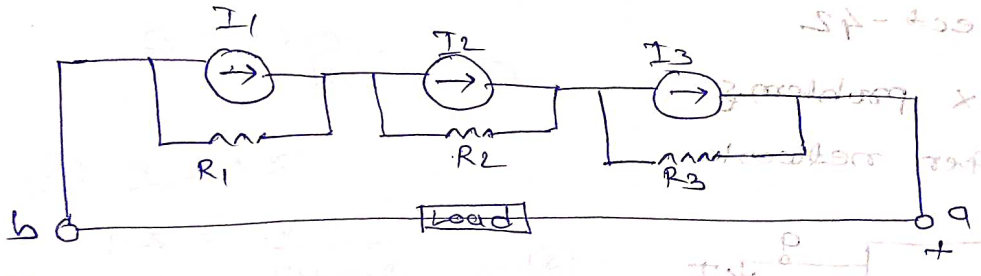


* if 'n' number of practical voltage source are connected in parallel, then its equivalent can be written as,

$$V_{th} = \frac{V_1G_1 + V_2G_2 + V_3G_3 + V_4G_4 + \cdots + V_nG_n}{G_1 + G_2 + G_3 + G_4 + \cdots + G_n}$$

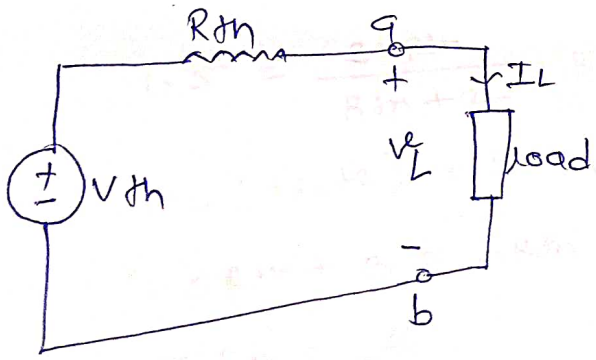
$$R_{th} = \frac{1}{G_1 + G_2 + G_3 + G_4 + \cdots + G_n}$$

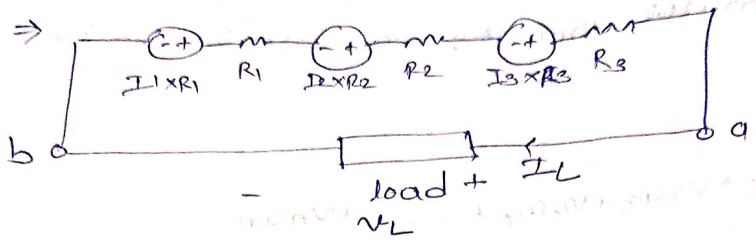
Dual millman's Theorem



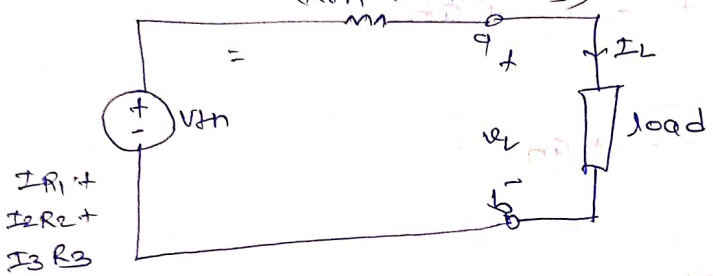
* find the equivalent across AB terminal

*





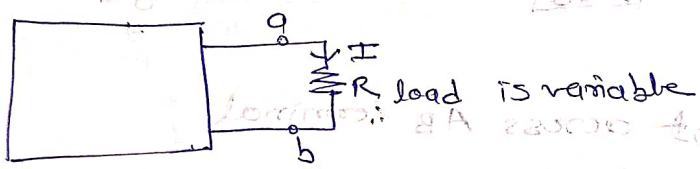
$(R_{th} = R_1 + R_2 + R_3)$



Lect - 42

Mix problems

Q) In the given network

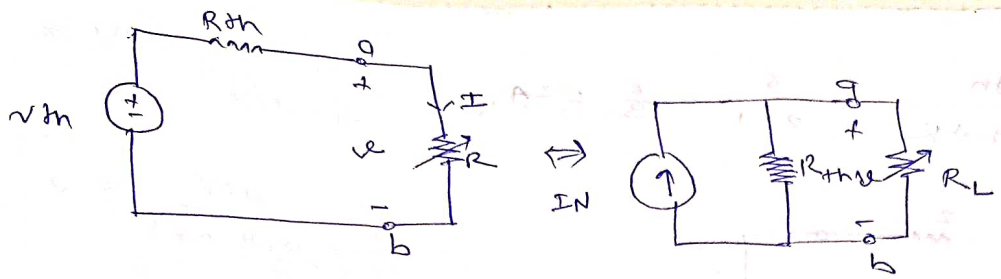


$R = 0$, then $I = 3A$

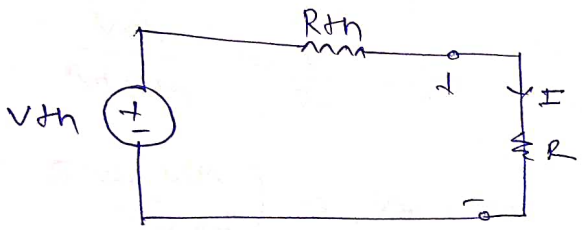
$R = 2\Omega$, then $I = 1.5A$

$R = 1\Omega$, then $I = ?$

* {R → variable}



* approach 01 :- Thevenin model



$I = \frac{V}{R} = \frac{V_{th}}{R_{th}+R}$

① $I = 3A$

$3 = \frac{V_{th}}{R_{th}}$ —①

② $I = 1.5$

$1.5 = \frac{V_{th}}{R_{th}+2}$ —②

From eqn ① & ②

$1.5 = \frac{3 \times R_{th}}{R_{th}+2}$

$1.5(R_{th}+2) = 3R_{th}$

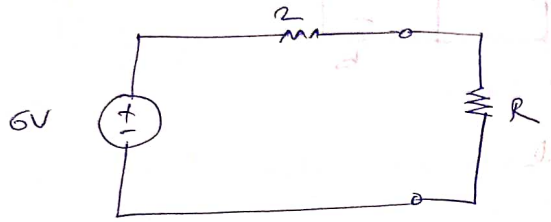
$1.5R_{th} + 3 = 3R_{th}$

$1.5R_{th} = 3$

$R_{th} = \frac{3}{1.5} = 2\Omega$

* $V_{th} = 3R_{th} = 2 \times 3 = 6V$

* $I = \frac{V_{th}}{R_{th}+R} = \frac{6}{2+1} = \frac{6}{3} = 2A.$

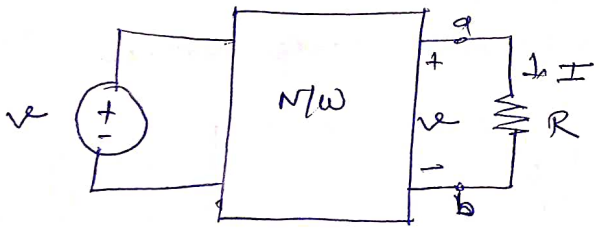


* under MPT

$$\boxed{R = R_{th} = 2\Omega}$$

$$P = \frac{V_{th}^2}{4R_{th}}$$

Q46)

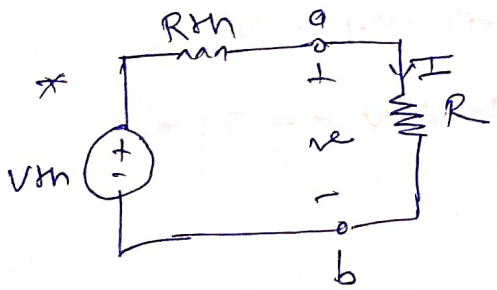


when $R = \infty$, $V = 5V$

$R = 0$, $I = 2.5A$

$R = 3\Omega$, $V = ?$

*



$$* \; V = \frac{V_{th} \times R}{R_{th} + R} \longrightarrow V.D.R$$

$$\left[V = \frac{V_{th}}{\left(1 + \frac{R_{th}}{R}\right)} \right] \quad -(1)$$

$$I = \frac{V_{th}}{R + R_{th}} = \frac{V}{R} \quad -(2)$$

$$* \; 5 = \left(\frac{V_{th}}{1 + \frac{R_{th}}{0}} \right) \Rightarrow V_{th} = 5V$$

$$* \; I = \frac{V}{R} = \frac{V_{th}}{R_{th} + R}$$

$$2.5 = \frac{V}{0} \Rightarrow 2.5 = \frac{V_{th}}{R_{th} + 0}$$

$$[V = 0V]$$

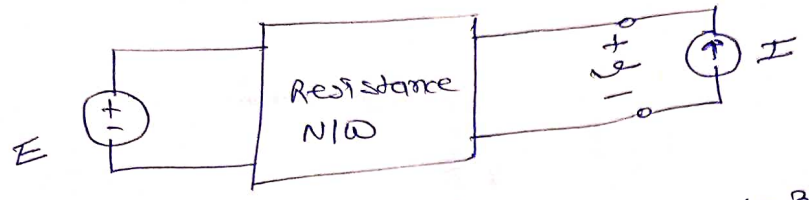
$$\boxed{\frac{V_{th}}{R_{th}} = 2.5 = I_{SC} = I_N}$$

$$* \; R_{th} = \frac{V_{th}}{2.5} = \frac{5}{2.5} = 2\Omega.$$

$$* \; V^{\circ} = \frac{V_{th} \times R}{R_{th} + R} = \frac{5 \times 3}{2 + 3} = \frac{15}{5} = 3V.$$

$$\boxed{V = 3V}$$

Q) In the given circuit,

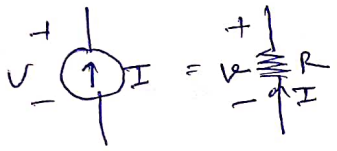


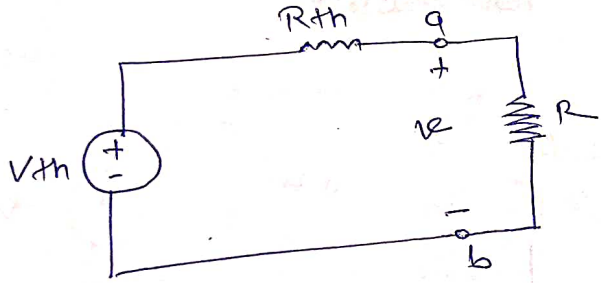
when, $E = 1V$, & $I = 0\,A$, then $V = 3V$

$E = 0V$, $I = 2A$, then $V = 2V$

$E = 1V$ & $I = 2A$, then $V = ?$

Lect-43

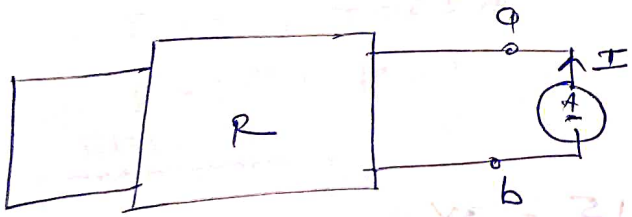




$$V = \frac{V_{th} \times R}{R_{th} \times R}$$

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

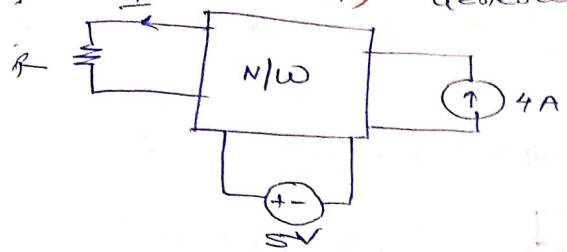
* $V_{th} = 3V$



$$\frac{V}{I} = \frac{2}{2} = 1\Omega = R_{th}$$

$$\Rightarrow V = \frac{3 \times 2}{1+2} = \frac{6}{3} = 2V.$$

Q) (VVV Imp) Generalized concept



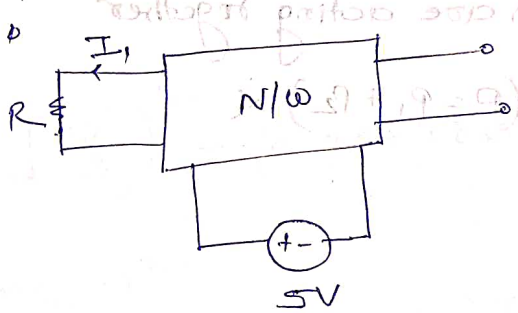
In the given N/W $\frac{50}{9}$ watt is supplied by 5V source & $\frac{32}{9}$ watt. is supplied by 4A current source.

when they are acting alone.

Find the total power due to 5V & 4A source when they are acting together in the Resistor(R).

Sol^n:- concept of power calculation in superposition theorem.

case-I:- when 5V is acting then 4A → deactive → o.c.



$I_1 \rightarrow \oplus$ or $\ominus$

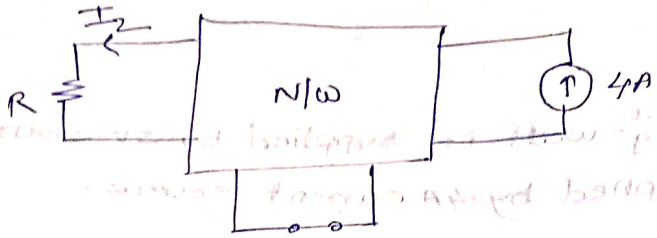
$$P_1 = \frac{50}{9} W = I_1^2 R$$

$$I_1^2 = \frac{P_1}{R}$$

$$\boxed{I_1 = \sqrt{\frac{P_1}{R}}}$$

Case 2:- 4A active

5V → S.C. or



$I_2 \rightarrow$ ⊕ or ⊖

$P_2 = \frac{32}{9} W = I_2^2 R$

$I_2 = \sqrt{\frac{P_2}{R}}$

Case 3:- when both are acting together

$I = I_1 + I_2$ ✓ , $(P = P_1 + P_2)$ ✗

or $I = I_1 - I_2$

or

$-I_1 - I_2 = I$

or

$-I_1 + I_2 = I$

$P_{Total} = I^2 R$

$P = (I_1 + I_2)^2 R$

$P = (I_1^2 + I_2^2 + 2I_1 I_2) R$

$P =$ ---- $(\pm I_1 \pm I_2)$

$$P = \left(\frac{P_1}{R} + \frac{P_2}{R} + \frac{2\sqrt{P_1 P_2}}{R}\right) \cdot R$$

$$= P_1 + P_2 + 2\sqrt{P_1 P_2}$$

$$= \left(\sqrt{P_1} + \sqrt{P_2}\right)^2$$

$$P_{\substack{Total \\ max}} = \left(\sqrt{P_1} + \sqrt{P_2}\right)^2 \quad \text{---} (\pm I_1 \pm I_2)$$

case 2:- $(I_1 - I_2)$ or $(\pm I_1 \pm I_2)$

$$P_{min} = \left(\sqrt{P_1} - \sqrt{P_2}\right)^2 \quad \text{---} (\pm I_1 \pm I_2)$$

$$\boxed{P_{total} = \left(\sqrt{P_1} \pm \sqrt{P_2} \pm \sqrt{P_3} \pm \sqrt{P_4}\right)^2}$$

$$P_{max} = \left(\sqrt{\frac{50}{9}} + \sqrt{\frac{32}{9}}\right)^2 = (2.35 + 1.8856)^2 = 17.94\,W$$

$$P_{min} = \left(\sqrt{\frac{50}{9}} - \sqrt{\frac{32}{9}}\right)^2 = (2.35 - 1.8856)^2 = 0.215\,W$$

If in the exam nothing provide max or min power then consider max. power.

Q 2.37)

$P_1 = 18W$

$P_2 = 50W$

$P_3 = 98W$

$$P_{max} = \left(\sqrt{P_1} + \sqrt{P_2} + \sqrt{P_3}\right)^2$$

$$= \left(\sqrt{18} + \sqrt{50} + \sqrt{98}\right)^2$$

$$= \left(4.24 + 7.07 + 9.89\right)^2$$

$$= 449.8\ W \approx 450W.$$

$$P_{min} = \left(+\sqrt{P_1} + \sqrt{P_2} - \sqrt{P_3}\right)^2$$

$$= \left(4.24 + 7.07 - 9.89\right)^2$$

$$= 2.0164\ W$$

or

$$= \left(\sqrt{P_1} - \sqrt{P_2} - \sqrt{P_3}\right)^2$$

$$= 161.7984\ W. \times$$

Lect-45

ch-03:- Transient Analysis

* This is valid only for inductive or capacitive networks
* It is not valid for Resistive N/w only.
* mainly we will focus on <u>first order ckt</u>

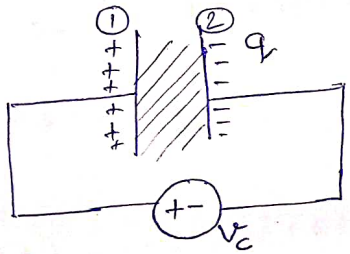
Chapter Based on L & C charging & discharging.

Capacitor

* It is a electrical device which stores energy and the ability due to which it stores energy is known as 'capacitance'.

Capacitance (c) → F or μF

* It has two conducting plates that has been separated by dielectric medium.



* ~~Pf~~

* The charge stored $q \propto V(t)$

$q(t) \propto V_c(t)$

$$\boxed{q(t) = C \cdot V_c(t)}$$

proportionality constant.

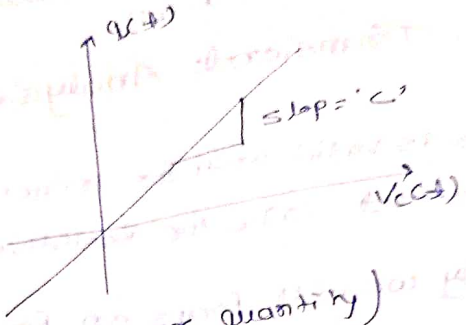
* $q(t) = C V_c(t)$

$\boxed{y = mx}$

after charge

* $q(t) = C V_c(t) \pm q_0$ (initial)

$\boxed{y = mx \pm c}$



C linear quantity

Bilateral quantity

~~Active~~ passive element

This is all true if the initial charge on capacitor is zero.

* (V.V.V Imp) Capacitor current

$$q(t) = C V_c(t) \quad -(1)$$

$$\frac{dq(t)}{dt} = C \cdot \frac{dV_c(t)}{dt}$$

$$i_c(t) = C \cdot \frac{dV_c(t)}{dt} \quad -(2)$$

* capacitor voltage

$$dV_c(t) = \frac{1}{C} i_c(t)\, dt$$

$$\int dV_c(t) = \frac{1}{C}\int i_c(t)\, dt$$

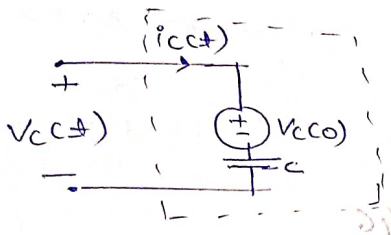
$$V_c(t) = \frac{1}{C}\int_{-\infty}^{t} i_c(t)\, dt$$

$$V_c(t) = \frac{1}{C}\int_{-\infty}^{0} i_c(t)\, dt + \frac{1}{C}\int_{0}^{t} i_c(t)\, dt$$

$$\boxed{V_c(t) = V_c(0) + \frac{1}{C}\int_0^t i_c(t)\,dt}$$

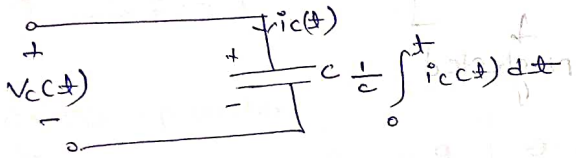
initial voltage
due to initial charge
or past charge

*



→ Total capacitor voltage

* If The capacitor is a uncharge capacitor. then initial charge $V_c(0)$ is s.c. or 0V.



* Instantaneous power

$$P_c(t) = V_c(t) \times i_c(t)$$

where $V_c(t) = V_c(0) + \frac{1}{C}\int_0^t i_c(t)\,dt$

$$i_c(t) = C \cdot \frac{dV_c(t)}{dt}$$

* Stored energy

$$P(t) = \frac{dE(t)}{dt}$$

$$dE(t) = P(t)\,dt$$

$$E(t) = \int P(t)\,dt$$

$$E(t) = \int v_c(t) \cdot i_c(t)\, dt.$$

$$= \int v_c(t) \cdot C \frac{dv_c(t)}{\cancel{dt}} \cancel{dt}$$

$$E(t) = C \int_{-\infty}^{t} \underset{x}{v_c(t)} \cdot \underset{dx}{dv_c(t)}$$

$$= \frac{C}{2} \left[v_c^2(t) \right]_{-\infty}^{t}$$

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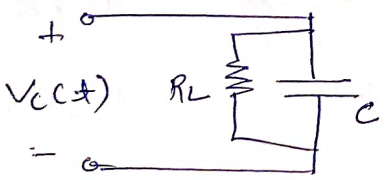
$$= \frac{1}{2} C \left[v_c^2(t) - \underset{\text{neglected}}{v_c^2(-\infty)} \right]$$

$$\boxed{E_c(t) = \frac{1}{2} C v_c^2(t)}$$

It always represent the stored energy from $-\infty$ to t (present)

→ Practical capacitor.

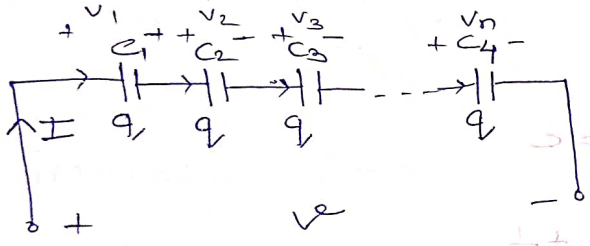


R_L → leakage Resistance (High value)

* Series and parallel operation of capacitor

* To find the equivalent capacitance in series & parallel connected capacitors just do in opposite fashion of series and parallel combination of resistors.

(A) Series operation



$q \longrightarrow f(I)$

* In series operation

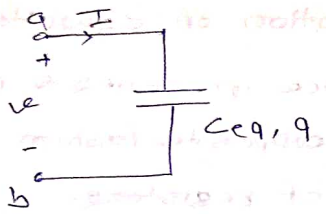
$$\boxed{q_1 = q_2 = q_3 = q_n = q}$$ as current remains same

* $V = V_1 + V_2 + V_3 + V_4 + \cdots + V_n$

$$= \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3} + \frac{q}{C_4} + \cdots + \frac{q}{C_n}$$

$$= q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \cdots + \frac{1}{C_n}\right)$$

$$\left[\frac{V}{q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \cdots + \frac{1}{C_n}\right]$$



$$q = C_{eq} \cdot v$$

$$\frac{v}{q} = \frac{1}{C_{eq}}$$

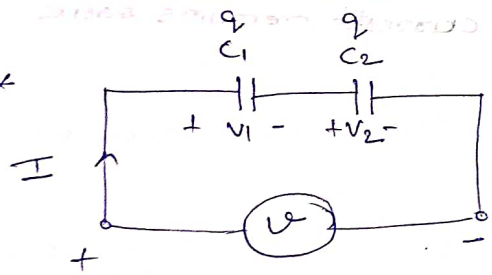
* if $C_1 = C_2 = C_3 = \cdots = C_n = C$

$$\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} + \cdots + \frac{1}{C}$$

$$= \frac{n}{C}$$

$$\boxed{C_{eq} = \frac{C}{n}}$$

*



$$\therefore \boxed{VC = q}$$

$$V_1 = \frac{q}{C_1}, \quad V_2 = \frac{q}{C_2}$$

$$q = C_{eq} \cdot V$$

$$V_1 = C_{eq} \cdot \frac{V}{C_1} \qquad V_2 = C_{eq} \cdot \frac{V}{C_2}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

* $V_1 = \frac{C_1 C_2}{C_1 + C_2} \frac{V_1}{C_1}$ $\qquad V_2 = \frac{C_1 C_2 V}{(C_1 + C_2) C_2}$

Imp

$$\boxed{V_1 = \left(\frac{C_2}{C_1 + C_2}\right) \times V}$$

$$V_2 = \left(\frac{C_1}{C_1 + C_2}\right) \times V$$

* Generalized form

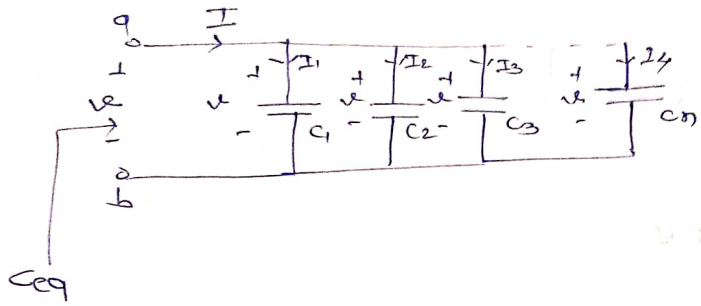
$$\boxed{V_x = \frac{\frac{1}{C_x} \times V}{\sum_{i=1}^{n} \frac{1}{C_i}}}$$ — VDR

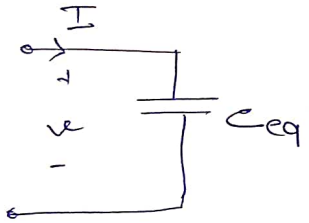
* $C_1 C_2$

$$V_1 = \frac{\frac{1}{C_1} \times V}{\frac{1}{C_1} + \frac{1}{C_2}} = \frac{V}{C_1 \left(\frac{C_1 + C_2}{C_1 C_2}\right)}$$

* $V_1 = \frac{C_2 V}{C_1 + C_2}$.

* parallel operation of capacitor :





* In parallel operation the voltages across each capacitor will remain same but the current or charge flowing through the each capacitor may be same or different.

* $I = I_1 + I_2 + I_3 + --- + I_n$

$q = q_1 + q_2 + q_3 + q_4 + --- + q_n.$

$= C_1V + C_2V + C_3V + --- + C_nV$

$= V(C_1 + C_2 + C_3 + C_4 + --- + C_n)$

$\Rightarrow \frac{q}{V} = C_1 + C_2 + C_3 + --- + C_n$

$C_{eq} = C_1 + C_2 + C_3 + --- + C_n.$

if $C_1 = C_2 = C_3 = C_n = C$

$$\boxed{C_{eq} = n \cdot C}$$

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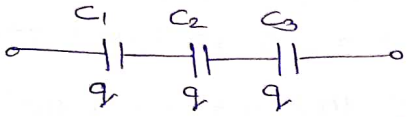
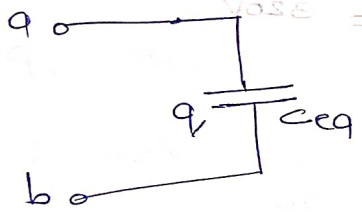
Q1)



$C_1 = 2\mu F$, $C_2 = 5\mu F$, $C_3 = 10\mu F$

$\downarrow$ 200V, $\downarrow$ 500V, $\downarrow$ 100V

The max. safe voltage that can be applied across the 'ab' & total stored charge in effective capacitance across 'ab' terminal?



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$= \frac{1}{2} + \frac{1}{5} + \frac{1}{10}$$

$$= 0.8\mu F = \frac{8}{10}$$

Sol^n:-

* charge will remains same

* $q_{1(max)} = C_1 \times 200$
$= 2\times10^{-6}\times200$
$= 400\mu C$

$q_{2\,max} = C_2 \times 500$
$= 5\times500\times10^{-6}$
$= 2500\mu C$

$q_{3\,max} = C_3 \times 100$
$= 10\times100$
$= 1000\mu C$

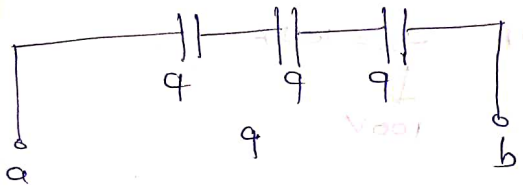
$$\boxed{C_{eq} = \frac{10}{8}\mu F}$$

Q2

$$V_{safe} = \frac{q}{C_{eq}}$$

$$= \frac{q}{\left(\frac{10}{8}\right)\mu F}$$

*



q minimum of $(q_1, q_2 \& q_3)$

$\rightarrow$ $400\mu C$

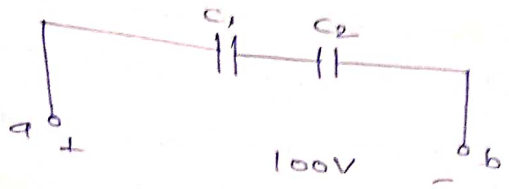
$$\rightarrow V_{safe} = \frac{400\mu C}{\frac{10}{8}} = \frac{400 \times 8}{10} = 320V$$

$$V_1 = \frac{q}{C_1} = \frac{400}{2} = 200V$$

$$V_2 = \frac{q}{C_2} = \frac{400}{5} = 80V$$

$$V_3 = \frac{q}{C_3} = \frac{400}{10} = 40V$$

Q2)

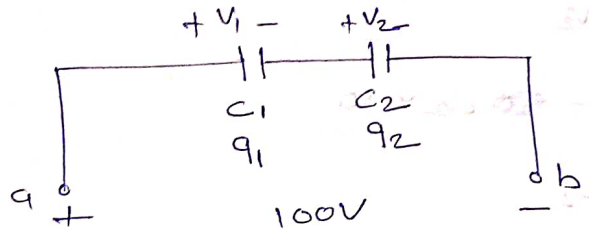


Potential drop $C_1 = 60V$
Potential drop $C_2 = 40V$

A Capacitor of 2μF is now connected in parallel with 'C_1' & potential drop across 'C_2' increases to 90V. the value of C_1 & C_2 are?

Sol^n:-

Case I:-



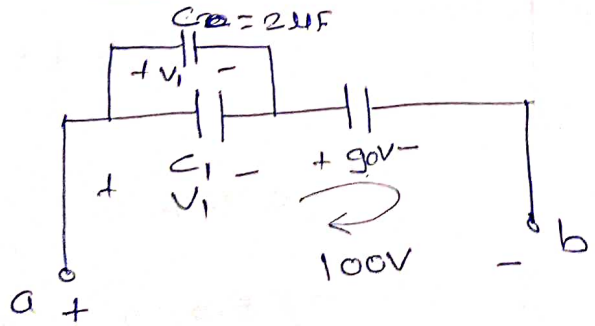
$$q_1 = q_2$$

$$C_1V_1 = C_2V_2$$

$$\frac{C_1}{C_2} = \frac{V_2}{V_1} = \frac{40}{60} = \frac{4}{6} = \frac{2}{3} \quad - (1)$$

$$\frac{C_1}{C_2} = \frac{2}{3} \Rightarrow \boxed{C_1 = \frac{2}{3} C_2}$$

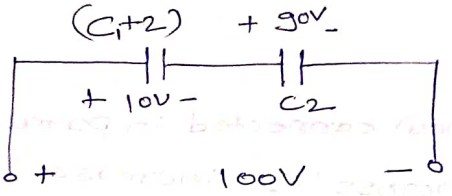
Case II =



$100 - V_1 - 90 = 0$

$100 - 90 = V_1$

$\therefore \boxed{10 = V_1}$



$q_1 = q_2$

$V_1 \times (C_1+2) = C_2 V_2$

$10 \times (C_1+2) = C_2 \times 90$

$C_1 + 2 = 9C_2$ — ②

Put eqⁿ ① in eqⁿ ②

$\frac{2}{3}C_2 + 2 = 9C_2$

$C_2\left(9 - \frac{2}{3}\right) = 2$

$C_2\left(\frac{27-2}{3}\right) = 2$

$C_2\left(\frac{25}{3}\right) = 2$

$C_2 = 2 \times \frac{3}{25}$

$= \frac{6}{25}\ \mu F$

$\boxed{C_2 = 0.24\ \mu F}$

$* C_1 = \frac{2}{3}C_2 = \frac{2}{3} \times 0.24$

$\boxed{C_1 = 0.16\ \mu F}$

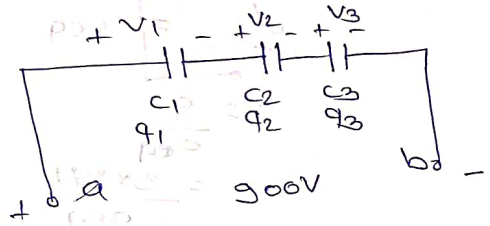
(V Imp)

Q3) Three capacitor are connected in series and charged from 900V. Find the voltage across condensors. Now they have been disconnected from the supply and reconnected with all ~~ca~~ positive plates connected together. Find the voltage across combination and charge on each capacitor after reconnection.

$C_1 \rightarrow 2\mu F$, $C_2 \rightarrow 3\mu F$, $C_3 \Rightarrow 5\mu F$

Sol^n:-

Case I



* Ceq across ab

$$\frac{1}{C_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{5} = \frac{15+10+6}{30} = \frac{31}{30}$$

$$C_{eq} = \left(\frac{30}{31}\right) \mu F$$

$$q = V \cdot C_{eq}$$
$$= 900 \times \frac{30}{31}$$

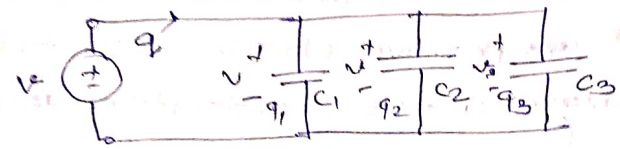
$$\boxed{q = 871\ \mu C}$$

$$V_1 = \frac{q}{C_1} = \frac{871}{2} = 435.5\,V$$

$$V_2 = \frac{q}{C_2} = \frac{871}{3} = 290.33\,V$$

$$V_3 = \frac{q}{C_3} = \frac{871}{5} = 174.2\,V$$

Case - II 900V → Remove



$$\boxed{q = 3 \times 871\ \mu C}$$

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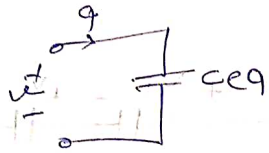
$q_1 = C_1 \times V$

$q_2 = C_2 \times V$

$q_3 = C_3 \times V$



$$V = \frac{q}{C_{eq}} = \frac{3 \times 871}{C_{eq}} = \frac{3 \times 871}{C_1 + C_2 + C_3} = \frac{3 \times 871}{10}$$

$$= 3 \times 87.1$$

$$\boxed{V = 261.3\ V}$$

$\therefore\ q_1 = 2 \times 261.3$

$= 522\ \mu C$

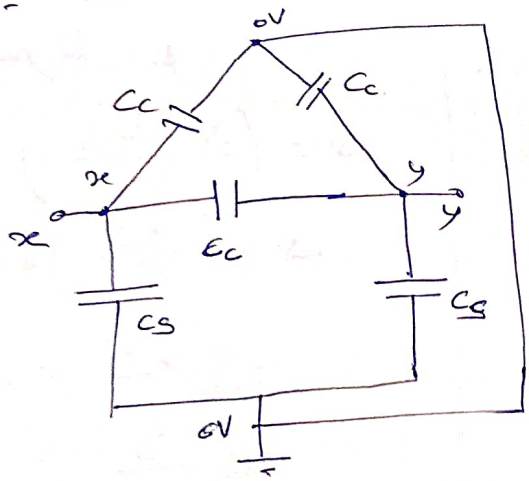
$q_2 = 3 \times 261.3$

$= 783\ \mu C$

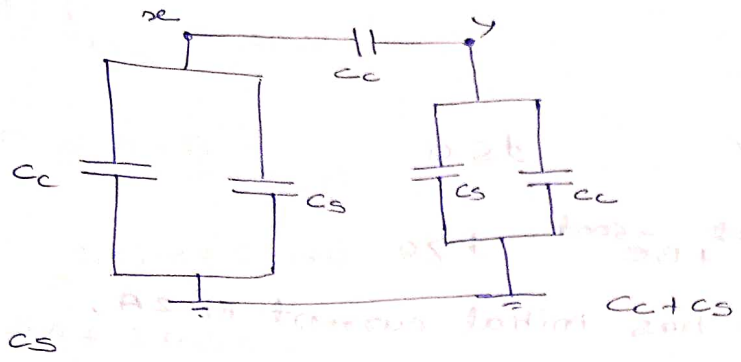
$q_3 = 5 \times 261.3$

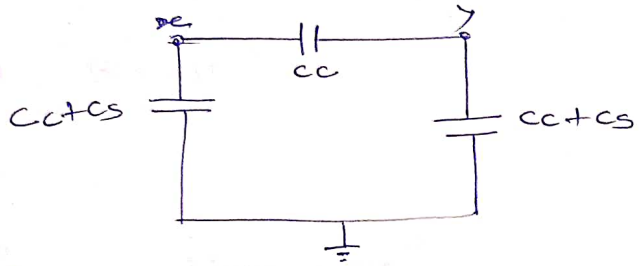
$= 1305\ \mu C$

Q4)



Sol^n:-

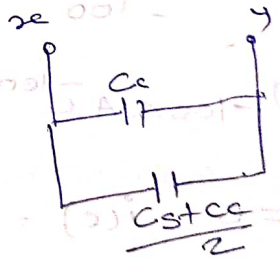




$$\frac{1}{C_{eq}} = \frac{1}{C_c + C_s} + \frac{1}{C_c + C_s}$$

$$= \frac{(C_s + C_c) \times (C_s + C_c)}{(C_s + C_c + C_s + C_c)}$$

$$= \frac{(C_s + C_c)^2}{2(C_s + C_c)} = \frac{C_s + C_c}{2}$$



$$C_{xy} = C_c + \frac{C_s + C_c}{2}$$

$$= \frac{2C_c + C_s + C_c}{2}$$

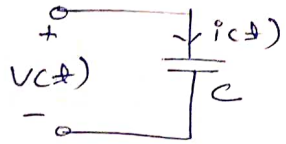
$$C_{xy} = \frac{3C_c + C_s}{2}$$

Q5) $C \rightarrow 4\,mF$

$$V(t) = \begin{cases} 50V & t \le 0 \\ A e^{-100t} + B e^{-600t} & t > 0 \end{cases}$$

If the capacitor has initial current of 2A, then the value of A & B = ?

Soln:-



$$i(t) = C \cdot \frac{dV(t)}{dt} \quad \text{for } t > 0$$

$$i(t) = C \cdot \frac{d}{dt}\left(A e^{-100t} + B e^{-600t}\right)$$

$$= \cancel{\frac{C \cdot A e^{-100t}}{-100}} + \cancel{\frac{C \cdot B e^{-600t}}{-600}}$$

$$i(t) = -100 C A e^{-100t} - C \cdot B\, 600\, e^{-600t}$$

At $t = 0$ $i(0) = 2A$

$$2 = -100 \times A \times C - 600 \times B \times C$$

$$100 \times 4 \times 10^{-3} \times A + 600 \times 4 \times 10^{-3} \times B = -2 \quad \text{— (1)}$$

* $V_c(t)\big|_{t=0} = 50V$

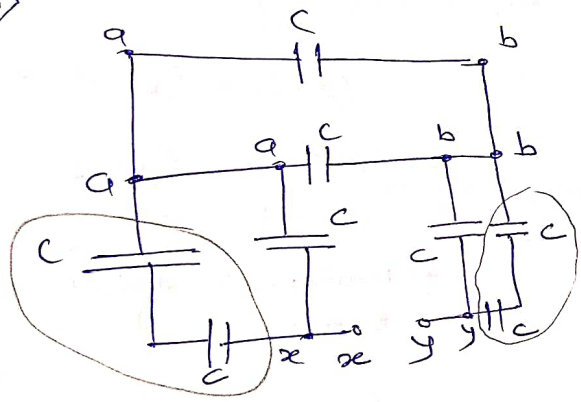
$$\boxed{50 = A + B} \quad -(2)$$

Solving (1) & (2) eqn.

$$0.4A + 2.4B = -2$$
$$A + B = 50 \quad -(1)$$

$$\boxed{A = 61, \quad B = -11}$$

Q6)

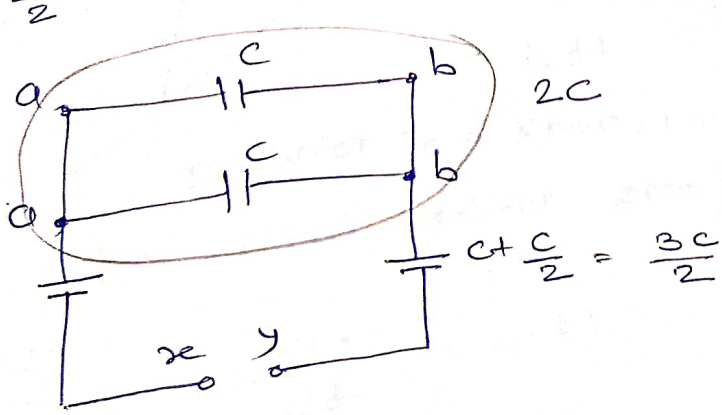


$C_{xy} = ?$

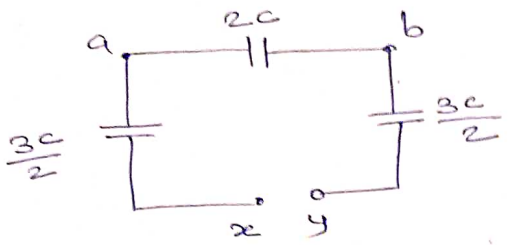
$by = \frac{C}{2}$

$ax = \frac{C}{2}$

$\Rightarrow$



$\frac{3C}{2}$



$$\frac{1}{C_{xy}} = \frac{2}{3c} + \frac{1}{2c} + \frac{2}{3c}$$

$$= \frac{4}{3c} + \frac{1}{2c}$$

$$= \frac{1}{c}\left(\frac{4}{3} + \frac{1}{2}\right)$$

$$= \frac{1}{c}\left(\frac{8+3}{6}\right)$$

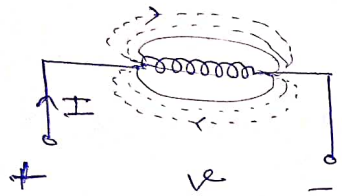
$$C_{xy} = \frac{1}{c} \times \frac{11}{6}.$$

Lect-49

Inductor

* It stores Energy in its magnetic field Hence it is a storing Element.

* Inductor is a coil having number of conducting wires.



Flux linkage $(\psi) \propto i(t)$

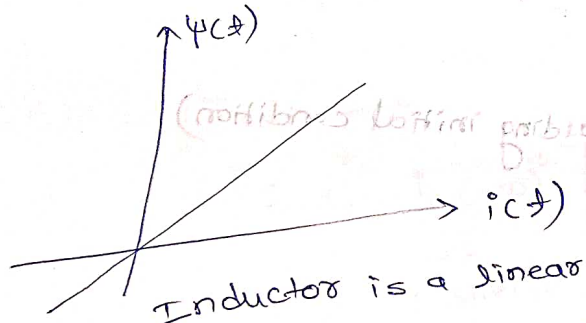
* $\psi(t) \propto i(t)$

$$\boxed{\psi(t) = L\, i(t)}$$

$i(t)$ → current flowing the inductor.

$\psi(t)$ → Flux linkage

L → proportionality constant



Inductor is a linear, passive, (when initial condition zero)

* $\dfrac{d\psi(t)}{dt} = L \cdot \dfrac{di(t)}{dt} = v_L(t)$

induce voltage

$$\boxed{\psi(t) = N\phi}$$

* $v_L(t) = L \cdot \dfrac{di(t)}{dt}$

$$di(t) = \frac{1}{L} v_L(t)\, dt$$

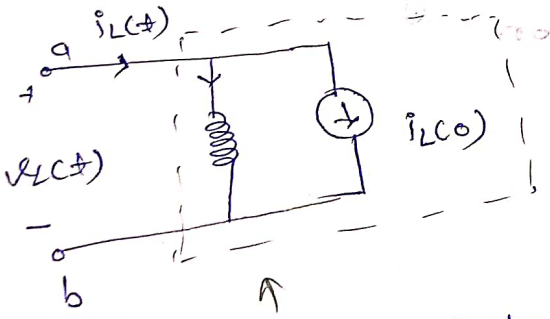
$$\int di(t) = \frac{1}{L}\int_{-\infty}^{t} v_L(t)\, dt$$

$$i(t) = \frac{1}{L}\int_{-\infty}^{0} v_L(t)\, dt + \frac{1}{L}\int_{0}^{t} v_L(t)\, dt$$

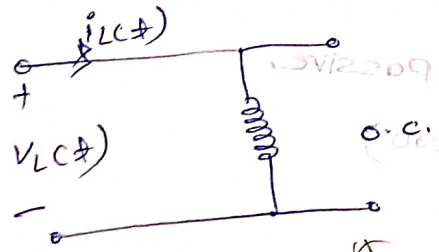
$$\boxed{i(t) = i_L(0) + \frac{1}{L}\int_{0}^{t} v_L(t)\, dt}$$

initial current

*



(equivalent ckt including initial condition)



(Equivalent ckt without initial condition)

* Instantaneous power ($P_L(t)$)

$$P_L(t) = V_L(t) \cdot i_L(t)$$

$$\boxed{P_L(t) = L\frac{di_L(t)}{dt} \times i_L(t)}$$

* Energy stored

$$P_L(t) = \frac{dE_L(t)}{dt}$$

$$dE_L(t) = P_L(t)\,dt$$

$$dE_L(t) = V_L(t) \cdot i_L(t)\,dt$$

$$= L\frac{di_L(t)}{dt} \cdot i_L(t)\,dt$$

$$\int dE_L(t) = L\int_{-\infty}^{t} \underset{x}{i_L(t)}\; \underset{dx}{di_L(t)}\,dt$$

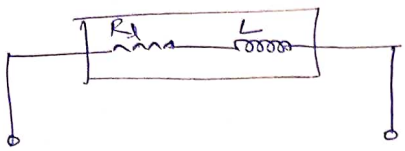
$$E_L(t) = L\left[\frac{i_L(t)^2}{2}\right]_{-\infty}^{t}$$

$$E_L(t) = \frac{L}{2}\left[i_L(t)^2 - \underbrace{i_L(-\infty)^2}_{\text{Neglect}}\right]$$

$$\boxed{E_L(t) = \frac{L}{2}\, i_L(t)^2}$$

--- Energy stored in 'L' from $-\infty$ to t.

* Practical inductor

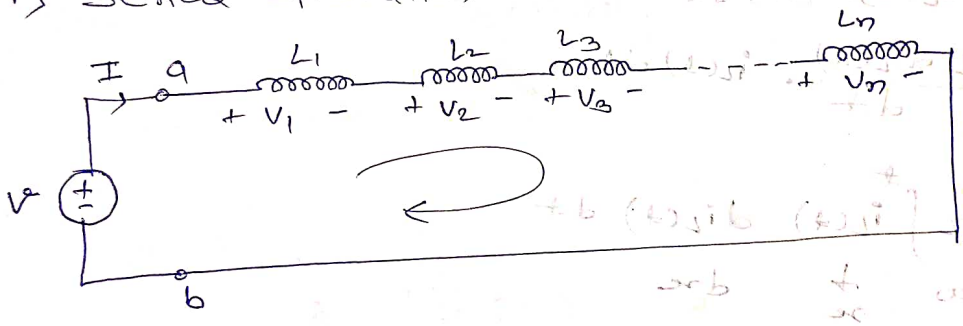


where
R_l is a leakage Resistance Having a very less value.

$R_l = 0\Omega \rightarrow$ Ideal inductor

Series & parallel operation of inductors
(This will be done same as Resistors)

1) series operation



* current will remain same.

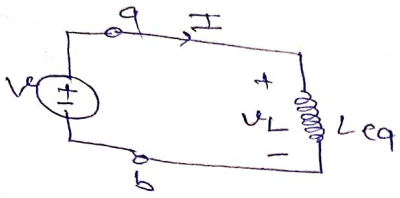
* But individual voltages may or may not remain same.

* $V = V_1 + V_2 + V_3 + \cdots + V_n$

$$= L_1 \frac{dI}{dt} + L_2 \frac{dI}{dt} + L_3 \frac{dI}{dt} + \cdots + L_n \frac{dI}{dt}$$

$$V = \frac{dI}{dt}(L_1 + L_2 + L_3 + \cdots + L_n)$$

$$\frac{V}{\frac{dI}{dt}} = L_1 + L_2 + L_3 + \cdots + L_n$$



$$v = L_{eq} \frac{dI}{dt}$$

$$\boxed{\frac{v}{\frac{dI}{dt}} = L_{eq}}$$

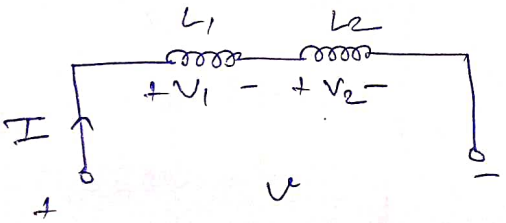
$$\boxed{L_{eq} = L_1 + L_2 + L_3 + \cdots + L_n}$$

* If $L_1 = L_2 = L_3 = L_n = L$

then

$$\boxed{L_{eq} = n \cdot L}$$

* Lets take L_1 & L_2



$$V_1 = L_1 \frac{dI}{dt}$$

$$= L_1 \cdot \frac{v}{L_{eq}}$$

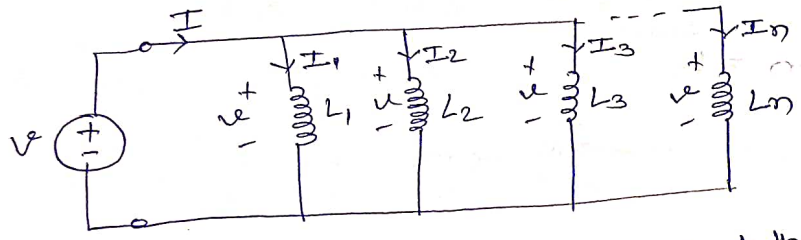
$$\boxed{V_1 = \frac{L_1 \times v}{L_1 + L_2}} \text{ --- VDR}$$

$$V_2 = L_2 \frac{dI}{dt} = \frac{L_2 \times V}{L_1 + L_2}$$

*

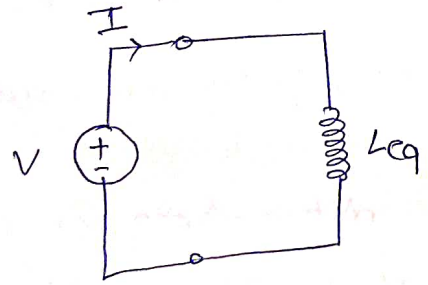
$$\boxed{V_x = \frac{L_x V}{\sum_{i=1}^{n} L_i}}$$ – VDR

ii) parallel operation



* The voltage remains the same but the individual current may or may not be same.

*



* $I = I_1 + I_2 + I_3 + \cdots + I_n$

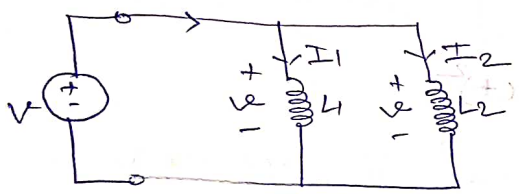
$$= \frac{1}{L_1}\int v(t)\,dt + \frac{1}{L_2}\int v(t)\,dt + \cdots + \frac{1}{L_n}\int v(t)\,dt$$

$$= \int v(t)\,dt \left[\frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}\right]$$

$$\frac{I}{\int v(t)\,dt} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_n}$$

$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_n}}$$

* Lets take L_1 & L_2



$$I_1 = \frac{1}{L_1}\int v(t)\,dt$$

$$= \frac{I \times L_{eq}}{L_1}$$

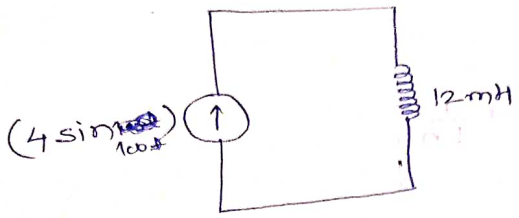
$$= \frac{I \times \cancel{L_1} \times L_2}{\cancel{L_1}\,(L_1 + L_2)}$$

$$\boxed{I_1 = \frac{I\,L_2}{L_1 + L_2}}$$

$$\boxed{I_2 = \frac{L_1\,I}{L_1 + L_2}}$$ — CDR

Lect-50

Q10)



Energy stored = ?

$[0 < t < \pi/200 \text{ sec}]$

$\Rightarrow$ Energy stored $= \frac{1}{2} L i_L(t)^2$

$$E = \frac{1}{2} \times 12 \times 10^{-3} \times (4 \sin 100t)^2$$

$$= \frac{1}{2} \times 12 \times 10^{-3} \times \left(16 \sin^2 \left(\frac{100 \times \pi}{200}\right)\right)$$

$$= \frac{1}{2} \times 12 \times 10^{-3} \times 16 \times \sin^2 \frac{\pi}{2}$$

$$= \frac{1}{2} \times 12 \times 10^{-3} \times 16 \times 1$$

$$= 16 \times 6 \text{ mj}$$

$$E = 96 \text{ mj}$$

Approch 02 :-

$$P(t) = \frac{dw(t)}{dt} = \frac{dE(t)}{dt}$$

$$\star \; dE(t) = P(t)\, dt$$

$$E(t) = \int P(t)\, dt = \int_0^{\pi/200} v(t) \cdot i(t)\, dt$$

$$= L \int_0^{\pi/200} \frac{d}{dt}(4 \sin 100t) \cdot 4 \sin(100t)\, dt$$

$$= 16L \int_0^{\pi/200} \cos 100t \times 100 \times \sin(100t)\, dt$$

$$= 16 \times 12 \times 10^{-3} \int \times 100 \int_0^{\pi/200} \cos 100t \cdot \sin(100t)\, dt$$

$$= \frac{16 \times 12 \times 10^{-3} \times 100}{2} \int_0^{\pi/200} \sin(2 \times 100t)\, dt$$

$$= \frac{16 \times 12 \times 100 \times 10^{-3}}{2} \left[\frac{-\cos 200t}{200} \right]_0^{\pi/200}$$

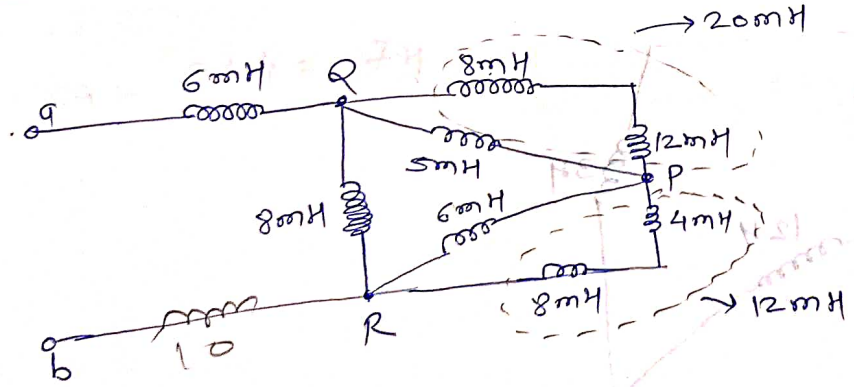
$$= \frac{16 \times 12 \times 100 \times 10^{-3}}{400} \left[-\cos\left(200 \times \frac{\pi}{200}\right) + \cos 0 \right]$$

$$= \frac{16 \times 12 \times 10^{-3}}{4} \left[\cancel{-\cos} \; 1 + 1 \right]$$

$$= \frac{16 \times 12 \times 10^{-3}}{2}$$

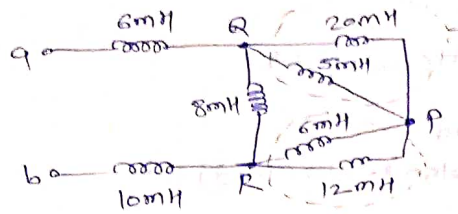
$$\boxed{E = 96\ mJ.}$$

Q 13)



Sol^n

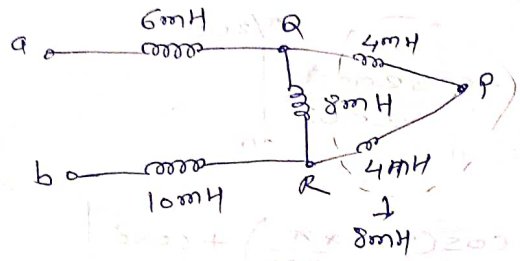
$\Rightarrow$

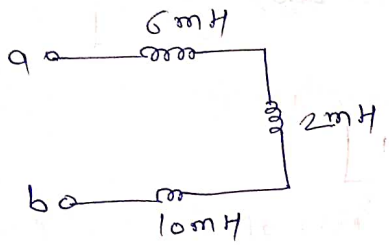


$\frac{20 \times 5}{25} = 4mH$

$\frac{6 \times 12}{18} = 4mH$

$\Rightarrow$

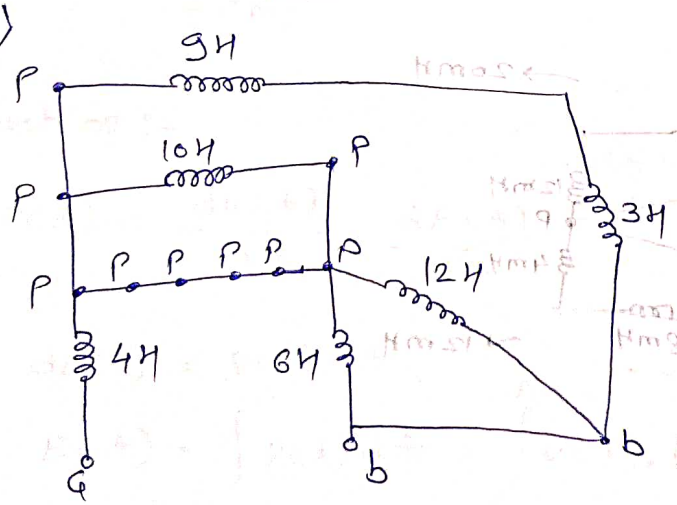




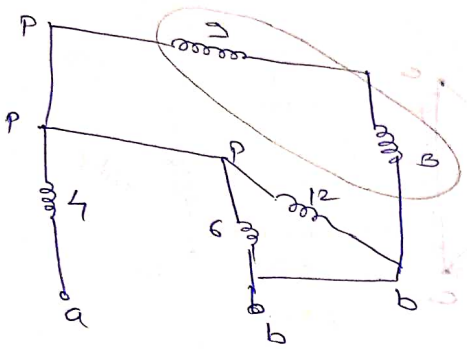
$\boxed{L_{eq} = 20mH}$

Lect- 51

Q14)

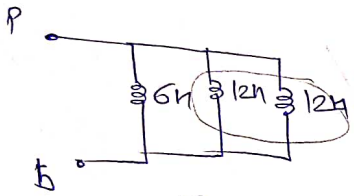


Sol^n:-



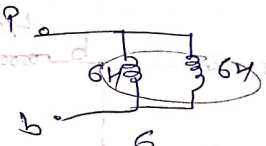
$9+3 = 12H$

$\Rightarrow$

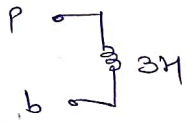


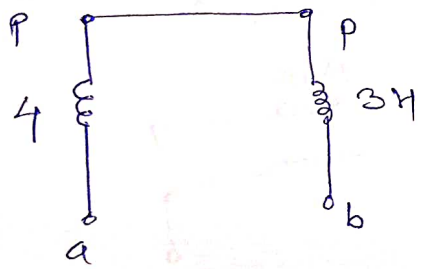
$\frac{12}{2} = 6H$

$\Rightarrow$



$\frac{6}{2} = 3H$

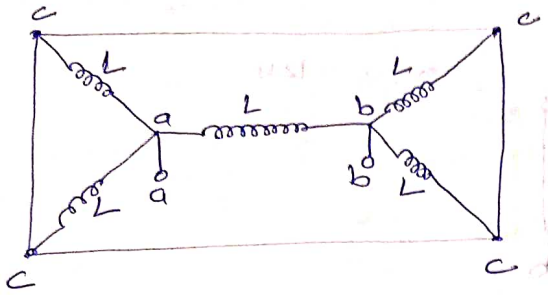




$= 3+4 = 7H$

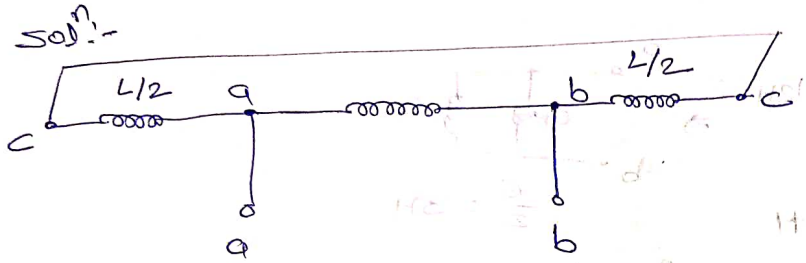
$L_{eq} = 3+4 = 7H$

Q)

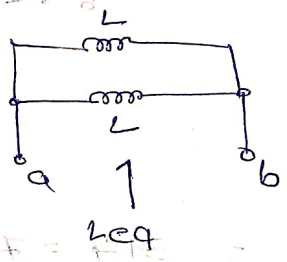


$L_{ab} = ?$

Sol^n:-

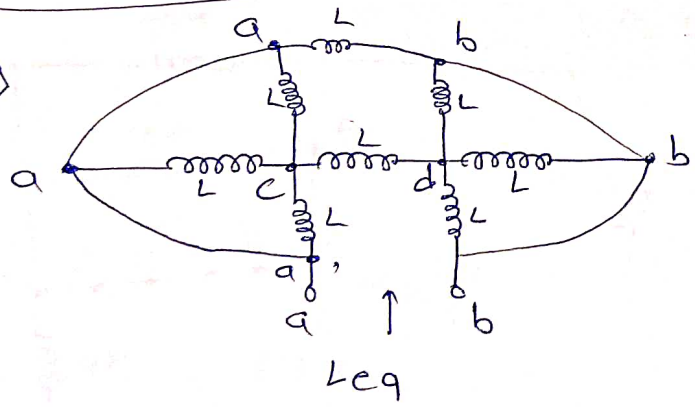


$L/2 + L/2 = L$

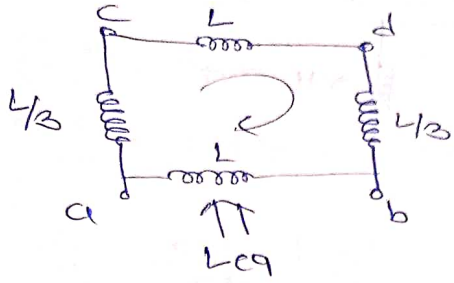


$$\boxed{L_{ab} = \frac{L}{2} = L_{eq}.}$$

Q15)



Soln:-



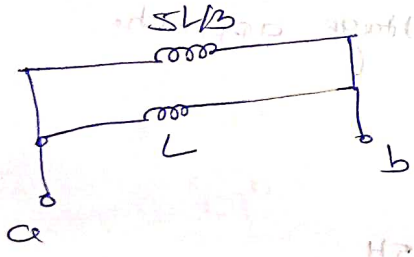
$$= \cancel{\frac{L}{3} + \frac{L}{3} + L}$$

$$= \cancel{\frac{2L}{3} + L}$$

$$= \cancel{\frac{2L+3L}{3} = \frac{5L}{3}}$$

$$L_{eq} = \frac{L}{3} + \frac{L}{3} + L$$

$$L_{eq} = \frac{5L}{3}$$

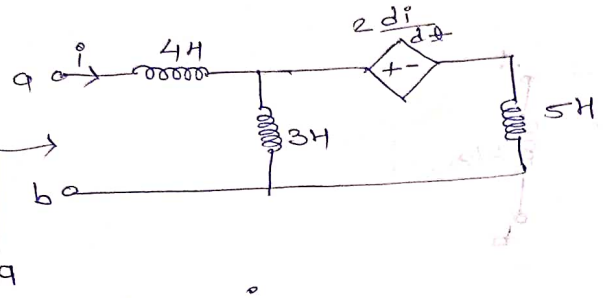


$$= \frac{5L/3 \times L}{5L/3 + L}$$

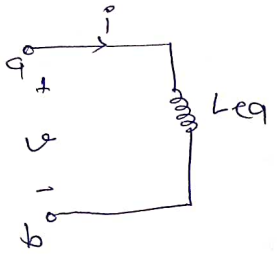
$$= \frac{5L^2}{3} \times \frac{3}{8L}$$

$$\boxed{L_{eq} = \frac{5L}{8}\ H}$$

Q16)

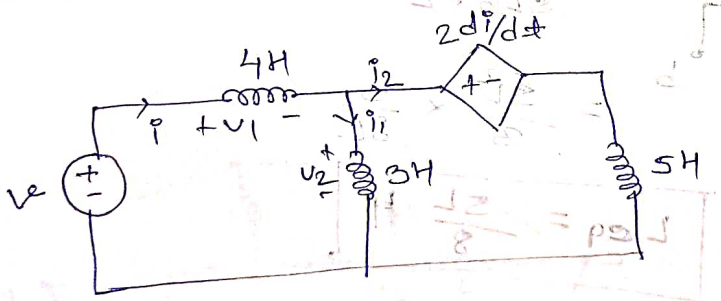


Soln:-



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

* As there is no independent sources are present Hence the circuit is a dead ckt. & to find the value of Leq we will proceed with test voltage approch.



* writing KVL

$$V = V_1 + V_2 \quad \text{— (1)}$$

* applying KCL

$$i = i_1 + i_2 \quad \text{— (2)}$$

$* V_2 = 3\frac{di_1}{dt} \Rightarrow \frac{di_1}{dt} = \frac{V_2}{3}$ — ③

* Applying KVL again,

$$V_2 - 2\frac{di}{dt} - 5\frac{di_2}{dt} = 0$$

$$V_2 - 2\frac{di}{dt} - 5\frac{d}{dt}(i - i_1) = 0$$

$$V_2 - 7\frac{di}{dt} + 5\frac{di_1}{dt} = 0$$

$$\therefore \frac{di_1}{dt} = \frac{V_2}{3}$$

$$V_2 - 7\frac{di}{dt} + 5\left(\frac{V_2}{3}\right) = 0$$

$$\Rightarrow 7\frac{di}{dt} = V_2\left(1 + 5/3\right)$$

$$7\frac{di}{dt} = V_2\left(\frac{8}{3}\right)$$

$$V_2 = \frac{21}{8}\frac{di}{dt}$$

* from ① eq^n

$$V = V_1 + V_2$$

$$= 4 \times \frac{di}{dt} + \frac{21}{8}\frac{di}{dt}$$

$$V = \underbrace{\left(4 + \frac{21}{8}\right)}_{L_{eq}}\frac{di}{dt}.$$

$$L_{eq} = 4 + \frac{21}{8} = \frac{32 + 21}{8} = \frac{53}{8}\ H.$$

Lect-52

Transient analysis

* Transient represents the speed of the system.
* Transient represents the variation of outcomes with time. It is dependent on time.
* Transient is a temperory response.
* steady state response represents the error of the system.
* steady state response doesnot vary with time. It is independent of time.
* Steady state response is a permanent response.
* for transient analysis there must be a storing element in the ckt.

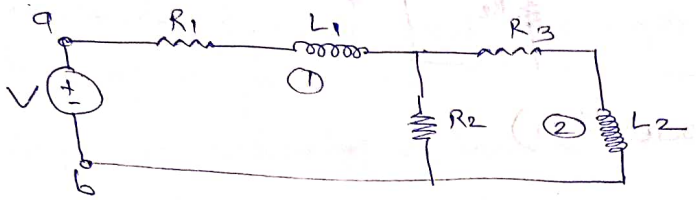
Inductor capacitor

* Transient analysis is not valid for purely resistive network.

Order of the system

* It is the number of non seperable storing elements in the N/w.

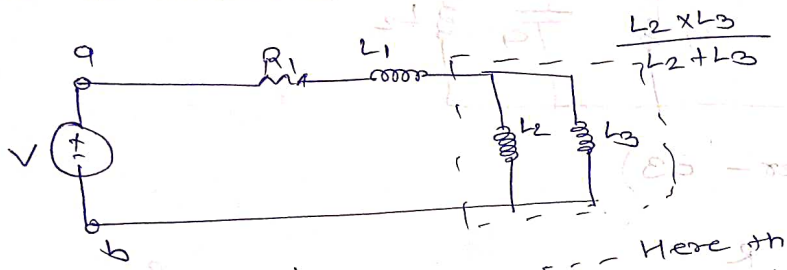
e.g ①



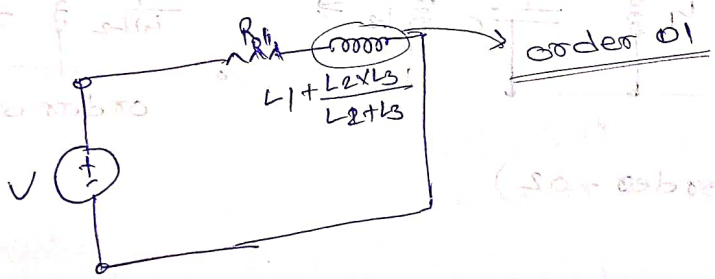
(order = 2)

Here the inductors are non seperable

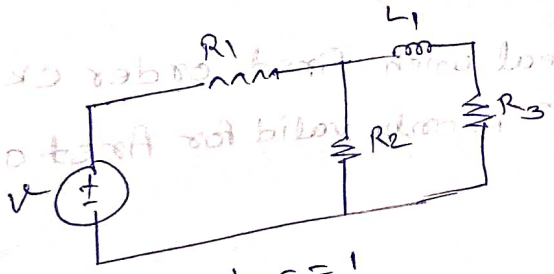
eg ②



Here the inductor are seperable



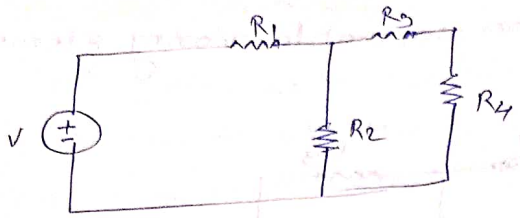
eg ③



order = 1

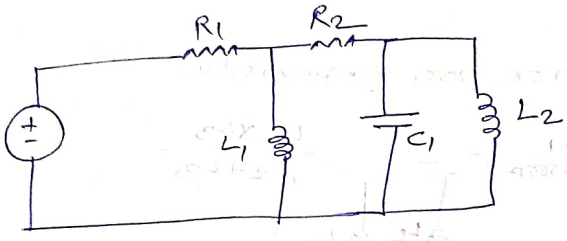
~~order~~

e.g ④



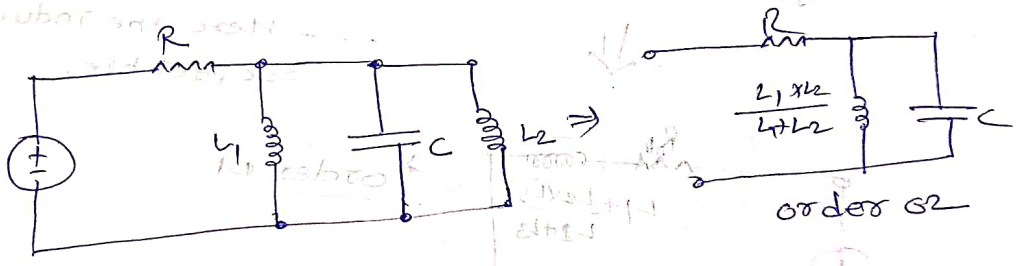
(order - 0)

e.g ⑤



(order - 03)

e.g ⑥



order 02

∴ (order - 02)

Remember

Notes: ① we are mainly going to deal with first order ckt.

② The transient analysis eqn is only valid for first order ckt.

Laplace of standard signals

* This is very helpful when the eqn are differential or integral type.

* It will convert the differential and integral eqn into simple algebric equation.

* only one single ~~solution~~ eqn provide the solution.

* Response $y(t) = PI + CF$

$= y_n(t) + y_f(t)$

$=$ Inverse laplace of $y(s)$

Lect - 53

i) $u(t) = \frac{1}{s}$

2) $r(t) =$ Ramp signal $= \frac{1}{s^2}$

3) $\delta(t) =$ Impulse $= 1$

4) $e^{-at}u(t) = \frac{1}{s+a}$

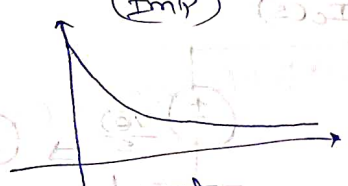
5) $\sin\omega_0 t = \frac{\omega_0^2}{s^2+\omega_0^2}$

6) $\cos\omega_0 t = \frac{s^2}{s^2+\omega_0^2}$

7) $\frac{d^2y(t)}{dt} = s^2y(s) - sy(0) - y'(0)$

8) $\int y(t)\,dt = \frac{y(s)}{s}$

(Imp)



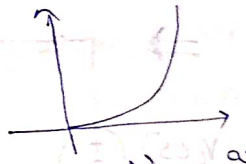
$y(t) = e^{-at}$

(Decreasing exponential)

= stable function

= bounded signal

- Transient analysis



$y(t) = e^{at}$

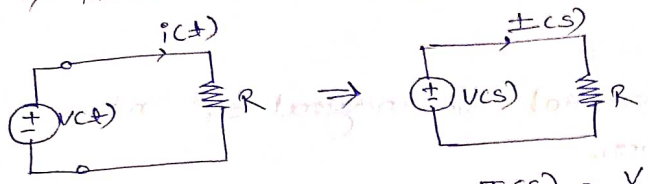
(Increasing exponential)

- unstable

- Transient analysis is no possible

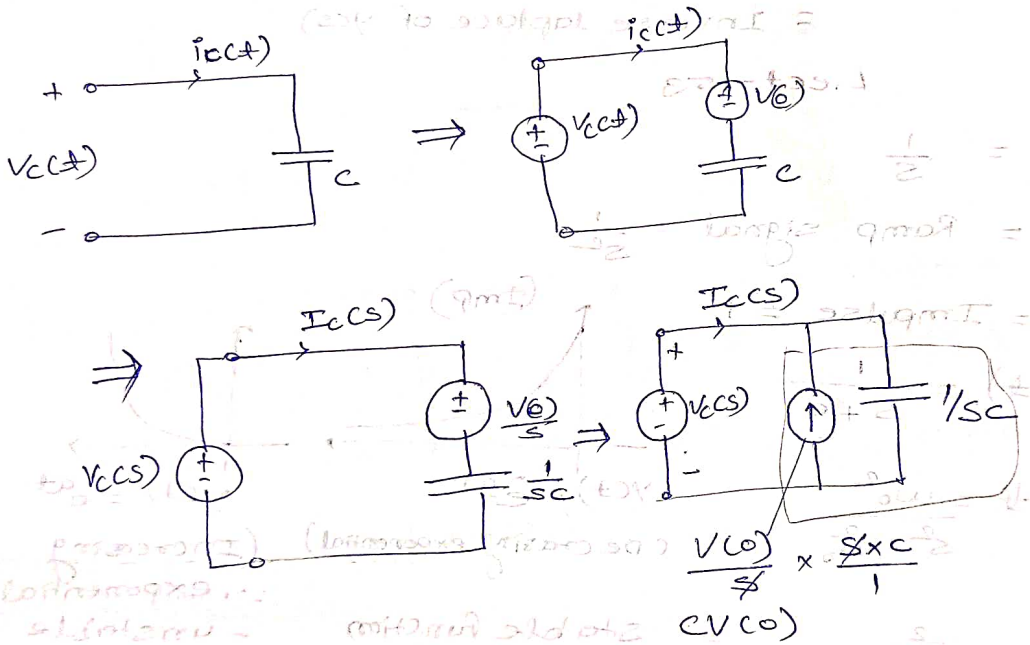
Laplace domain model of R, L, C circuits

i) Resistive ckt

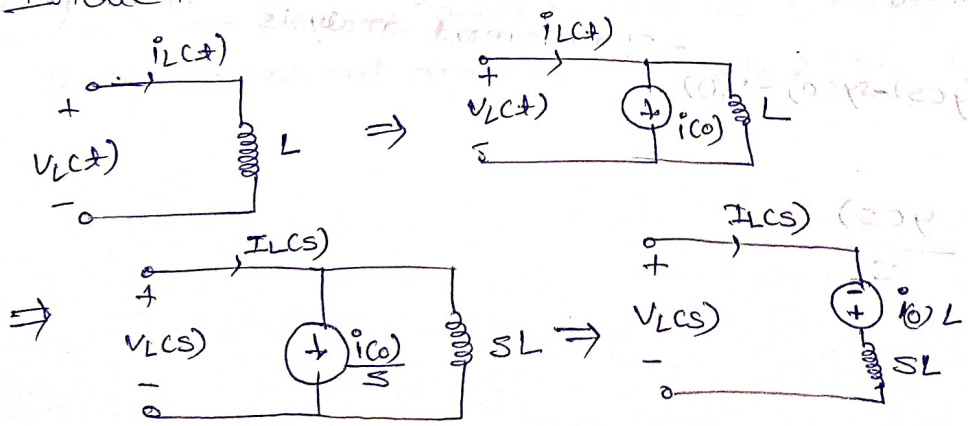


$$i(t) = \frac{v(t)}{R} \qquad I(s) = \frac{V(s)}{R}$$

ii) capacitive ckt



iii) Inductive ckt



Lect - 54

Q) The differential eqn for a system i/p & o/p relation is given below.

$$\frac{d^2y(t)}{dt^2} + 6\frac{dy(t)}{dt} + 7y(t) = \frac{dx(t)}{dt} + 7x(t)$$

where $y(t) \rightarrow$ o/p, $x(t) \rightarrow$ input signal

$y(0^-) = 1$, $y'(0^-) = 2$.

Find $y(t)$ for $x(t) = u(t)$

Soln:- Taking the time domain eqn into laplace domain

$$\left[s^2 y(s) - sy(0^-) - y'(0)\right] + 6\left[sy(s) - y(0^-)\right] + 7y(s) = \left[sX(s) - x(0^-)\right] + 7X(s)$$

$$s^2 y(s) + 6sy(s) + 7y(s) = sX(s) + 7X(s) + sy(0^-) + y(0^-) - x(0^-)$$

$$Y(s)\left[s^2 + 6s + 7\right] = X(s)\left[s+7\right] + \underbrace{sy(0^-) + y'(0^-) - x(0^-)}_{\text{Initial condn.}}$$

$$Y(s) = X(s)\cdot\frac{(s+7)}{(s^2+6s+7)} + \frac{sy(0^-) + y(0^-) - x(0)}{s^2+6s+7}$$

$y(t)$ = Response due to input signal + response due to initial conditions

Forced Response $y_f(t)$ (P.I of Time Domain Analysis)

Natural Response $y_n(t)$ → C.F → zero i/p response

$\therefore y(t) = y_F(t) + y_n(t)$

$= (P.I + CF)$

$$Y(s) = \frac{s+7}{s(s^2+6s+7)} + \frac{s+2}{(s^2+6s+7)}$$

$$= \frac{s+7}{s(s+1.6)(s+4.4)} + \frac{s+2}{(s+1.6)(s+4.4)}$$

$$\Rightarrow \frac{s+7}{s(s+1.6+s+4.4)} = \frac{A}{s} + \frac{B}{s+1.6} + \frac{C}{s+4.4}$$

$$s+7 = A(s+1.6)(s+4.4) + B(s)(s+4.4) + C(s)(s+1.6)$$

$s \to 0$

$A = 1.136$

$s \to -4.4$

$C = \frac{2.6}{+12.32} = +0.21$

$s \to -1.6$

$B = \frac{5.4}{-4.48} = -1.2$

$\Rightarrow (s+2) = A(s+4.4) + B(s+1.6)$

$s = -4.4 \to B = \frac{-2.4}{2.8} = 0.85$

$s \to -1.6 \to A = \frac{0.4}{2.8} = (0.142)$

$$y(s) = \left[\frac{1.136}{s} - \frac{1.2}{(s+1.6)} + \frac{0.21}{s+4.4}\right] + \left[\frac{0.142}{s+1.6} + \frac{0.85}{s+4.4}\right]$$

Taking inverse Laplace

$$y(t) = \underbrace{\left[1.136 - 1.2e^{-1.16t} + 0.21e^{-4.4t}\right]u(t)}_{y_f(t)} + \underbrace{\left[0.142e^{-1.6t} + 0.85e^{-4.4t}\right]}_{y_n(t)}$$

Note:- force Response is possible with source
Natural Response possible without source

$$y(t) = \underbrace{\left[1.136 - 1.2e^{-16t} + 0.21e^{-4.4t}\right]}_{y_f(t)} + \underbrace{\left[0.142e^{-1.6} + 0.85e^{-4.4t}\right]}_{y_n(t)}$$

$$y(t) = \left[1.136\right] + \left[0.21e^{-4.4t} - 1.2e^{-1.6t} + 0.142e^{-1.6t} + 0.85e^{-4.4t}\right]$$

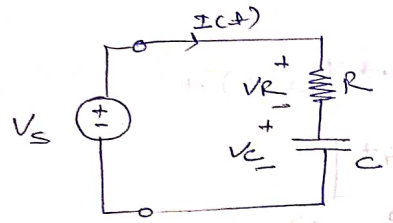
y_{ss} → steady state response
↓
Fixed value
↓
Time independent Response
↓
permanent response
↓
always part of force Response

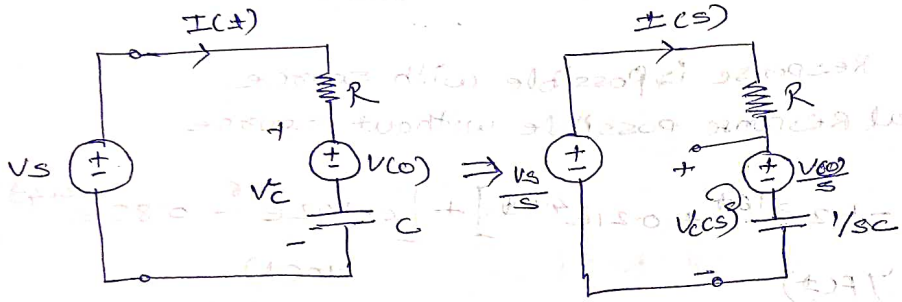
↓
$y_{(transient\ response)}$
↓
variable response
↓
Time dependent response
↓
Temporary Response
↓
(part of y_f & y_n)
but it always have Whole natural response. $y_n(t)$

Lect-55

First order RC & LC circuits

* RC circuit





Find the response $V_c(t)$

* $$V_c(s) = \frac{V(0)}{s} + I(s) \times \frac{1}{sC} \quad \text{— (1)}$$

$$I(s) = \frac{\frac{V_s}{s} - \frac{V(0)}{s}}{\left(R + \frac{1}{sC}\right)} \quad \text{— (2)}$$

from eqn (1) & (2)

$$V_c(s) = \frac{V(0)}{s} + \frac{\frac{V_s}{s} - \frac{V(0)}{s}}{\left(R + \frac{1}{sC}\right)} \times \frac{1}{sC}$$

$$= \frac{V(0)}{s} + \frac{V_s - V(0)}{s(sRC+1)}$$

$$= \frac{V(0)}{s} + \frac{[V_s - V(0)]/RC}{s(s + 1/RC)}$$

$$V_c(s) = \frac{V(0)}{s} + \frac{A}{s} + \frac{B}{s + \frac{1}{RC}}$$

$$A = \cancel{\frac{V(0)}{s}} + \left[\cancel{\frac{V_s - V(0)}{s}}\right] + \left[\frac{V(0) - V_s}{s + \frac{1}{RC}}\right]$$

$$V_c(s) = \frac{V_s}{s} + \frac{V(0) + V_s}{\left(s + \frac{1}{RC}\right)}$$

Taking L.I

$$V_c(t) = V_s + [V(0) - V_s]\, e^{-t/RC}$$

V_s → Steady state Response → permanent Response

$[V(0) - V_s]\, e^{-t/RC}$ → Transient Response → temporary Response

$$V_c(t) = V_{cn}(t) + V_{cf}(t)$$

$V_{cn}(t)$ → Put supply $V_s = 0$

Hence $[V(0)\, e^{-t/RC}]$ → Natural Response

$V_{cf}(t)$ → put initial value $V(0) = 0$

$V_s(1 - e^{-t/RC})$

$$* \; I_C(t) = C \frac{dV_C(t)}{dt}$$

$$= C \times \frac{d}{dt}\left(V_S + [V(0) + V_S]\, e^{-t/RC}\right)$$

$$= C \times \left[0 + [V(0) - V_S]\, e^{-t/RC} \times \left(-\frac{1}{RC}\right)\right]$$

$$i_C(t) = \underbrace{\frac{1}{R}\,[V_S - V(0)]\, e^{-t/RC}}_{\text{(Transient Response)}}$$

(S.S.R = 0)

(Imp)

* Theoretically steady state $[t = \infty]$

$V_C(\infty) = V_S$ = max voltage

$I_C(\infty) = 0\,A \rightarrow C \rightarrow OC$

Steady state → voltage (V_S)

current is zero.

τ = time constant = $\frac{1}{RC}$

* For a first order RC ckt, the standard voltage expression across capacitor ~~for~~ will be

(Imp RC)

$$\boxed{V_C(t) = V_C(\infty) + [V_C(0) - V_C(\infty)]\, e^{-t/\tau}}$$

---- $t > 0$

--- Generalized expression

* If the network is a sourcefree

$V_C(t) = V_{Cn}(t)$ = Natural response

$= (V(0)\, e^{-t/RC})$ → standard discharging eq?

* If the network has input and initial conditions are zero

then $V_C(t) = V_{Cf}(t)$ = forced Response.

$= V_S(1 - e^{-t/RC})$ = standard charging expression.

* Remember :-

* Standard charging expression

$y(t) = y_0(1 - e^{-t/\tau})$

* standard discharging expression

$y(t) = y_0\, e^{-t/\tau}$

Lect - 56

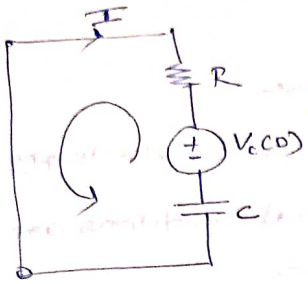
* Natural Response (Discharging ckt)

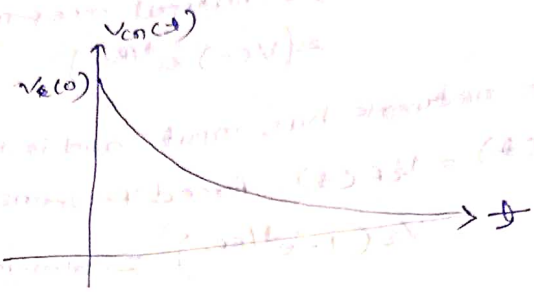
$$\boxed{V_C(t) = V_{Cn}(t) = \text{initial conditions} = V(0)\, e^{-t/RC}}$$

$$i_C(t) = C\frac{dV_C(t)}{dt} = C \cdot V(0)\, e^{-t/RC} \times \left(\frac{-1}{RC}\right)$$

$$\boxed{i_C(t) = \frac{-V(0)}{R}\, e^{-t/RC}}$$

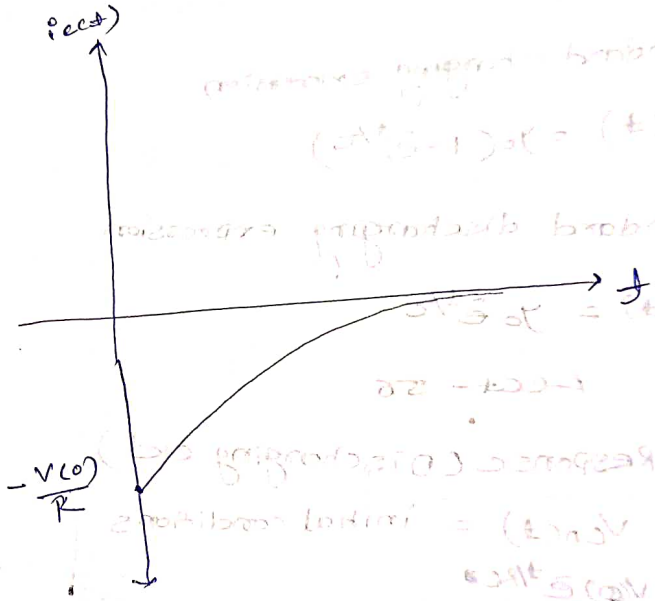
$$\boxed{E_C(0) = \frac{1}{2} C\, V_C(0)^2}$$ --- Initial energy





$\Delta E_c = \frac{1}{2} C \cdot V_c^2 \Delta$

$t=0$

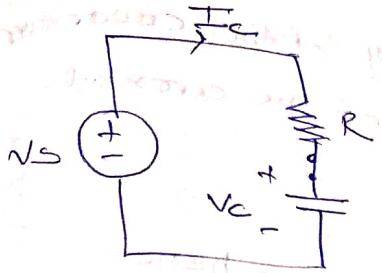


* forced Response (only excitation) ⇒ charging ckt

$$V_c(t) = V_s\left(1 - e^{-t/RC}\right)$$

$$I_c(t) = C \cdot \frac{V_c(t)}{dt} = \cancel{C} \times V_s\left(e^{-t/RC}\right) \times \frac{1}{R\cancel{C}}$$

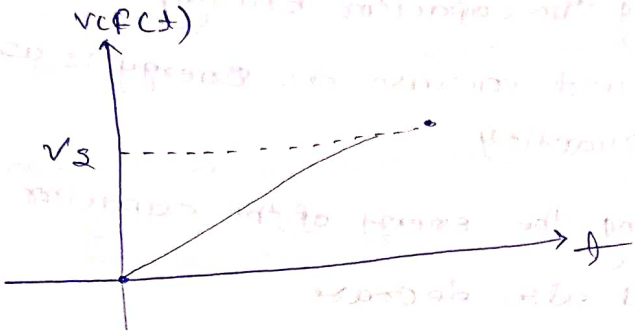
$$= \frac{V_s}{R}\left(e^{-t/RC}\right)$$



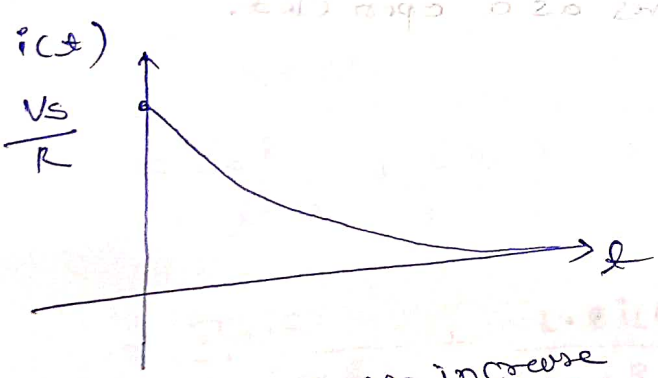
at initially

$E_c(0) = \frac{1}{2} \times V_c(0)^2$

0V



$$\left[E_c(\infty) = \frac{1}{2} \times c \times V_c(\infty)^2 = \frac{1}{2} \times c \times V_s^2 \right]$$



During charging V = increase
I = Decrease

During discharging

= V = decrease
I = decrease

* conclusion

① during charging & discharging the polarity of the capacitor voltage never changes but the direction of the current changes

② during charging the capacitor Energy increases hence the voltage must increase as Energy is associated with the voltage quantity

③ during discharging the Energy of the capacitor decreases Hence the voltage will also decrease

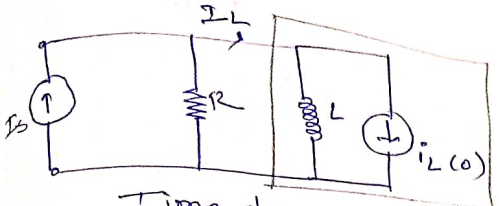
④ during charging or discharging at ($t = \infty$) steady state

$i_c(t) = 0A$ (always)

Capacitor always behaves as a open ckt.

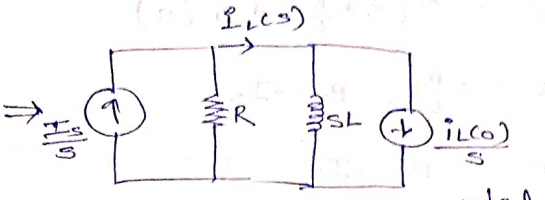
Lect- 57

First order RL circuit



Time domain model

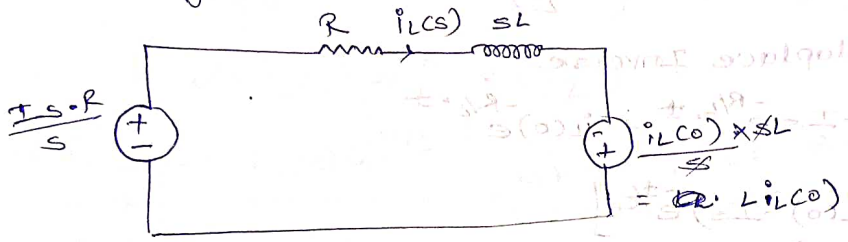
$\Rightarrow$



Laplace domain model

$I_L(t)$ for $t>0$

Sol^n:- Using Source Transformation Theorem



$$* \; I_L(s) = \frac{\frac{I_s \cdot R}{s} + L i_L(0)}{R + sL}$$

$$= \frac{I_s R}{s(R+sL)} + \frac{L\, i_L(0)}{(R+sL)}$$

$$= \frac{I_s \cdot R}{sL\left(s+\frac{R}{L}\right)} + \frac{L \cdot i_L(0)}{L\left(s+\frac{R}{L}\right)}$$

$$\Rightarrow I_L(s) = \frac{I_s R/L}{s(s+R/L)} + \frac{i_L(0)}{\left(s+\frac{R}{L}\right)}$$

~~Take~~

$$I_L(s) = \left[\frac{A}{s} + \frac{B}{s+R/L}\right] + \frac{i_L(0)}{(s+R/L)}$$

A =

$$I_s \cdot \frac{R}{L} = A\left(s+\frac{R}{L}\right) + B\,(s)$$

if $s = \frac{-R}{L}$, $B = -I_s$,

$s = 0$ $\quad B = -I_s$

$A = I_s$

$$I_L(s) = \frac{I_s}{s} - \frac{I_s}{\left(s+\frac{R}{L}\right)} + \frac{i_L(0)}{\left(s+\frac{R}{L}\right)}$$

Taking laplace Inverse

$$i_L(t) = I_s - I_s e^{-R/L \cdot t} + i_L(0) e^{-R/L \cdot t}$$

$$\left[i_L(t) = \underbrace{I_s}_{\text{S.S. Response}} + \underbrace{(i_L(0) - I_s)\, e^{-t/\tau}}_{\text{Transient Response.}}\right]$$

when $\tau = \frac{L}{R}$ = time constant

$$* \boxed{i_L(t) = \text{total Response} = i_{Ln}(t) + i_{Lf}(t)}$$

case-I - Natural Response (Response due to initial conditions only)

Excitation = 0 → $i_s = 0$

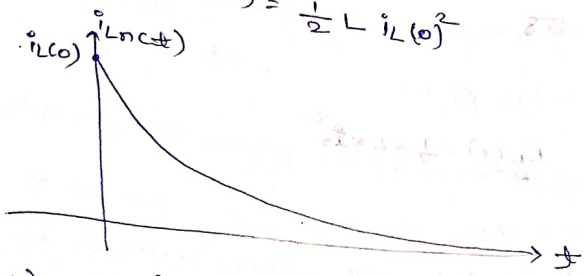
$$\boxed{i_L(t)\Big|_{I_s=0} = i_{Ln}(t) = i_L(0)\, e^{-t/\tau}}$$

- -- Natural Response

This response is only possible with source free ckt.

- -- standard discharging eqn for RL circuit.

initial Energy $E_L(0) = \frac{1}{2} L\, i_L(0)^2$



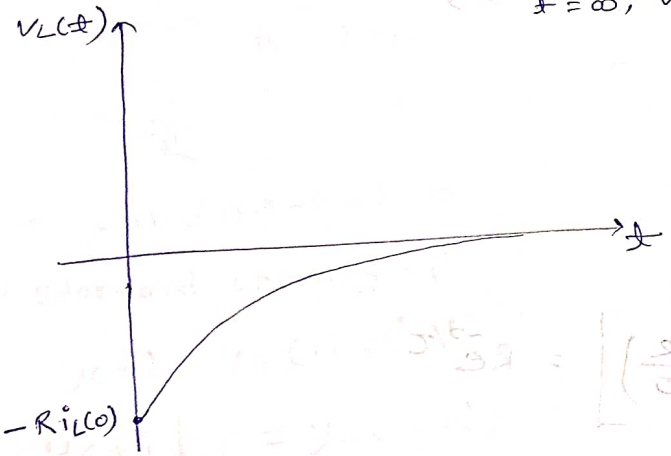
$\cancel{*}\ V_L(t) = \frac{1}{L}\int i_L(t)\, dt$ ×

$V_L(t) = L\frac{di}{dt}$ ✓

$= \cancel{L} \times i_L(0)\, e^{-\frac{tR}{L}} \times \left(-\frac{R}{\cancel{L}}\right)$

$$\boxed{V_L(t) = -R\, i_L(0)\, e^{-t/\tau}}$$

at $t=0$, $V_L = -R \cdot i_L(0)$
$t=\infty$, $V_L = 0V$



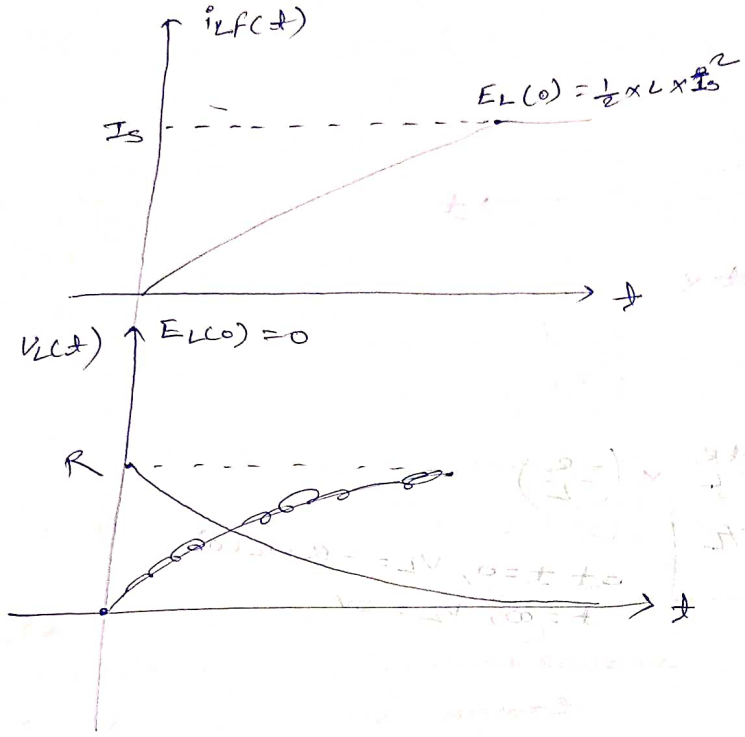
Case - II forced response (only due to exitation)

Here exitation $\longrightarrow$ I_s (Ampere) & $i_L(0) = 0A$

$$\boxed{i_L(t)\Big|_{i_L(0)=0A} = I_s + (0 - I_s)\, e^{-\frac{tR}{L}} = i_{Lf}(t)}$$

- standard charging eqn for RL circuit

LCC# - 58



$$\boxed{\begin{aligned} V_L(t) &= \frac{L\, di(t)}{dt} \\ V_L(t) &= L \times \left[-e^{-t/\tau} \times \left(\frac{-R}{\tau} \right) \right] = R e^{-t/\tau} \end{aligned}}$$

$$E = \frac{1}{2} L\, i_L(t)^2$$

Notes :- ① During charging or discharging at $t = \infty$, SS $\rightarrow v_L(t) = 0$

② During charging and discharging of inductor the direction of current will never but the polarity of voltage will definately change.

* Inductor

$$i_L(t) = I_s + (i_L(0) - I_s)\, e^{-t/\tau}$$

$$\boxed{i_L(t) = i_L(\infty) + [\, i_L(0) - i_L(\infty)]\, e^{-t/\tau}}$$

... The general expression for first order RL circuit for $t > 0$

$$\tau = \frac{L}{R}$$

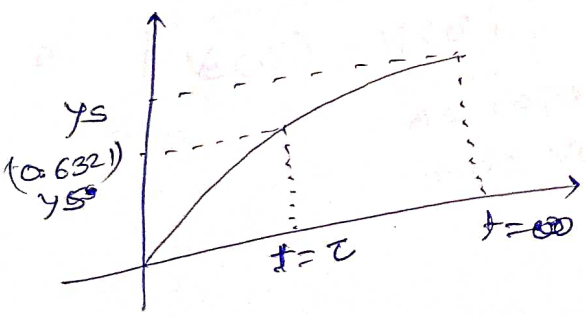
* Calculation of τ

i) standard charging eqn

$$y(t) = y_s (1 - e^{-t/\tau})$$

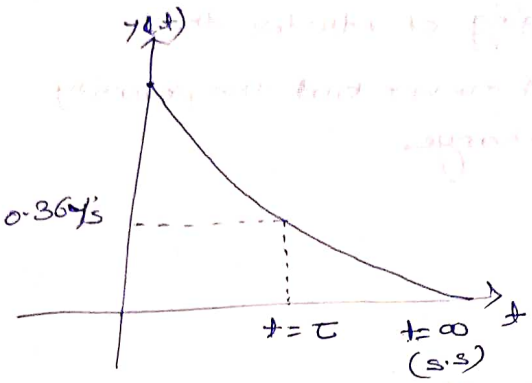
$$y(t)\Big|_{t=\tau} = y_s (1 - e^{-1})$$

$$= (0.6321)\, y_s$$



2) standard discharging eqⁿ

$$y(t) = y_0 e^{-t/\tau}$$



$$y(t)\Big|_{t=\tau} = y_0 e^{-1}$$

* Stead state $\begin{cases} t \to \infty \to \text{Theoretical value} \\ t \to 5\tau \to \text{practical value} \end{cases}$

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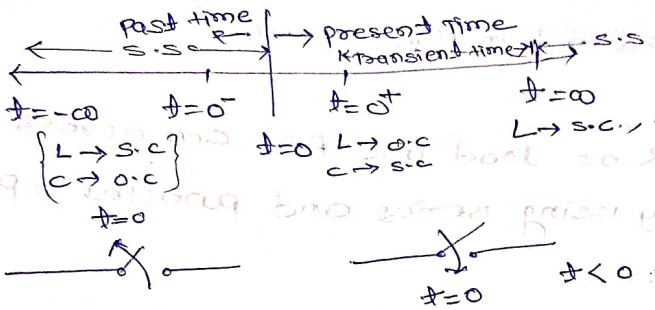
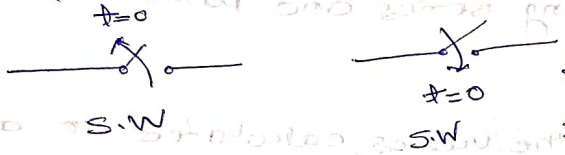
Problem Discussion on for RC circuit

Step 01:- Just write down the transient eqn for $t > 0$

$$V_c(t) = V_c(\infty) + \left[V_c(0^-) - V_c(\infty)\right] e^{-t/\tau}$$

There are 3 type of cases.





$t < 0 \rightarrow$ S.W. closed

$t > 0 \rightarrow$ S.W open

$t \geq 0$ S.W. ~~open~~ closed

$t < 0$ S.W. open

Before switching is known as past time → steady state condition

After switching is known as present time and transient will occure.

Step 2:- Evaluate the value of $V_c(\infty)$ & $V_c(0)$

S.S (After switching) — Initial condition (Before switching)

$$\boxed{V_c(0^-) = V_c(0^+)}$$

∴ As capacitor doesnot allow sudden changes in its voltage.

Step 03:- Evaluate the value of Time constant τ

$$\boxed{\tau = R_{eq} \cdot C_{eq}}$$

- τ is calculated after switching always.

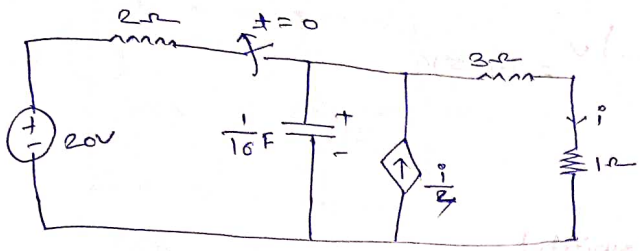
R_{eq} → just take C_{eq} as load & find R_{eq} across the terminals by using all three cases discussed in N/W theorem.

C_{eq} → Just take R as load and find C_{eq} across the terminal by using series and parallel operation

Step 04:- Just put all the values calculated in a step 02, 03 in step-01. and we will get $V_c(t)$ voltage across the capacitor.

Step 05:- If other than $V_c(t)$ has been asked then always Remember that first calculate the $V_c(t)$ and apply basic laws of N/W theory to get your desired results.

Q)

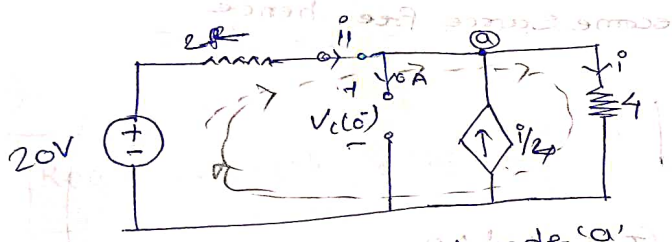


$V_c(t) = ?$, $\tau = R_{eq} \cdot C_{eq}$.

sol:- step 01:- $V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

step 02:- case-1 at $t<0 \rightarrow t = 0^- \rightarrow$ switch is closed

(C → o.c), (L → s.c)



applying KCL at node 'a'

$i_1 + i/4 = i$

$i_1 = i - i/4 = \frac{3i}{4}$

$* \quad 20 - 2 \times i_1 - 4i = 0$

$20 = 2\left(\frac{3i}{4}\right) + 4i$

$= \left(\frac{3}{2} + 4\right) i$

$20 = \frac{11}{2} i$

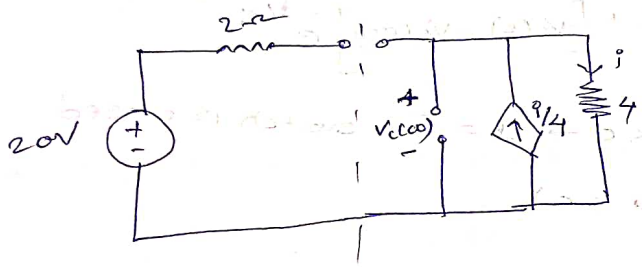
$$\boxed{i = \frac{40}{11} A}$$

$V_c(0^-) = 4 \times i = \left(\frac{4 \times 40}{11}\right) V = 14.5V$

$V_c(0^-) = V_c(0^+)$

Case 2:- For $t > 0$ → (open switch)

$t = \infty$ $c \rightarrow$ o.c.

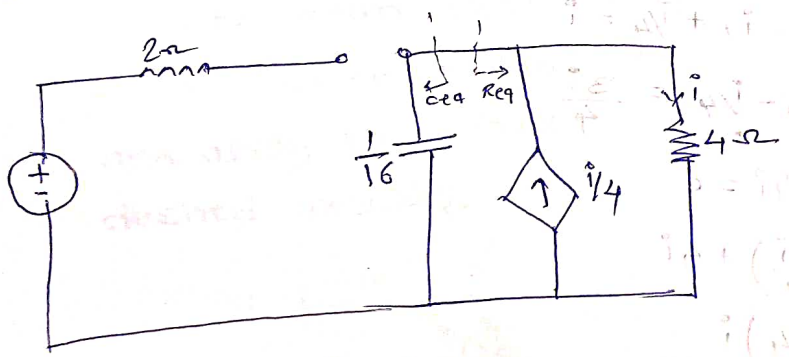


As the ckt will become source free, hence

$i = 0A$,

$\boxed{V_c(\infty) = 4 \times i = 0V}$

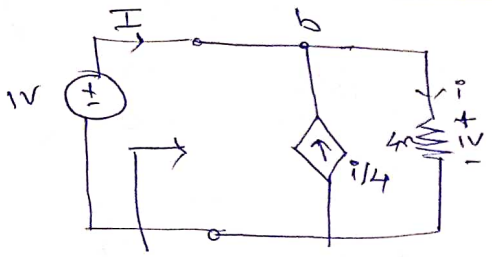
Step 03:- Time constant (τ) → $t > 0$



$\tau = R_{eq} \times C_{eq}$

$C_{eq} = \frac{1}{16} F$

* R_{eq} calculation → Test voltage approach



$R_{eq} = \frac{1}{I}$

$i = \frac{1}{4}$ A

- Apply KCL at node b

$I = \frac{-i}{4} + i$

$= i\left(1 - \frac{1}{4}\right) = \frac{3}{4} \times i$

$= \frac{3}{4} \times \frac{1}{4} = \frac{3}{16}$ A

$$\boxed{R_{eq} = \frac{1}{3} \times 16 = \frac{16}{3}\,\Omega}$$

$\tau = \frac{16}{3} \times \frac{1}{16}$

$$\boxed{\tau = \frac{1}{3}\ \text{sec}}$$

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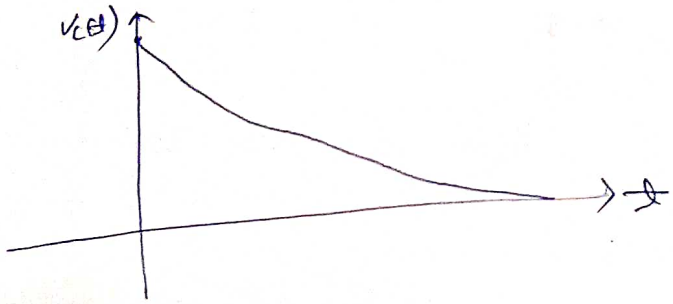
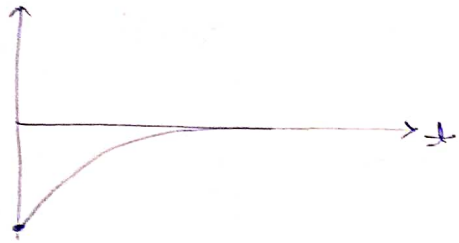
- $V_c(t) = 0 + [14.5 - 0]\, e^{-3t}$

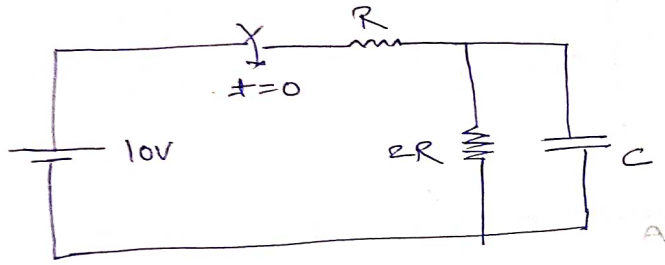
$$\boxed{V_c(t) = 14.5\, e^{-3t}}$$ — discharging eqn.



$$I_c(t) = C\left(\frac{dv}{dt}\right)$$

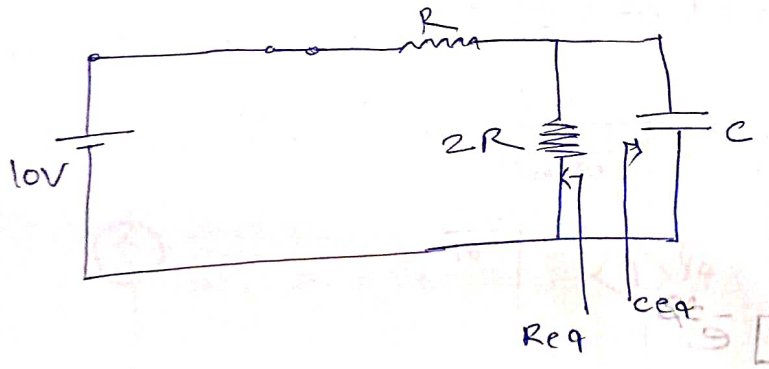


Q)



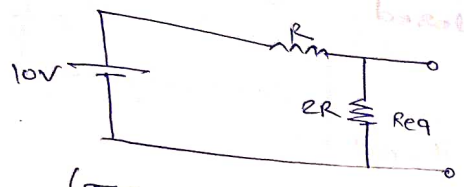
$\tau = ?$

Sol:- Time constant is defined for $t \geq 0$ i.e. after switching



$\tau = R_{eq} \times C_{eq}$

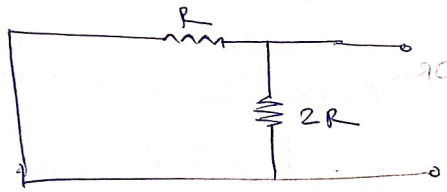
⇒



(This is case I problem of Rth calculation)

I.V.S → S.C

I.C.S → O.C

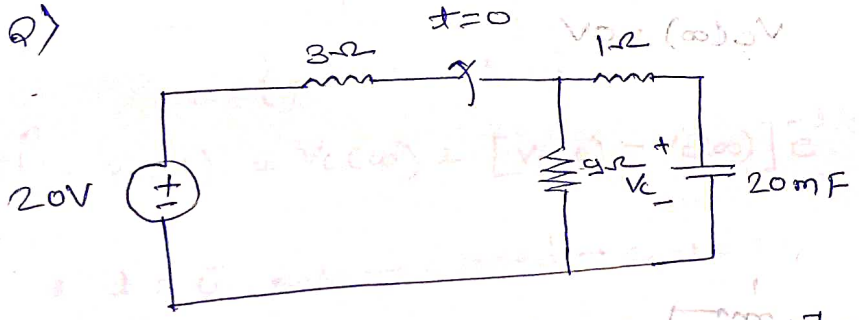


$$R_{eq} = \frac{R \times 2R}{3R} = \frac{2}{3}R$$

C_{eq}

$$\boxed{\tau = R_{eq} \cdot C_{eq} = \frac{2}{3}RC}$$

Q)

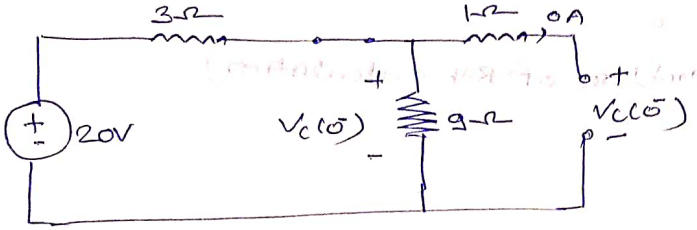


Soln:- $V_C(t) = V_C(\infty) + [V_C(0) - V_C(\infty)]\, e^{-t/\tau}$

$- - - \quad t > 0$

* At Before switching → S.W. closed

L → S.C , C → O.C.

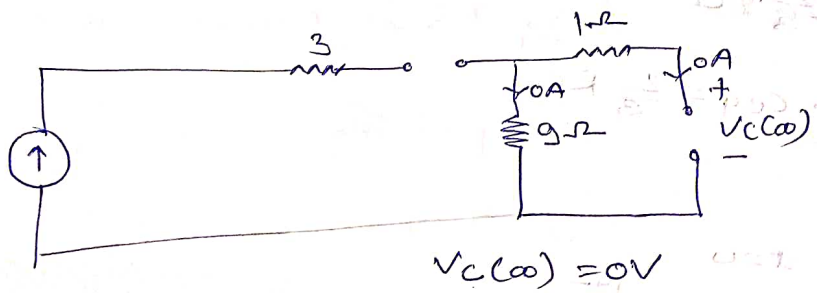


$$V_c(0^-) = \frac{20 \times 9}{12} \text{ V} \quad \text{--- VDR}$$

$$V_c(0^-) = 15\text{V} = V_c(0^+)$$

* at $t = \infty$, After switching SW → open

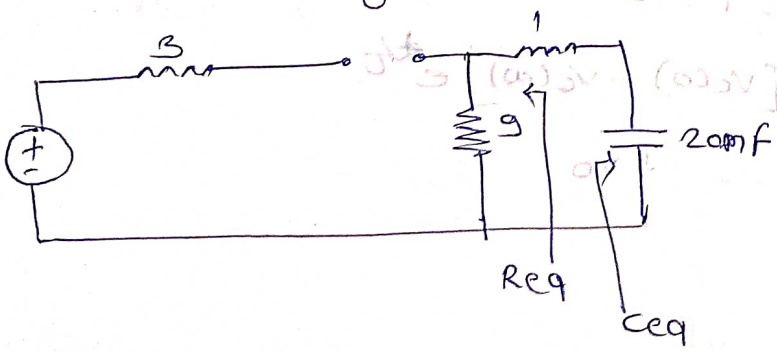
L → S.C. C → O.C.

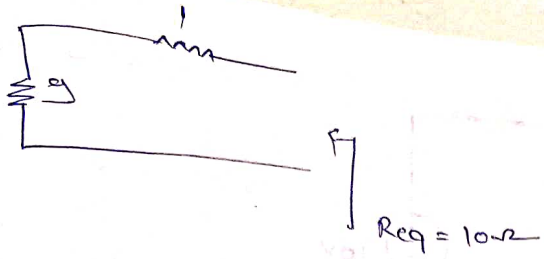


$$V_c(\infty) = 0\text{V}$$

* $\tau = R_{eq} \times C_{eq}$

after switching





$\tau = R_{eq} \times C_{eq}$

$= 10 \times 20 \times 10^{-3}$

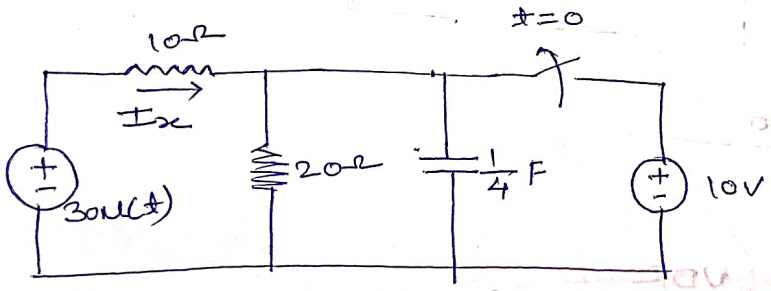
$\tau = 200$ m sec

$V_c(t) = 0 + [15 - 0]\, e^{-t/200\times10^{-3}}$

$= \left[15\, e^{-t/200\times10^{-3}}\right]$ volt

$i_c(t) = C \dfrac{dV_c(t)}{dt}$

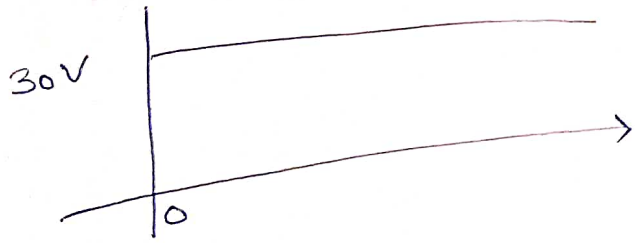
Q)

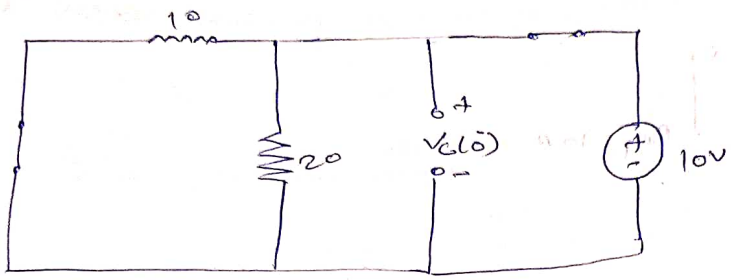


{ I_x for $t>0$ }

Sol^n:- $V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

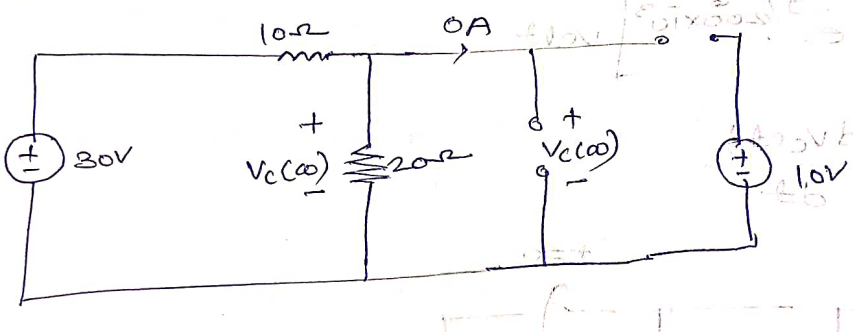
* $t = 0^-$ S.W. → closed → C → o.c.





* $V_c(0^-) = 10V$

* $t = \infty$, SW → open
  L → S.C , C → O.C.



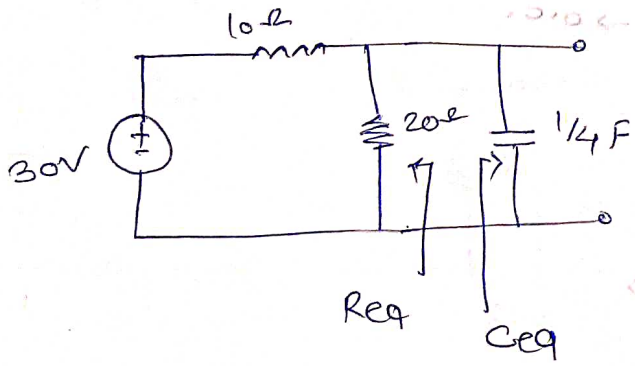
$$V_c(\infty) = \frac{30 \times 20}{30}$$

$$= 20V$$

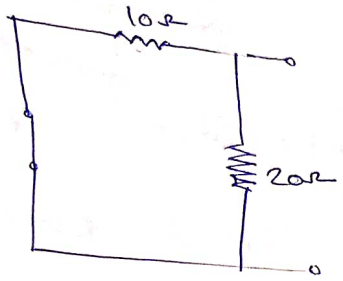
--- NDR

* $\tau = R_{eq} \times C_{eq}$

--- $t > 0$



Req →



$$R_{eq} = \frac{20 \times 10}{30}$$

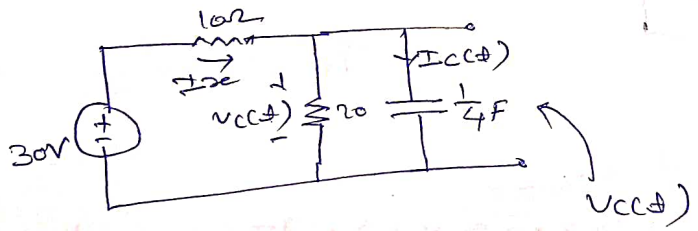
$$\tau = \frac{200}{30} \times \frac{1}{4} = \frac{50}{30}$$

$$= 5/3 \text{ sec}$$

$$V_c(t) = 20 - 10e^{-3t/5}$$

$$\boxed{V_c(t) = 20 - 10e^{-0.6t}}$$

find I_x



$$I_x = \frac{30 - V_c(t)}{10}$$

$$= 30 - 20 + 10e^{-0.6t}$$

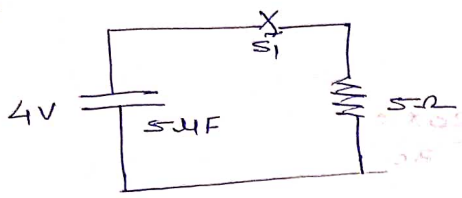
$$\boxed{I_x = 10 + 10e^{-0.6t}}$$

$t = 5$ sec

$$\boxed{I_x = 1.049 A}$$

Lect-61

Q)



decrease

S_1 close at $t=0$

q_1 (μC) lost from $t = 25\mu sec$ to $t = 100\mu sec$

Sol^n:-

$q_1(t) = C \cdot V_c(t)$

$$\boxed{q_1(t) = 5\times10^{-6} \times V_c(t)}$$

for $t>0 \rightarrow$ There is no source

source free circuit $\rightarrow$ Natural response

$$\boxed{V_c(t) = V_c(0)\, e^{-t/\tau}}$$

$* \; V_c(t) = 4 \times e^{-t/\tau}$

$\tau = R_{eq} \times C_{eq}$

$= 5 \times 5 \times 10^{-6}$

$= 25\mu sec$

$* \; V_c(t) = 4 \times e^{\left(\frac{-t}{25\times10^{-6}}\right)}$ ✓

$$q_c(t)\Big|_{t=25\times10^{-6}} = 5\times10^{-6} \times 4 \times e^{\frac{-25\times10^{-6}}{25\times10^{-6}}}$$

$= \cancel{7.3575\mu C}\ 7.3575 \times 10^{-6}$

$= 7.35\mu C$

$$q_c(t)\Big|_{t=100\mu sec} = 5\times10^{-6}\times4\times e^{-\left(\frac{100\times10^{-6}}{25\times10^{-6}}\right)}$$

$$q_c(t) = 0.3663\,\mu C$$

$$q_{lost} = q_c(t)\Big|_{t=25} - q_c(t)\Big|_{t=100}$$

$$= 7.357 - 0.3663$$

$$\boxed{q_{lost} = 6.99\,\mu C}$$

* Initial Energy $= \frac{1}{2}C\times V_c(0)^2$

$$= \frac{1}{2}\times5\times10^{-6}\times16$$

$$= 40\,\mu J$$

$$E_c(t)\Big|_{t=25\mu sec} = \frac{1}{2}\times C\times V_c(t)^2$$

$$= \frac{1}{2}\times5\times10^{-6}\times\left(4\times e^{-\frac{25\times10^{-6}}{25\times10^{-6}}}\right)^2$$

$$= \frac{1}{2}\times5\times10^{-6}\times16\times e^{-2}$$

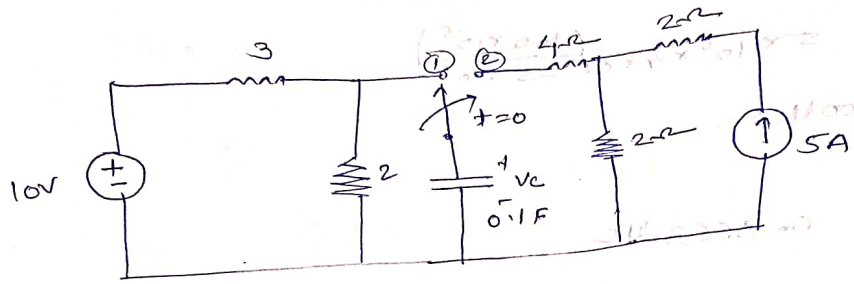
$$= 5.41\,\mu J$$

$$E_c(t)\Big|_{t=100\mu sec} = \frac{1}{2}\times5\times16\times e^{-\frac{200}{25}}\,\mu J$$

$$= \cancel{0.340}\ 0.013\times10^{-6}\,\mu J.$$

$$E_{lost} = E_c\Big|_{\cancel{t=25}} - E_c\Big|_{t=100}$$

Q)

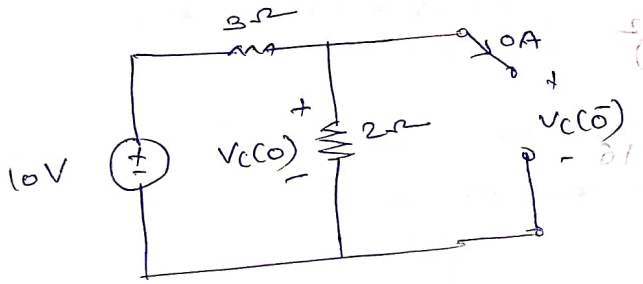


$V_c(t) = ?$ for $t > 0$

Soln:- $V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

at $t = 0^-$ S.W at position 1

$C \rightarrow$ O.C $L \rightarrow$ S.C

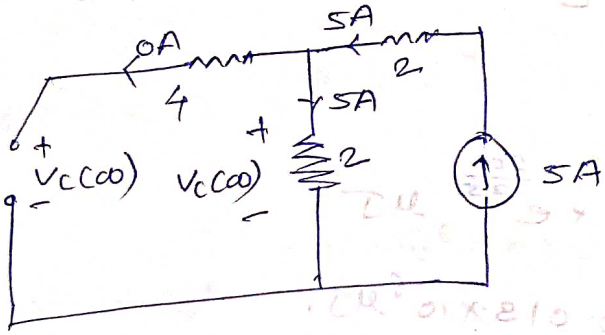


$V_c(0^-) = \frac{10 \times 2}{5} = 4V$

$= V_c(0^+)$

* at $t = \infty$, S.W. $\rightarrow$ (2)

$C \rightarrow$ O.C. $L \rightarrow$ S.C.



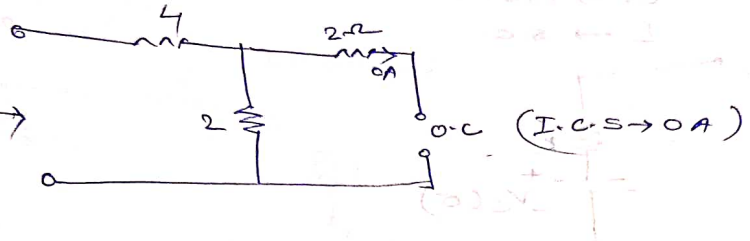
$V_c(\infty) = 5 \times 2$

$= 10V$

* Time constant τ

$\tau = R_{eq} \times C_{eq}$

$R_{eq} \rightarrow$



$R_{eq} = 4 + 2 = 6\Omega$

$\tau = 6 \times 0.1$

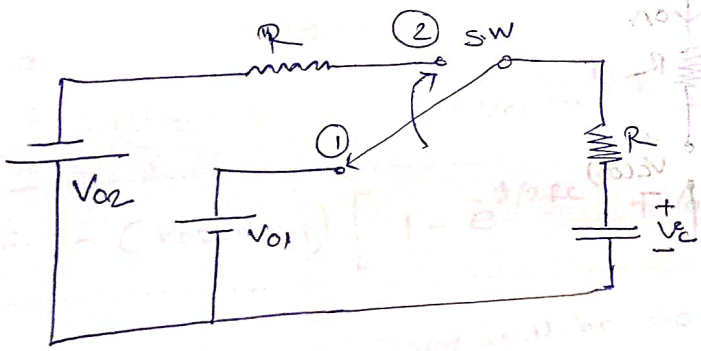
$\tau = 0.6 \text{ sec}$

* $V_c(t) = 10 + [4 - 10]e^{-t/0.6}$

$$\boxed{V_c(t) = 10 - 6e^{-t/0.6}}$$

*

Q)

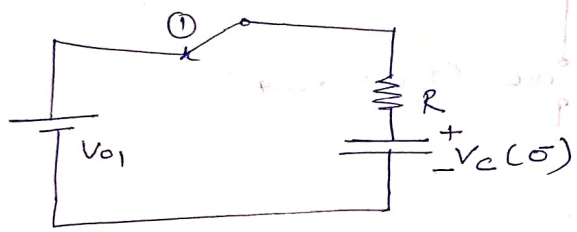


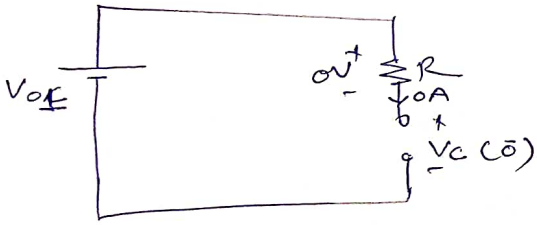
$|V_{o2}| > |V_{o1}|$

Sol^n:- $V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

At $t = 0^-$, S.W. → ①

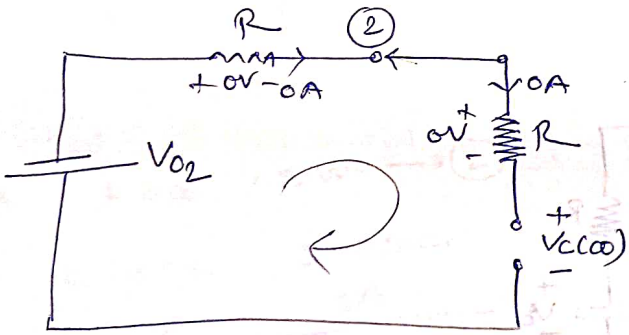
C → O.C.
L → S.C.





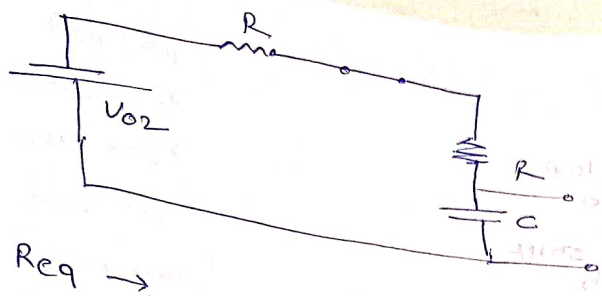
$$\boxed{V_c(0^-) = V_c(0^+) = V_{01}}$$

* at $t = \infty$, S.W. → ② C → O.C.

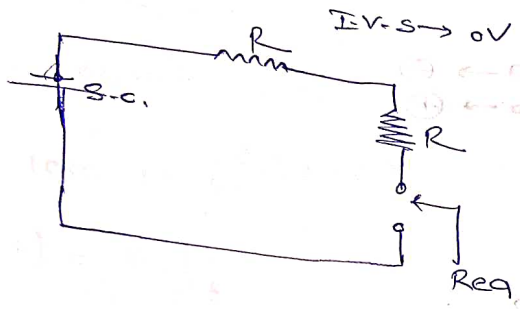


$V_c(\infty) = -V_{02}$

* $\tau = R_{eq} \times C_{eq}$ → $t > 0$ or after switching



* R_{eq} →



$R+R = 2R = R_{eq}$

$\tau = 2R \times C$
$= 2RC$

$$V_c(t) = -V_{02} + [V_{01} + V_{02}]\, e^{-t/2RC}$$

$$= -V_{02} + V_{01} + V_{02}\, e^{-t/2RC}$$

$$= -V_{02} + V_{01} + V_{01}\, e^{-t/2RC} + V_{02}\, e^{-t/2RC} - V_{01}$$

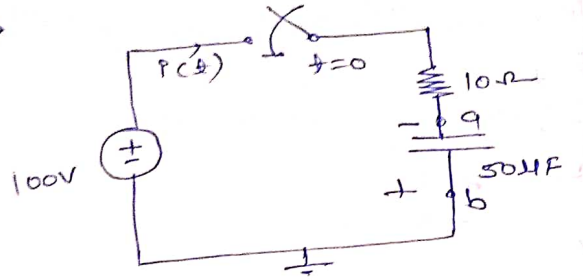
~~Lect~~ 62

$$= -(V_{02}+V_{01}) + (V_{02}+V_{01})\, e^{-t/2RC} + V_{01}$$

$$\boxed{V_c(t) = -(V_{02}+V_{01})\left[1 - e^{-t/2RC}\right] + V_{01}}$$

- - - There will be no option match but answer is correct.

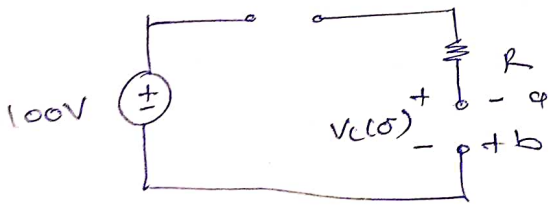
Q)



$q_c(0^-) = 2.5\,mC \longrightarrow a \rightarrow \ominus$, $b \rightarrow \oplus$

* for $t>0$ find $i(t) = ?$

Sol^n:- At $t = 0^-$ → S.W. → open



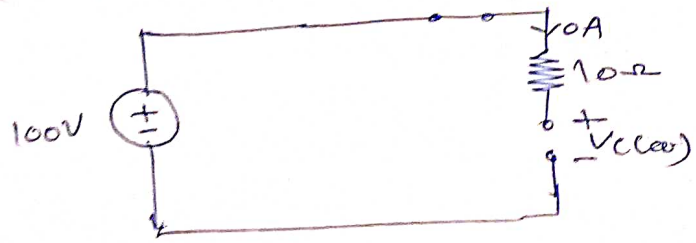
$$V_c(0^-) = \frac{-q_c(0)}{C}$$

$$= \frac{-2.5\times10^{-3}}{50\times10^{-6}} = -50V$$

$$= -\frac{1}{2}\times10^{3}$$

$$= -0.5\,kV = -500V$$

* $(t=\infty) \longrightarrow$ S.W. → closed, C → O.C.



$[V_c(\infty) = 100V]$

$\tau = R_{eq} C_{eq}$

$= 10 \times 50 \times 10^{-6}$

$= 500 \times 10^{-6}$

$= 0.5 \times 10^{-3}$

$\boxed{\tau = 0.5 \text{ msec}}$

* $V_c(t) = 100 + [-50 - 100]\, e^{-t/0.5\times10^{-3}}$

$= 100 - 150 e^{-t/0.5\times10^{-3}}$

* $i(t) = C \dfrac{dv}{dt}$

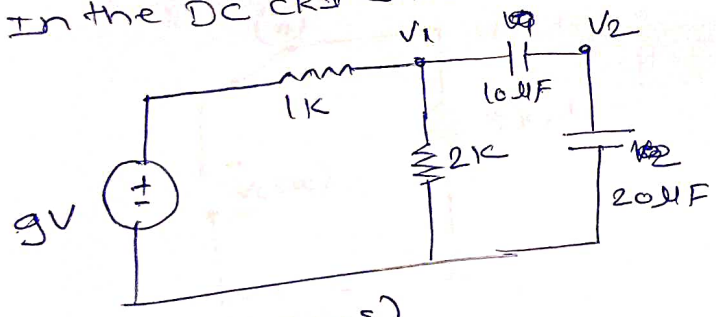
$= 50 \times 10^{-6} \times (-150)\, e^{-t/0.5\times10^{-3}} \times \left(\dfrac{-1}{0.5\times10^{-3}}\right)$

$= \dfrac{50 \times 150 \times 10^{-6}}{0.5 \times 10^{-3}} \times e^{-t/0.5\times10^{-3}}$

$= 150 \times 100 \times 10^{-3} \times e^{-t/0.5\times10^{-3}}$

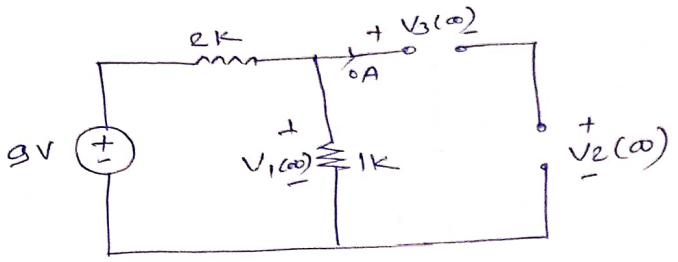
$\boxed{i(t) = 15 e^{-t/0.5\times10^{-3}}}$

Q) In the DC ckt shown



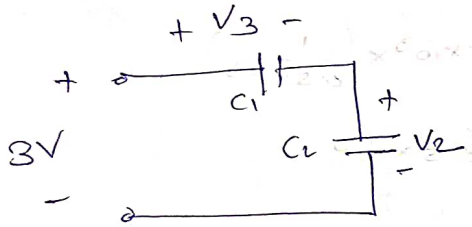
$V_2 = ?$ (s.s)

* $t = \infty$, $C \rightarrow$ (o.c)



$$V_1(\infty) = \frac{9 \times 1K}{3K}$$

$$\boxed{V_1(\infty) = 3\ V}$$



$$V_2(\infty) = \frac{3 \times C_1}{C_1 + C_2}$$

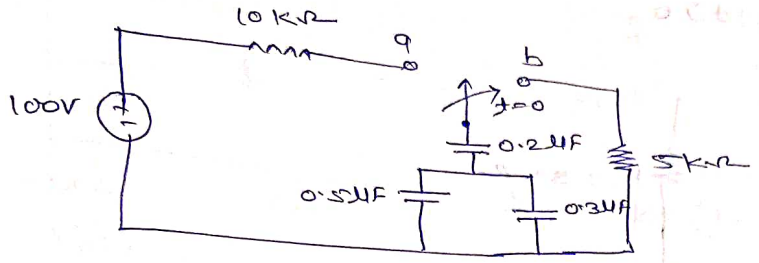
$$\boxed{V_2(\infty) = \frac{3 \times 10\mu F}{30\mu F} = 1V}$$

$$* \ V_3(\infty) = \frac{3 \times C_2}{C_1 + C_2}$$

$$= \frac{3 \times 20}{30}$$

$$\boxed{V_3(\infty) = 2V}$$

Q) The sw. in the ckt



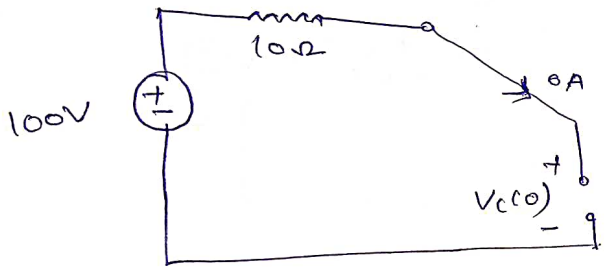
$i(t) = ?$

$C_{eq} = \frac{0.8 \times 0.2}{1}$

$\boxed{C_{eq} = 0.16\mu F}$

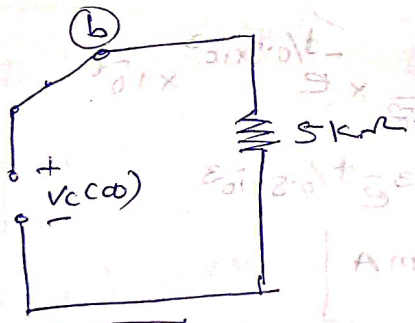
sol^n:-

* $t = 0^-$ sw → ⓐ $C_{eq} \to$ o.c.



$\boxed{V_c(0^-) = 100V}$

At $t = \infty$, sw → b, $C_{eq} \to$ o.c.

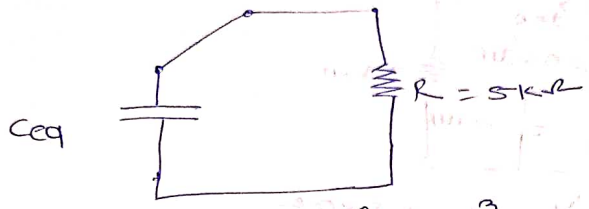


$\boxed{V_c(\infty) = 0V.}$

* as after switching there is no excitation in the circuit hence the response will be a natural response.

$V_c(t) = V_c(0^-)\, e^{-t/\tau}$.

* $\tau = R_{eq} \cdot C_{eq} \longrightarrow t > 0$



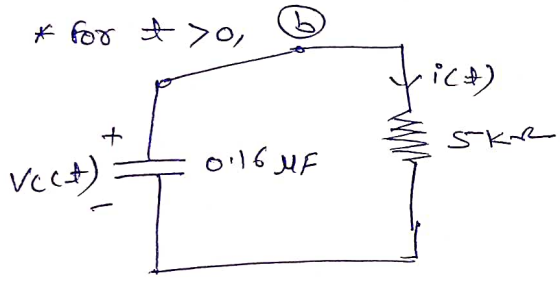
$\tau = 0.16 \times 10^{-6} \times 5 \times 10^{3}$

$= 0.80 \times 10^{-3}$

$\boxed{\tau = 0.8\,msec}$

$V_c(t) = 100\, e^{-t/0.8\times10^{-3}}$

* for $t > 0$,



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

$$= 0.16 \times \frac{d}{dt}\left(100\, e^{-t/0.8\times10^{-3}}\right) \times 10^{-6}$$

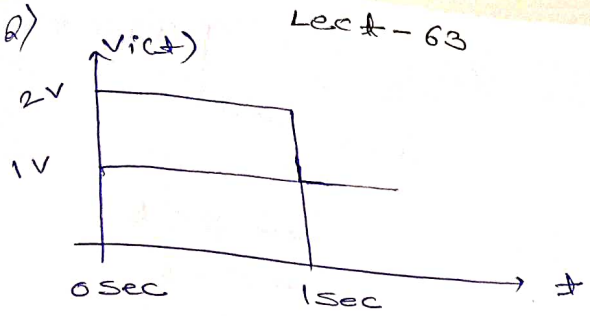
$$= 0.16 \times 100 \times -\frac{1}{0.8\times10^{-3}} \times e^{-t/0.8\times10^{-3}} \times 10^{-6}$$

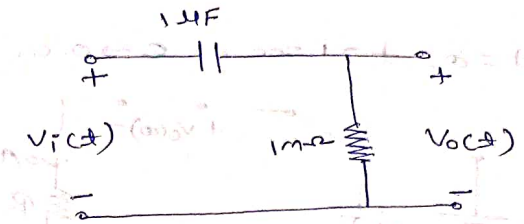
$$= -0.2 \times 100 \times 10^{-3}\, e^{-t/0.8\times10^{-3}}$$

$$\boxed{i(t) = 20\, e^{-t/0.8\times10^{-3}}\ mA}$$

$$\boxed{i(t) = 20\, e^{-1250t}}\ mA$$

Q) Lect - 63



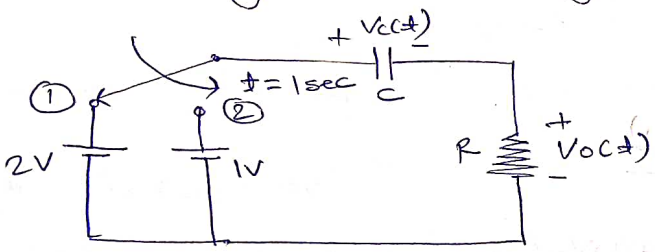


for (t = 2sec)

$V_o(t) = ?$

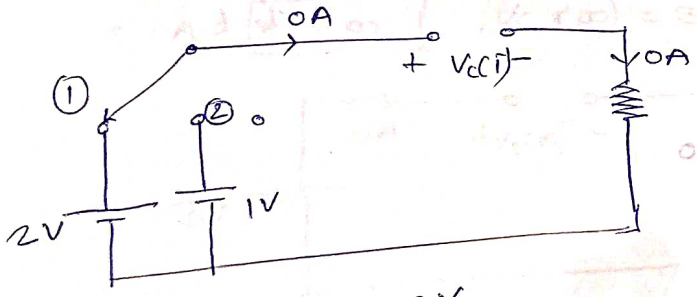
* we have to calculate first $V_c(t)$

sol^n:- The switching action is taking place at 1 sec.



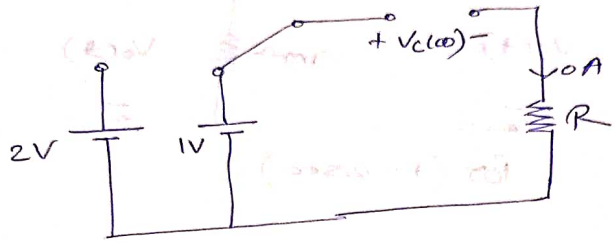
* $V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

* $t = 1^- \longrightarrow C \rightarrow$ o.c.



$V_c(1^-) = 2V$

* $t = \infty$, $t > 1$ sec $\rightarrow$ C $\rightarrow$ O.C.



$(V_c(\infty) = 1V)$

$\tau = R_{eq} C_{eq}$

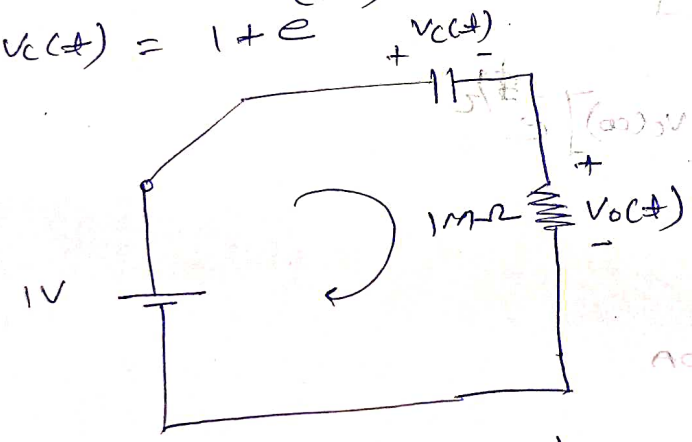
$= 1 \times 10^{6} \times 1 \times 10^{-6}$

$\boxed{\tau = 1 \text{ sec}}$

* $V_c(t) = 1 + [2-1]\, e^{-\frac{(t-1)}{1}}$

$V_c(t) = 1 + e^{-(t-1)}$

*



$1 - V_c(t) - V_o(t) = 0$

$V_o(t) = 1 - V_c(t)$

$$\boxed{V_o(t) = -e^{-(t-1)} \text{ V}}$$

$* V_o(t)\Big|_{t=2} = -e^{-(2-1)}$

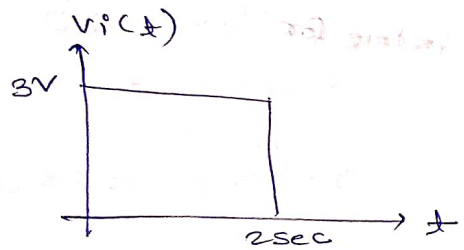
$= -e^{-1}$

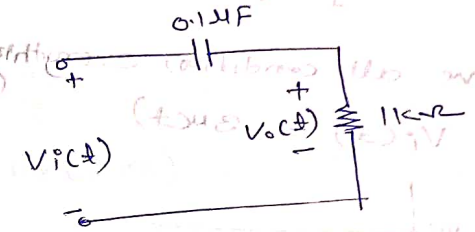
$t > 2$ sec

$t = 3$ sec

$V_o(t)\Big|_{t=3} = -e^{-2}$.

Q)





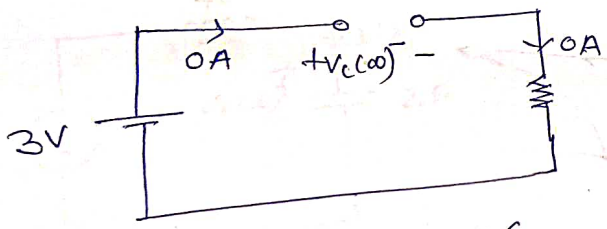
$* \quad V_c(0^-) = 0V$

$V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]e^{-t/\tau}$

$--- (t \geq 0)$

$*$ at $t = 0^-$, $V_c(0^-) = 0V$

$*$ At $\boxed{t = \infty}$, $V_c(\infty) = 3V$



$* \tau = R_{eq} \cdot C_{eq} = 1 \times 10^3 \times 0.1 \times 10^{-6}$

$= (0.1 \times 10^{-3})$ sec

$V_c(t) = 3 + [0-3]e^{-t/\tau}$

$= 3(1 - e^{-t/\tau}) = 3(1 - e^{-t/0.1\times10^{-3}})$

$= 3(1 - e^{-10^4 t})$ for $t > 0$

$$I_c(t) = (0.1 \times 10^{-6}) \times (e^{-10^4 t} \times 10^4)$$

$$= (0.1 \times 10^{-2} \times e^{-10^4 t})$$

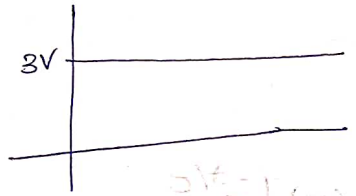
$$I_c(t) = I_c(t) \times 10^3$$

$$= e^{-10^4 t}$$

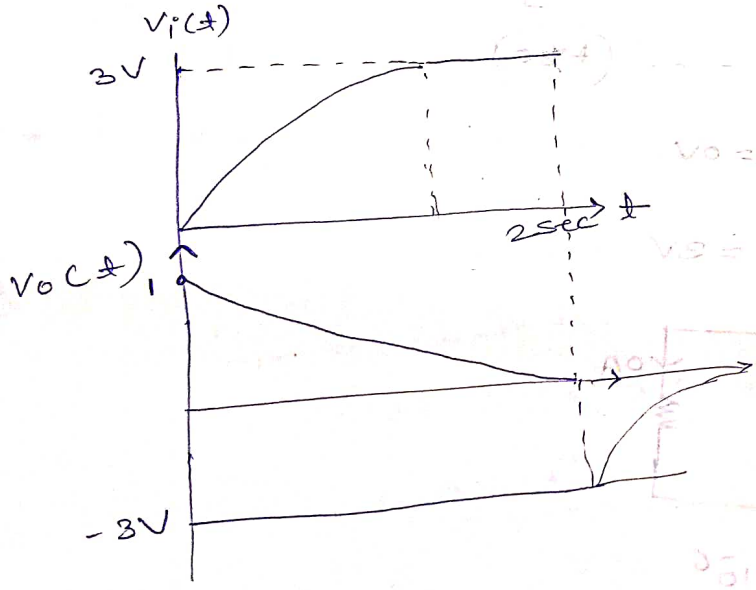
$$\boxed{V_o(t) = e^{-10^4 t}} \quad (t > 0)$$

above all condition everything is true for

if $V_i(t) = 3u(t)$



Lect – 64



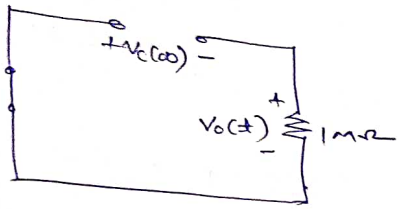
* for $(t > 2\,sec)$

$$V_c(t) = V_c(\infty) + [V_c(2^-) - V_c(\infty)]\, e^{-\frac{(t-2)}{\tau}}$$

$$V_c(2^-) = 3V$$

at

$t = \infty$ $\quad C \rightarrow$ o.c.



$V_c(\infty) = 0V$

$* \quad \tau = 1 \times 10^{+3} \times 0.1 \times 10^{-6}$

$= 0.1 \times 10^{-3}$

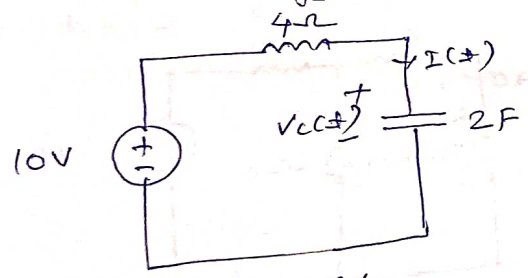
$V_c(t) = 3 e^{-\frac{(t-2)}{0.1 \times 10^{-3}}}$ --- for $(t > 2)$

$V_o(t) = -V_c(t) = -3 e^{-\left(\frac{t-2}{0.1 \times 10^{-3}}\right)}$

$\boxed{-3V}$

$V_c(t) = 3\left(1 - e^{\frac{-t}{0.1 \times 10^{-3}}}\right) + 3 e^{\frac{-(t-2)}{0.1 \times 10^{-3}}}$

Q) Total Energy absorbed by 4Ω from 0 to ∞ is



$V_c(0^-) = 6V$

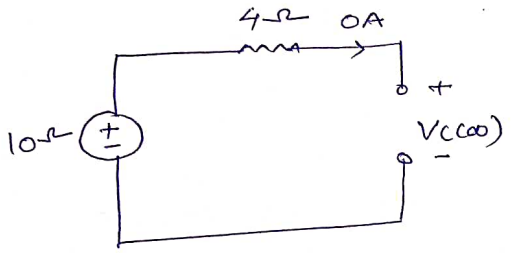
Sol^n:- Energy $= \int_0^\infty p(t)\, dt$

$= \int_0^\infty I(t)^2 R\, dt = \int_0^\infty I(t)^2 \times 4\, dt$

$* \; V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]\, e^{-t/\tau}$

① $t = 0^-$, $V_c(0^-) = V_c(0^+) = 6V$

② $t = \infty$, $C \rightarrow$ o.c.



③ $\tau = R \times C = 4 \times 2 = 8\,sec$

$* \; V_c(t) = 10 + [6-10]\, e^{-t/8}$

$V_c(t) = (10 - 4e^{-t/8})$ Volt

$i(t) = C \dfrac{dV_c(t)}{dt}$

$= 2 \times \dfrac{4}{8} e^{-t/8}$

$i(t) = (e^{-t/8})$ A

$E_R(t) = \int_0^\infty e^{-2t/8} \times 4\, dt$

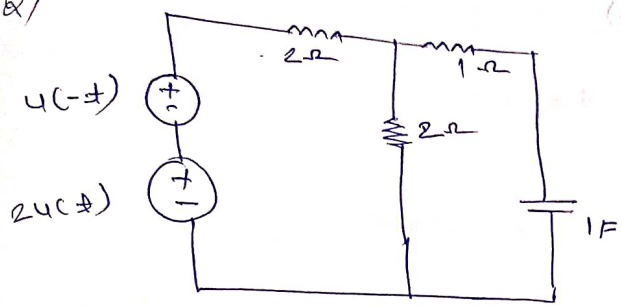
$= 4 \times 8 \left[\dfrac{e^{-2t/8}}{-2} \right]$

$= -\dfrac{32}{2} \left[e^{-2t/8} \right]_0^\infty$

$= \frac{32}{2}[0-1]$

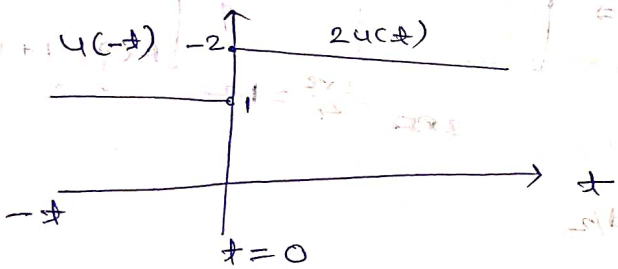
$\boxed{E_R = 16 \text{ Joule}}$

Q)



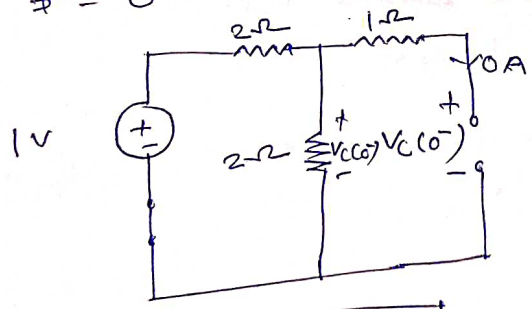
Find $V_c(t) \longrightarrow t>0$

Sol^n:- Source $= u(-t) + 2u(t)$



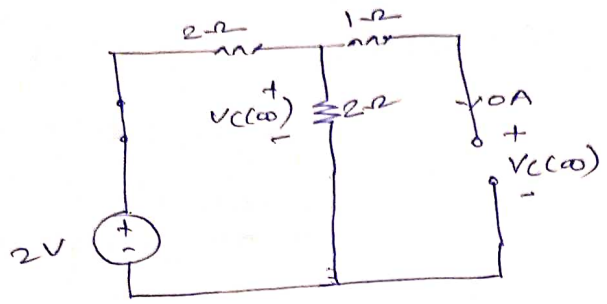
*

* $t = 0^-$ $\quad C \longrightarrow$ o.c.



$\boxed{V_c(0^-) = 0.5V}$

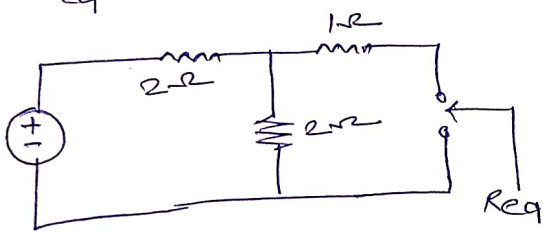
* $t = \infty$ $\quad C \rightarrow o.c \quad (t > 0)$



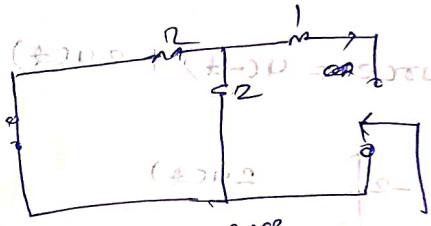
$$\boxed{V_C(\infty) = 1V}$$

* $\tau = R_{eq} \cdot C_{eq}$

$R_{eq} \longrightarrow$



$\Rightarrow$



$\frac{2 \times 2}{4} = 1\Omega$

$R_{eq} = 1 + 1$
$= 2$

* $V_C(t) = 1 + [0.5 - 1]\, e^{-t/2}$

$$\boxed{V_C(t) = 1 - 0.5\, e^{-t/2}}$$

Lect - 65

Problems based on RL circuits.

Step 01 :- write down the transient eqn for $t > 0$.

$$i_L(t) = i_L(\infty) + [i_L(0) - i_L(\infty)]\, e^{-t/\tau}$$

τ = time constant $= \frac{L_{eq}}{R_{eq}}$

Step 02 :- Evaluate the value of $i_L(0)$ & $i_L(\infty)$

Initial value (before switching) — steady state value

at $\begin{cases} t = 0^- , & L \rightarrow \text{s.c.} \\ t = \infty , & L \rightarrow \text{s.c.} \end{cases}$

Step 03 :- Evaluate the time constant (τ) after switching.

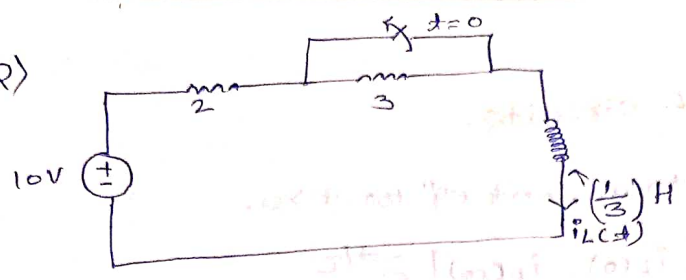
$L_{eq} \rightarrow$ Then take R as load

$R_{eq} \rightarrow$ Then take L as load.

Step 04 :- put the values obtained in step ② & ③ in step 01 and get the desired Response.

Step 05 :- if some other response is ask then always calculate first $i_L(t)$ only.

Q)

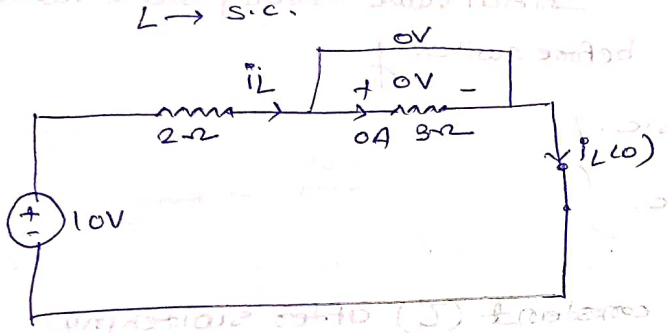


soln:-

$$i_L(t) = i_L(\infty) + [i_L(0) - i_L(\infty)]\, e^{-t/\tau}$$

i) at $t=0$, S.W → closed

L → S.C.

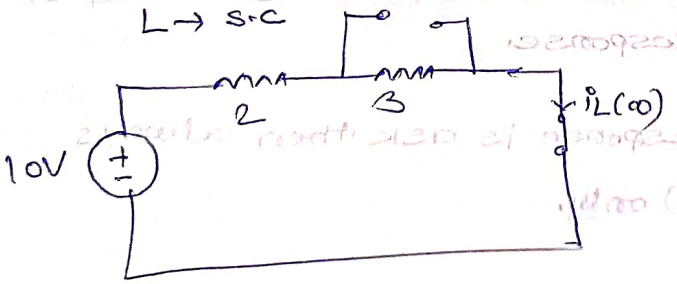


$$i_L(0^-) = \frac{10}{2}$$

$$\boxed{i_L(0^-) = 5A = i_L(0^+)}$$

* At $t = \infty$ S.W. → open

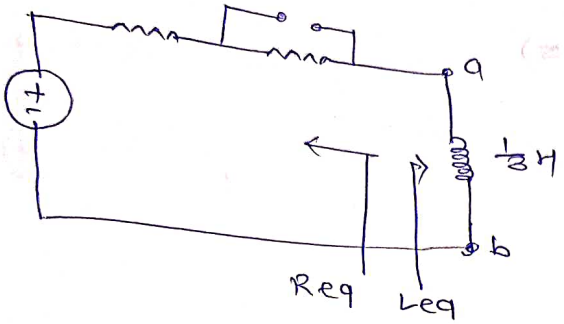
L → S.C



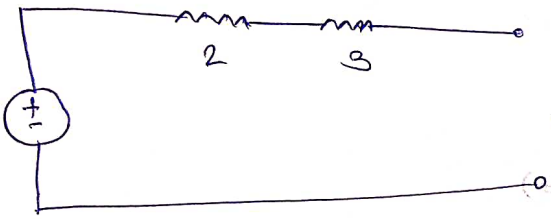
$$i_L(\infty) = \frac{10}{5}$$

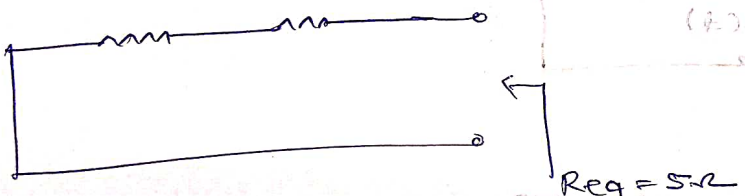
$$\boxed{i_L(\infty) = 2A}$$

$* \ \tau = \frac{L_{eq}}{R_{eq}}$, $t > 0$



Req →





$\tau = \frac{1}{3} \times \frac{1}{5}$

$= \frac{1}{15}$ sec.

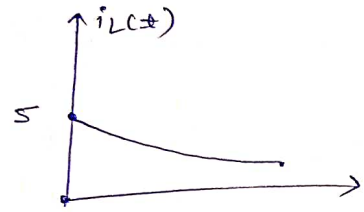
$* \ i_L(t) = 2 + [5-2]\, e^{-15t}$

$$\boxed{i_L(t) = 2 + 3e^{-15t}}$$

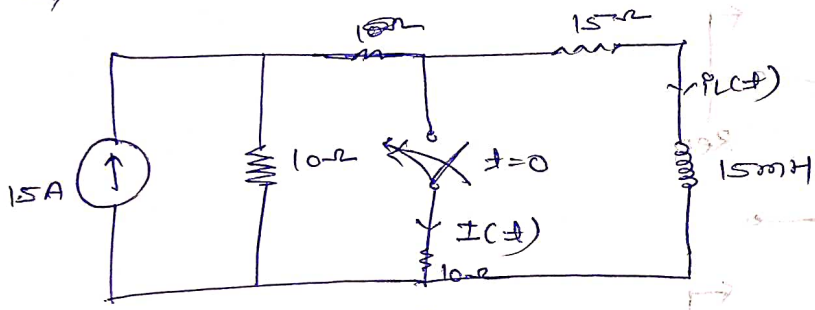
$$* \; V_L(t) = \frac{L \cdot di_L(t)}{dt}$$

$$= \frac{1}{3} \times 3e^{-15t} \times (-15)$$

$$\boxed{V_L(t) = -15e^{-15t}}$$



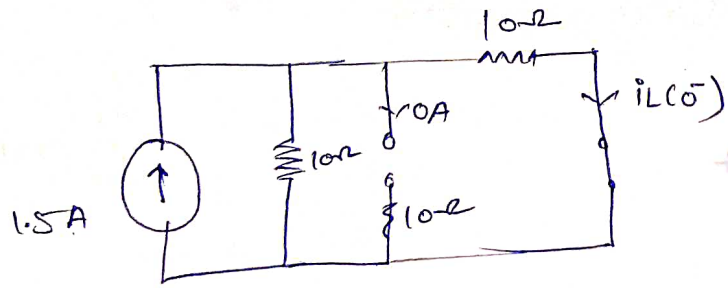
Q)



$I(t) = ?$

Soln:- at $t = 0^- \rightarrow$ S.W - open

$L \rightarrow$ S.C.

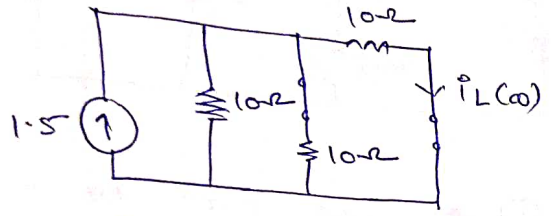


$$i_L(0^-) = \frac{1.5}{2} = 0.75 \text{ A}$$

$$= i_L(0^+)$$

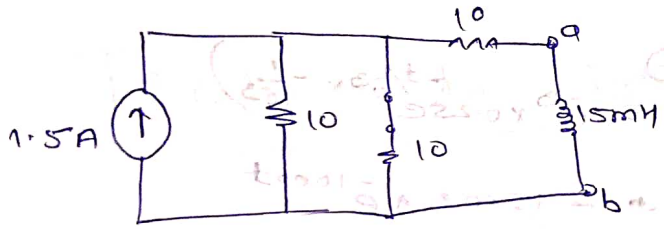
At $t = \infty$ S.W. → closed

L → S.C.

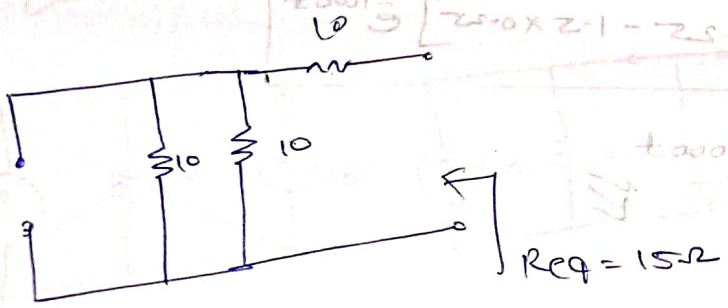


$$i_L(\infty) = \frac{1.5}{3}$$
$$= 0.5A$$

$$* \ \tau = \frac{L_{eq}}{R_{eq}}, \quad t > 0$$



Req :

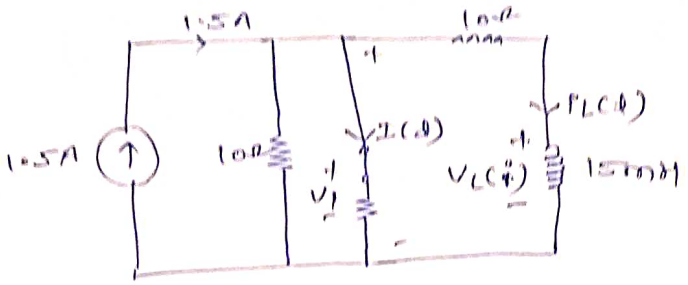


$$\tau = \frac{15 \times 10^{-3}}{15}$$

$$\boxed{\tau = 1 \text{ msec}}$$

$$i_L(t) = 0.5 + [0.75 - 0.5]\, e^{-t/1\times10^{-3}}$$

$$\boxed{i_L(t) = 0.5 + 0.25\, e^{-t/1\times10^{-3}}}$$



$V_1 = I(t) \times 10\Omega$ --- (1)

Applying KVL,

$V_1 = i_L(t) \times 10 + V_L(t)$ --- (2)

$$I(t) \times 10 = 5 + 2.5\, e^{-t/10^{-3}} + 15\times10^{-3} \times 0.25\, e^{\left(-t/10^{-3} \times -\frac{1}{10^{-3}}\right)}$$

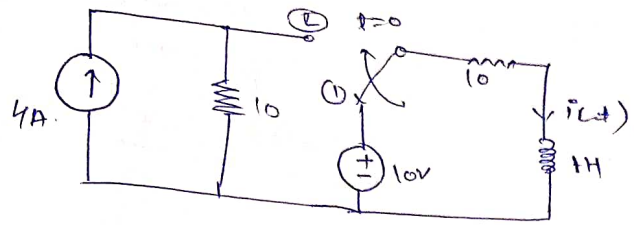
$$= 5 + 2.5\, e^{-1000t} + 15\times0.2 \times e^{-1000t}$$

$$I(t) = 0.5 + 0.25\, e^{-1000t} - 1.5\times0.25\, e^{-1000t}$$

$$\boxed{I(t) = 0.5 + [0.25 - 1.5\times0.25]\, e^{-1000t}}$$

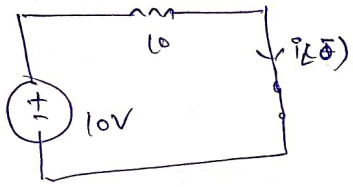
$$I(t) = 0.5 - 0.125\, e^{-1000t}$$

Q)



Soln:- at $t = 0^-$ SW → ①

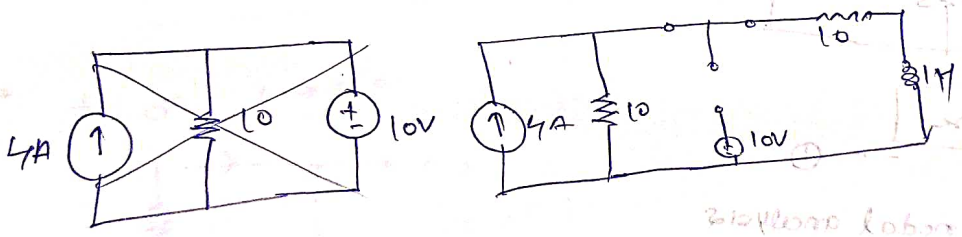
L → S.C.



$$\boxed{i_L(0^-) = \frac{10}{10} = 1A} = i_L(0^+)$$

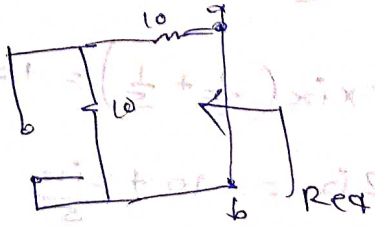
at $t = \infty$ SW → ②

L → S.C.



$i_L(\infty) = 2A$

$$\tau = \frac{L_{eq}}{R_{eq}} = \frac{1}{R_{eq}}$$



$R_{eq} = 20\Omega$

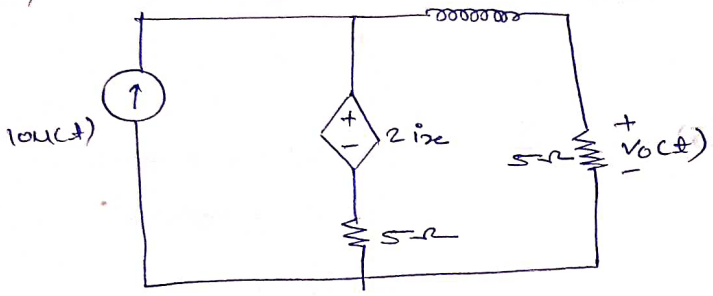
Lect- 66

$\tau = \frac{1}{20}$ sec.

* $i_L(t) = 2 + [1-2]\, e^{-t \times 20}$

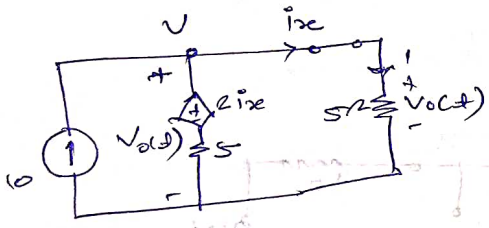
$$\boxed{i_L(t) = 2 - e^{-20t}}$$

Q)



find $V_o(t)$ at $t \to \infty$

* at $t = \infty \to$ S.S $\to$ L $\to$ S.C



$$\boxed{V_o = 5 \times i_x} \quad \text{---} (1)$$

* applying nodal analysis

$$V_o\left(\frac{1}{5} + \frac{1}{5}\right) = \frac{2 i_x}{5} + 10$$

$$5 \times i_x\left(\frac{1}{5} + \frac{1}{5}\right) = 10 + \frac{2 i_x}{5}$$

$$2 i_x = 10 + \frac{2 i_x}{5}$$

$$i_x = \frac{50 + 2 i_x}{5 \times 2}$$

$$i_x = \frac{50}{10} + \frac{2 i_x}{10}$$

$$i_x - \frac{2 i_x}{10} = 5$$

$$10 i_x - 2 i_x = 50$$

$8\, i_x = 50$

$i_x = \frac{50}{8}$

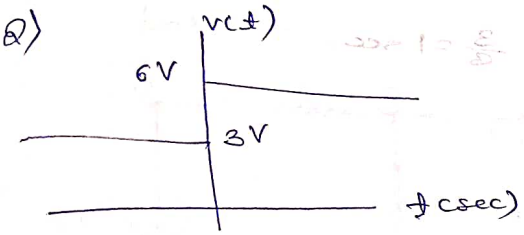
$\boxed{i_x = 6.25\,A}$

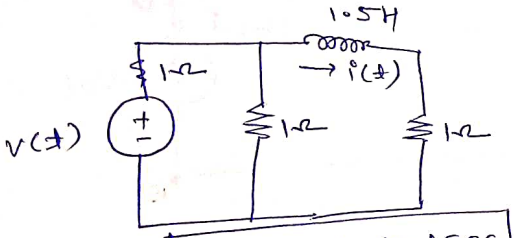
$V_o = 5 \times i_x$

$= 5 \times 6.25$

$\boxed{V_o = 31.25\,V}$

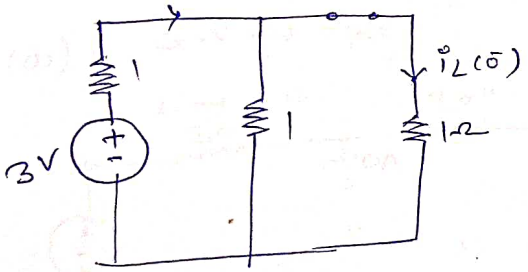
Q)





$\boxed{i(t) \text{ at } t = 1\,sec}$

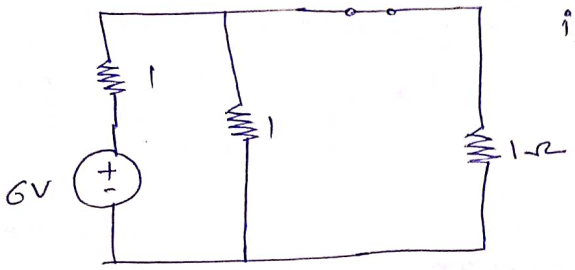
* $t = 0^-$, $L \to$ s.c.



$I = \frac{3}{1.5} = 2A$

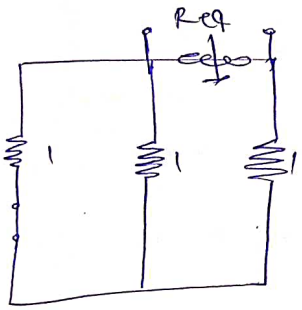
$\left(i_L(0^-) = \frac{2}{2} = 1A \right)$

* $t \to \infty$, $L \to$ s.c.



$i_L(\infty) = 2A$

* $\tau = \frac{L_{eq}}{R_{eq}} = \frac{1.5}{R_{eq}} = \frac{1.5 \times 2}{3} = \frac{3}{3} = 1$ sec.



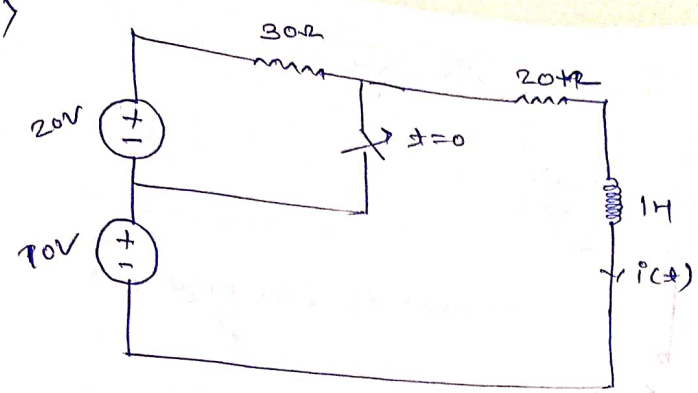
$= R_{eq} = \frac{1}{2} + 1 = \frac{3}{2}$

* $i_L(t) = i(t) = 2 + [1-2]\, e^{-t}$

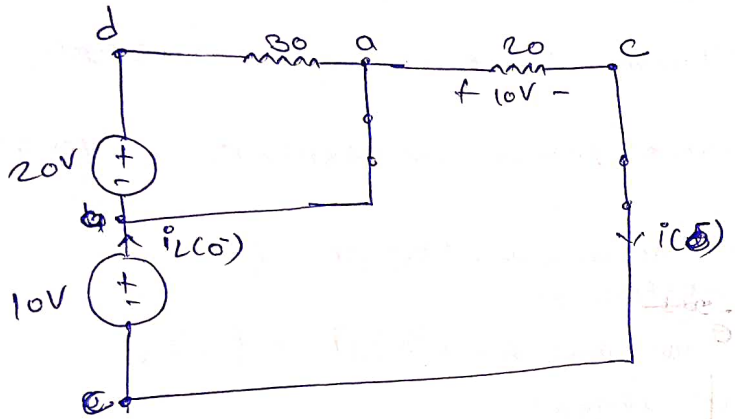
$i(t) = [2 - e^{-t}]\, A$

~~$i_L(t)$~~ $i(t)\Big|_{t=1} = (2 - e^{-1}) = 1.632A$

Q)



* $t = 0^-$, S.W → closed
L → S.C.

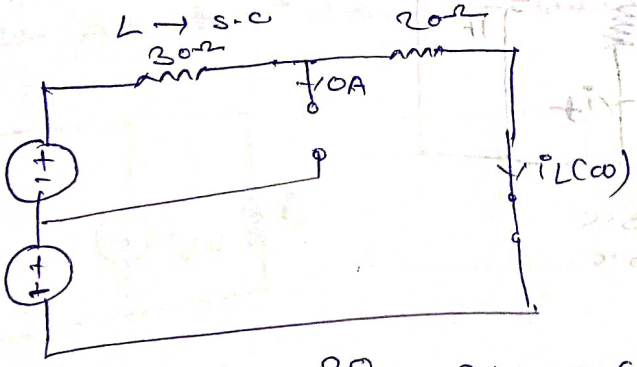


$$i_L(0^-) = \frac{10}{20} = 0.5A.$$

$$= i_L(0^+).$$

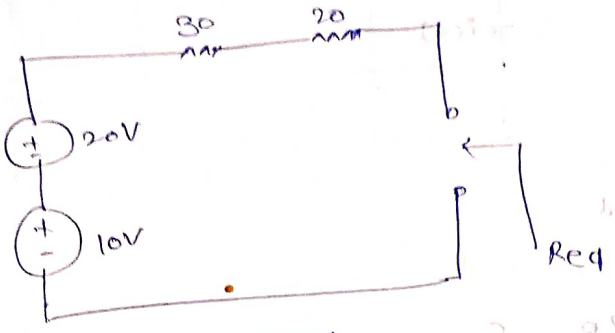
$i_L(\infty) =$ S.W → open

L → S.C



$$i_L(\infty) = \frac{30}{50} = 3/5 = 0.6A.$$

$$* \tau = \frac{L_{eq}}{R_{eq}} = \frac{1}{R_{eq}}$$



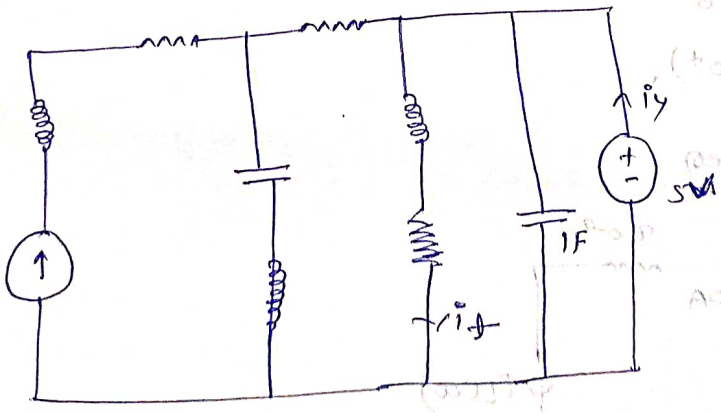
$$\boxed{R_{eq} = 50\Omega}$$

$$\boxed{\tau = \frac{1}{50} = 0.02\ sec}$$

$$* \ i_L(t) = 0.6 + [0.5 - 0.6]\, e^{-50t}$$

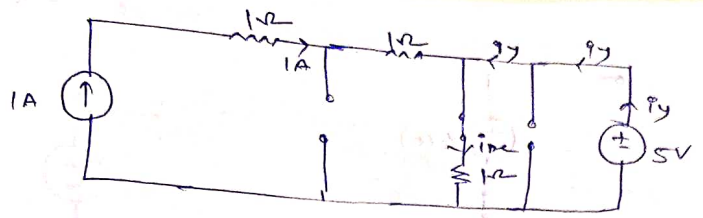
$$\boxed{i_L(t) = 0.6 - 0.1\, e^{-50t}}$$

Q)



$t \to \infty$ $\quad L \to S.C$

$C \to O.C$



Applying KCL at node 'a'

$i_y + 1 = 5$

$\boxed{i_y = 5 - 1 = 4\ A}$

Lect - 67

Problem based on $t = 0^+$ condition

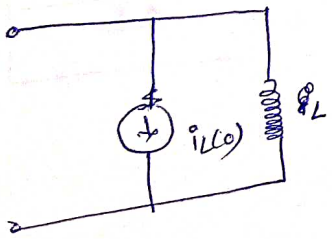
Step 01 :- Evaluate the initial condition for RC & RL Network.

$V_C(0^-) = V_C(0^+)$ → capacitor does not allow sudden change in voltage

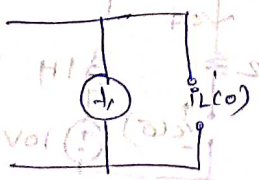
$i_L(0^-) = i_L(0^+)$ → Inductor does not allow sudden change in current.

To avoid the generation impulse signal as if it does not so then energy conservation principle would be failed.

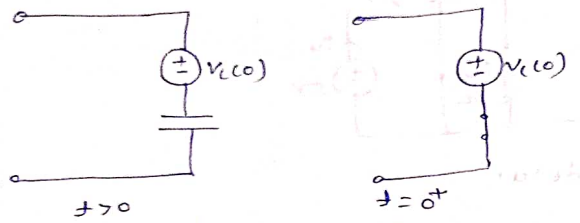
Step 02 :- At $t = 0^+$ draw the equivalent ckt's of RC & RL Network.



$t > 0$

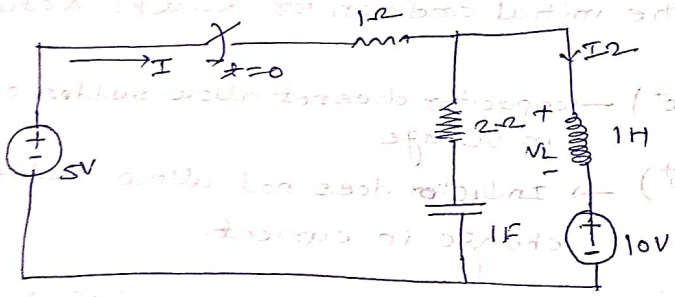


$t = 0^+$



Step 03:- Apply the basics concepts of N/W theory to get the desired results.

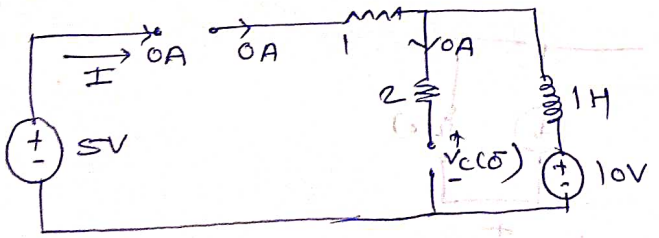
Q)



$$\left\{ I(0^+) \;\&\; \frac{dI_2(0^+)}{dt} \right\}$$

Sol^n:- * At $t=0^-$ S.W → open

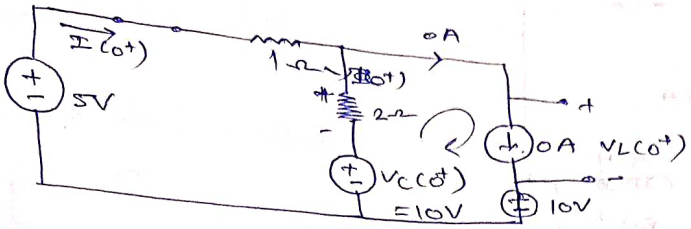
L → s.c & C → o.c



$i_L(0^-) = 0A = i_L(0^+)$

$V_c(0^-) = 10V = V_c(0^+)$

* At $t = 0^+$, → S.W → closed



$$5 - I(0^+) \times 3 - 10 = 0$$

$$\boxed{I(0^+) = \frac{-5}{3} A}$$

* KVL apply ②

$$10 + I(0^+) \times 2 - V_L(0^+) - 10 = 0$$

$$\boxed{V_L(0^+) = 2I(0^+)}$$

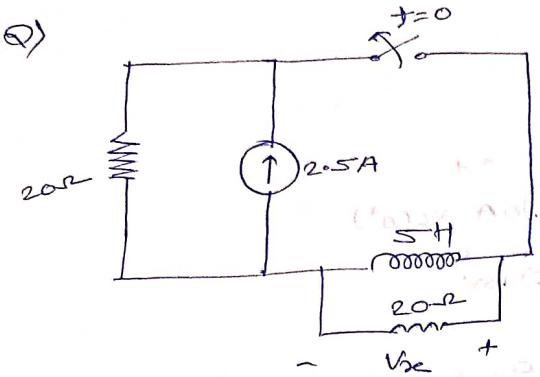
$$V_L(0^+) = \frac{-2 \times 5}{3} = \frac{-10}{3}$$

$$L \cdot \frac{dI_2(0^+)}{dt} = \frac{-10}{3}$$

$$\frac{dI_2(0^+)}{dt} = \frac{-10}{3} \times \frac{1}{L}$$

$$\boxed{\frac{dI_2(0^+)}{dt} = \frac{-10}{3} \frac{Amp}{sec}}$$

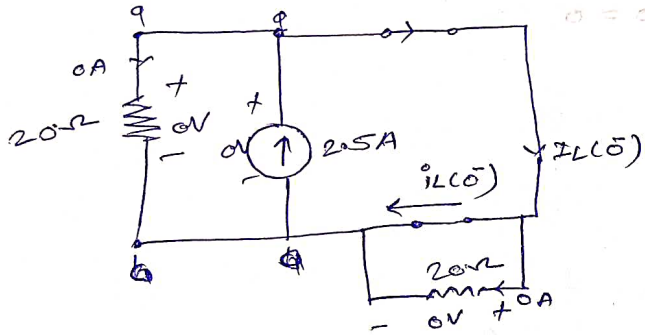
Q)



Find the value of V_x at $t = 0^+$

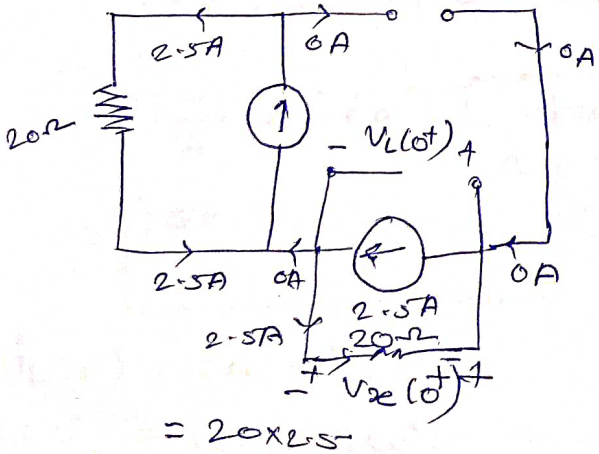
Sol^n:- at $t = 0^-$ S.W → closed

L → S.C C → O.C.



$$\boxed{i_L(0^-) = 2.5A}$$

* At $t = 0^+$ S.W → open



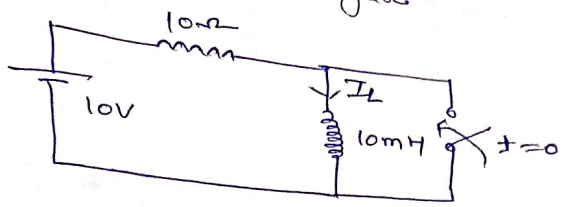
$= 20 \times 2.5$

$V_x(0^+) = -50\,V$

Lect 68

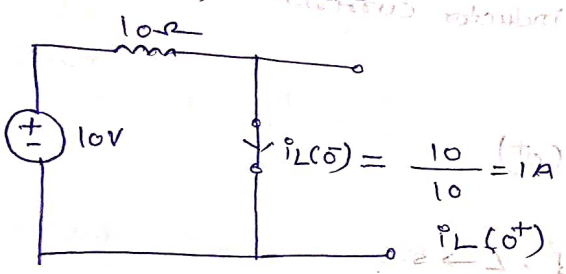
$$\frac{dI_L}{dt}(0^+) = \frac{-50}{5} = -10\,A/sec.$$

Q) The ckt shown in figure

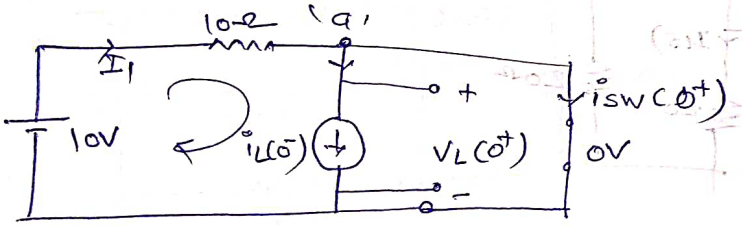


Sol^n:-

$t = 0^-$, L → S.C



⇒ At $t = 0^+$



$$\boxed{i_L(0^+) = 1A}$$

* $V_L(0^+) = 0V$

* $I_1 = 1A$

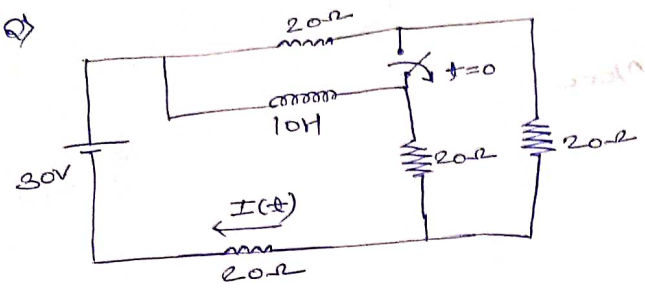
* Apply KCL at node a

$i_{sw}(0^+) + 1 = 1$

$$\boxed{i_{sw}(0^+) = 0A}$$ (Imp)

$$\boxed{\frac{di_L(0^+)}{dt} = 0 = A/sec}$$

Q



$I(t)\big|_{t=0^-} = ?$

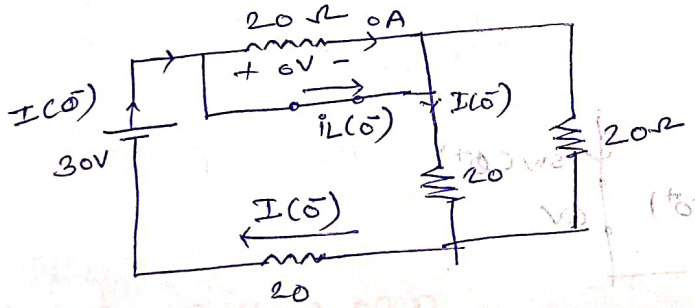
$I(t)\big|_{t=0^+} = ?$

This is Resistance current not inductor current.

∴ Not always equal to $I(t)$

$t(0^-) \neq t(0^+)$

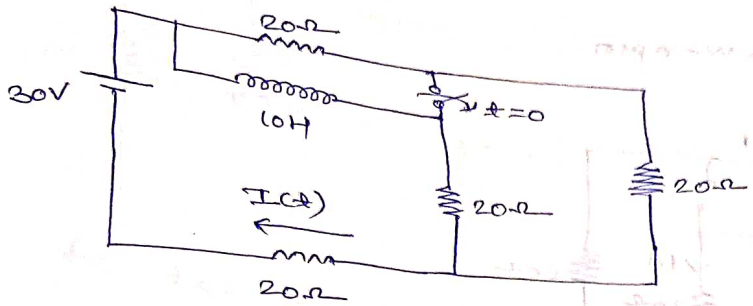
Sol^n:- At $t=0^-$ S.W. → closed, L → s.c.



$I(0^-) = i_L(0^-)$

$I_L(0^-) = I(0^-) = \frac{30}{30} = 1A$

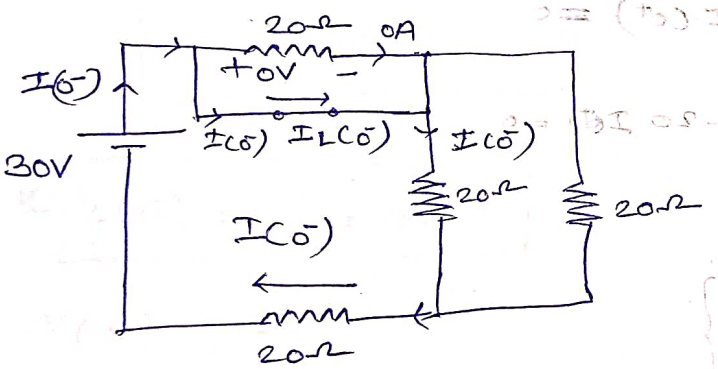
Q) ⊕



$$I(t)\Big|_{t=0^-} = ?$$

$$I(t)\Big|_{t=0^+} = ?$$

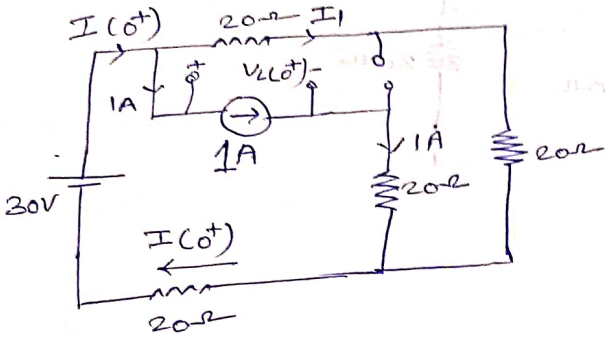
Sol^n:- At $t = 0^-$ sw. → closed L → S.C.



$$\therefore I(0^-) = I_L(0^-)$$

$$I(0^-) = \frac{30}{30} = 1A$$

* At $t = 0^+$, S.W — open



* Applying KCL

$$I(0^+) = 1 + I_1$$

$$\boxed{I_1 = I(0^+) - 1}$$

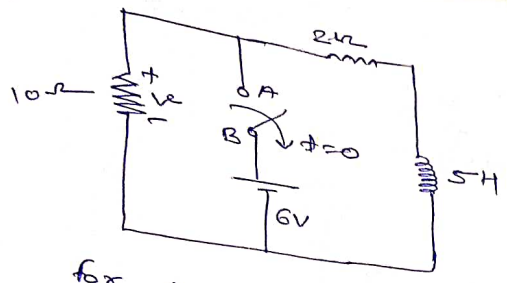
$$30 - 40 \times I_1(0^+) - 20 I(0^+) = 0$$

$$30 - 40 \times I_0(0^+) + 40 - 20 I(0^+) = 0$$

$$-60 I(0^+) + 70 = 0$$

$$\left\{ I(0^+) = \frac{70}{60} = \frac{7}{6} A \right\}$$

Q)

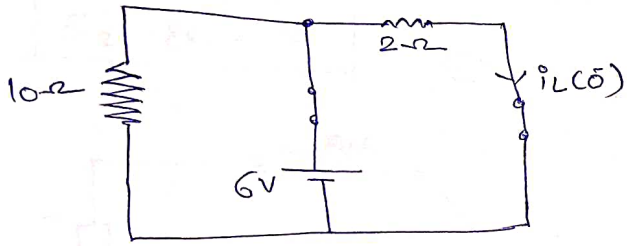


for $t<0 \rightarrow$ s.w at 'A'

$t>0 \rightarrow$ s.w at 'open

* $V(0^+) = ?$

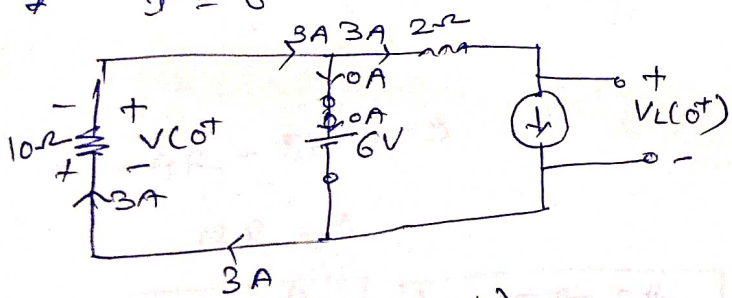
sol^n:- at $t = 0^-$ $L \rightarrow$ s.c.



$\therefore$ $\boxed{i_L(0^-) = \frac{6}{2} = 3A}$

$V(0^-) = 6V$

* $t = 0^+$



$\therefore$ $3 \times 10 = 30V = -V(0^+)$

$\boxed{V(0^+) = -30V}$

$-30 - 6 - V_L(0^+) = 0$

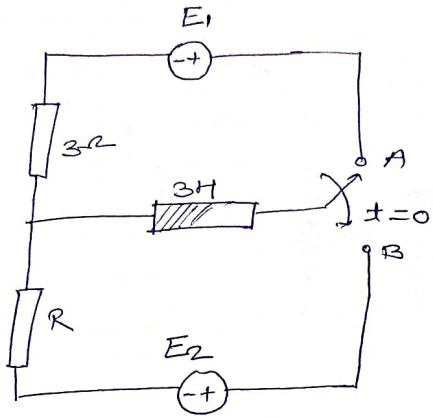
$\boxed{V_L(0^+) = -36V}$

* $L\frac{di_L(0^+)}{dt} = -36$

$\frac{di_L(0^+)}{dt} = \frac{-36}{5}$ A/sec

Lect - 69

Q)

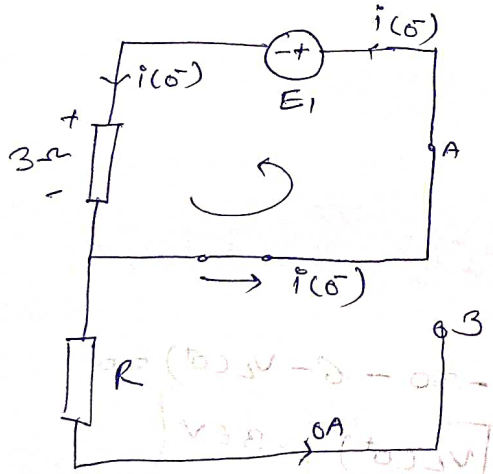


i) $i(0) = -8A$ ii) $\frac{di}{dt}(t=0) = 3A/sec$

iii) $i(\infty) = 4A$

The value of $R = ?$

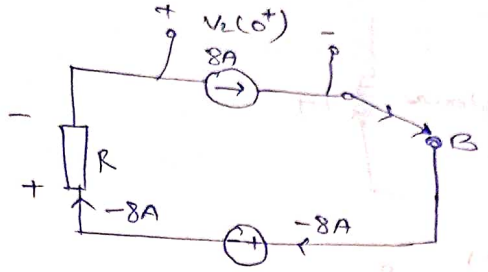
* At $t = 0^-$; $L \rightarrow$ S.C.



$-E - 3 \times i(0^-) = 0$

$\boxed{E_1 = -3 \times (-8) = 24}$ --- (1)

* At $t = 0^+$,



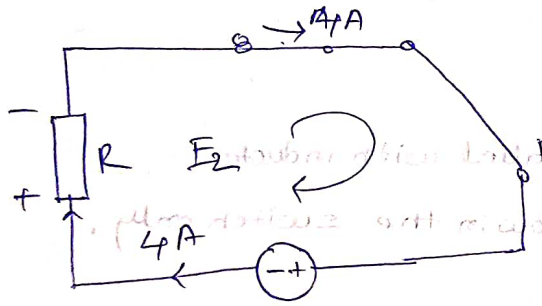
$$-V_L(0^+) - E_2 + 8 \times R = 0$$

$$-L\frac{di(0^+)}{dt} - E_2 + 8R = 0$$

$$-3 \times 3 - E_2 + 8R = 0$$

$$\boxed{E_2 - 8R = -9} \quad \text{---} (2)$$

*



$$-E_2 - 4 \times R = 0$$

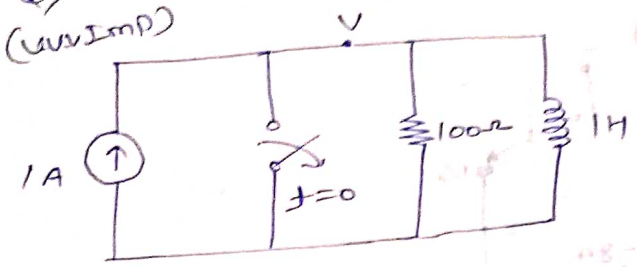
$$\boxed{E_2 = -4R} \quad \text{---} (3)$$

* $-4R - 8R = -9$

$$12R = 9$$

$$\boxed{R = \frac{9}{12}} = \boxed{0.75\,\Omega = R}$$

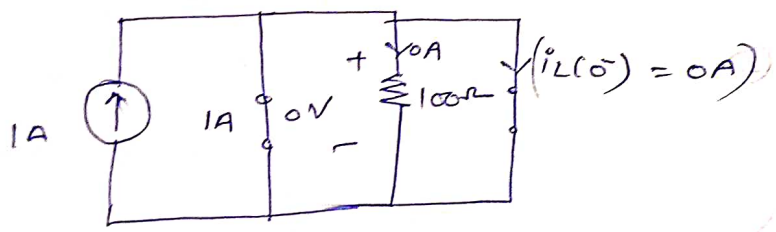
Q) (VVVIMP)



$V(0^+)$ & $\frac{dV(0^+)}{dt} = ?$

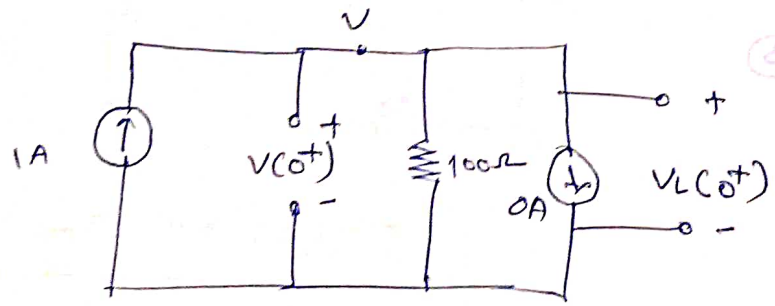
Soln:- $t = 0^-$ S.W → closed

L → S.C.



Note:- whenever A switch in parallel with inductor first of the current path follow in the switch only.

* $t = 0^+$

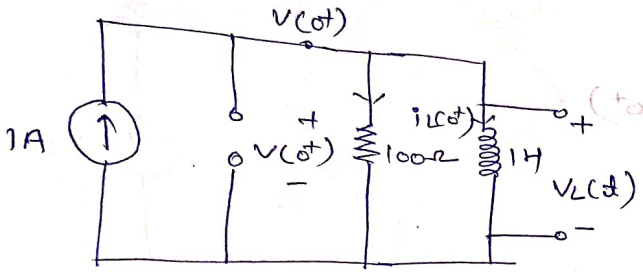


$V(0^+) = V_L(0^+)$

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

$$\boxed{V(0^+) = V_L(0^+) = 100 \times 1 = 100V}$$

$$* \quad \frac{dV(0^+)}{dt} \rightarrow \text{(calculation)}$$



$$\frac{V(0^+)}{100} + i_L(0^+) = 1$$

$$\frac{1}{100} \times \frac{dV(0^+)}{dt} + \frac{di_L(0^+)}{dt} = 0$$

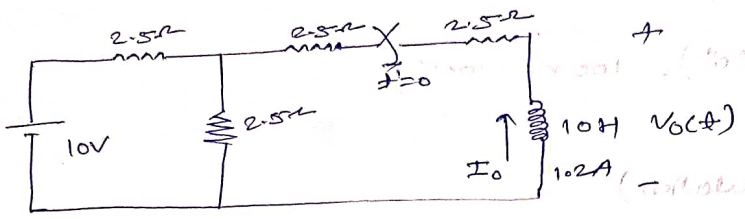
$$\frac{dV(0^+)}{dt} = -100 \times \frac{di_L(0^+)}{dt} = \cancel{100}\ -10^4\ V/sec.$$

$$V_L(0^+) = \frac{L\, di_L(0^+)}{dt}$$

$$\frac{di_L(0^+)}{dt} = \frac{V_L(0^+)}{L}$$

$$= \frac{100}{1}$$

Q)

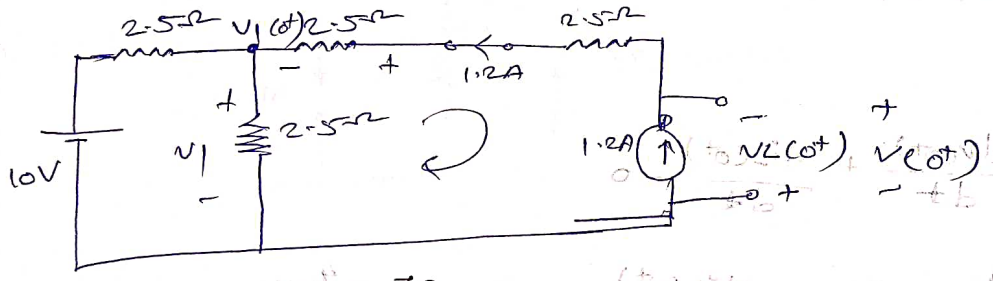


$i_L(0^-) = I_o = 1.2A = I_L(0^+)$

$V_o(0^+) = ?$

Soln:- $t = 0^+$

SW → closed



Lect-70

* Applying Nodal at V_1

$$V_1(0^+)\left(\frac{1}{2.5}+\frac{1}{2.5}\right) = \frac{10}{2.5} + 1.2$$

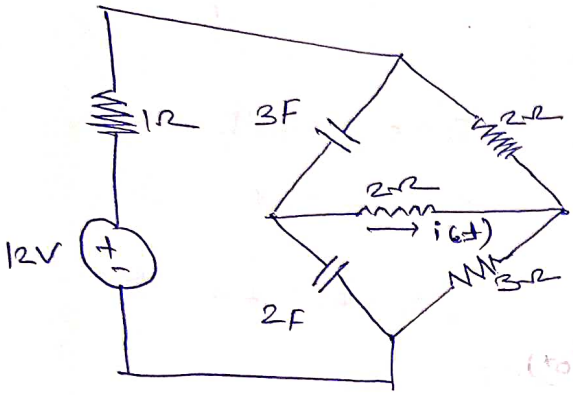
$$V_1(0^+)\left(\frac{2}{2.5}\right) = \frac{10 + 1.2\times 2.5}{2.5}$$

$$\boxed{V_1(0^+) = \frac{10 + 1.2\times 2.5}{2} = \frac{13}{2} = 6.5V}$$

$\Rightarrow 6.5 + 1.2 \times 5 - V(0^+) = 0$

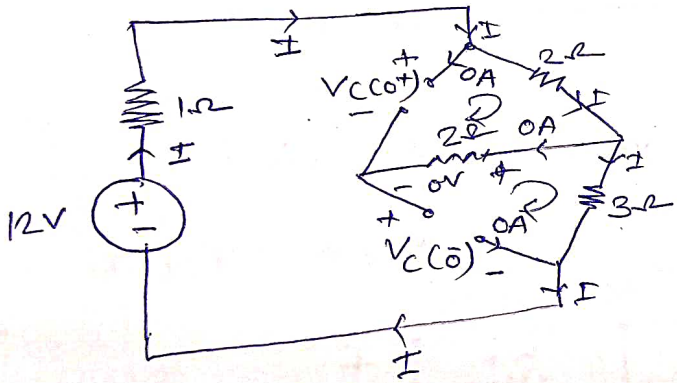
$\Rightarrow \boxed{V_0(0^+) = 12.5V}$

Q)



* $t<0 \rightarrow$ the circuit is at s.s cond^n.

$t = 0^-$, s.s. $\rightarrow$ C $\rightarrow$ o.c.



$\boxed{V_{C1}(0^-) = 2 \times I} \rightarrow$ — (1)

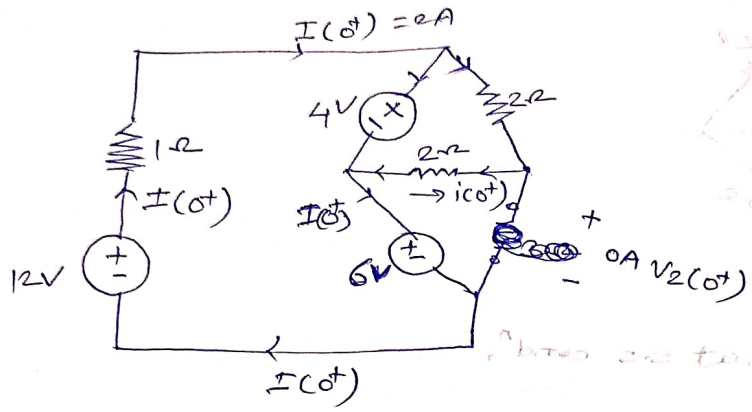
$V_{C2}(0^-) = 3 \times I$ --- (2)

$12 - I(6) = 0$

$\boxed{I = \frac{12}{6} = 2A}$

$$\begin{cases} V_{C1}(0^-) = 4V \\ V_{C2}(0^-) = 6V \end{cases}$$

* At $t = 0^+$



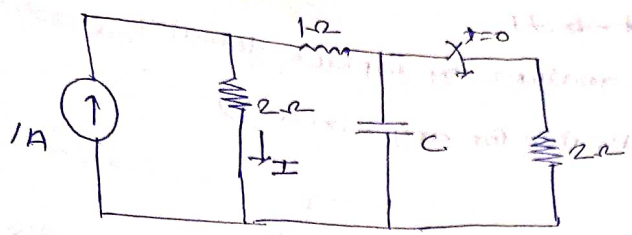
$$12 - I(0^+) \times 1 - 4 - 6 = 0$$

$$\boxed{I(0^+) = 2A}$$

$$I_1(0^+) = \frac{4}{4} = 1A$$

$$\boxed{i(0^+) = 1A}$$

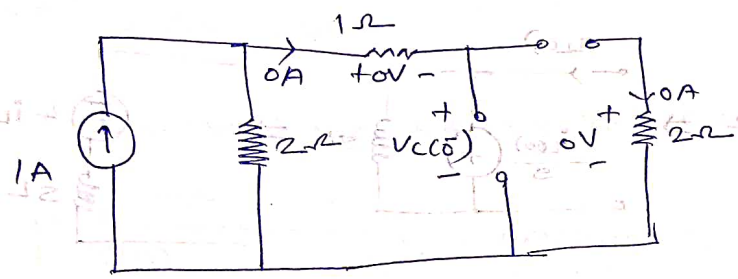
Q)



$I(0^+)$ at $t = 0^+$

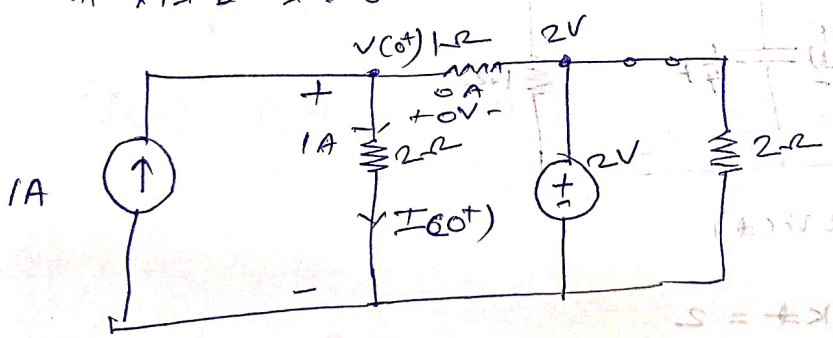
$t < 0 \rightarrow$ S.S.

* At $t = 0^-$,



$V_c(0^-) = V_c(0^+) = 2V$

* At $t = 0^+$



* $V(0^+)\left(\frac{1}{2} + \frac{1}{1}\right) - \frac{2}{1} = 1$

$V(0^+)\ \frac{3}{2} = 3$

$\boxed{V(0^+) = 2V}$

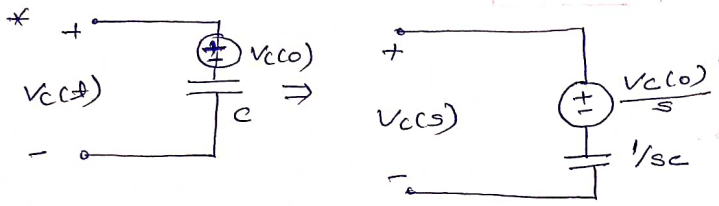
$I(0^+) = \frac{V(0^+)}{2}$

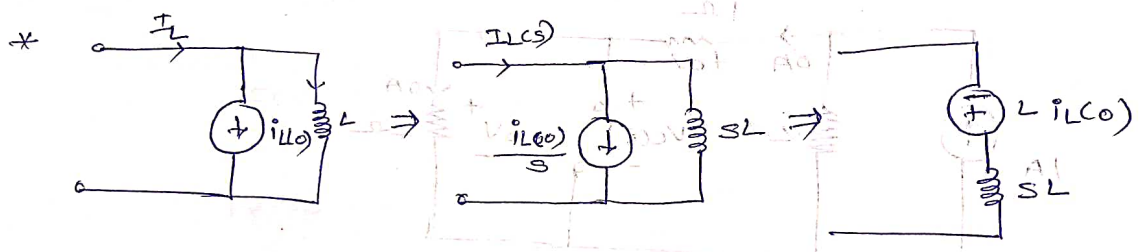
$= \frac{2}{2} = 1A$.

Lect-to 71

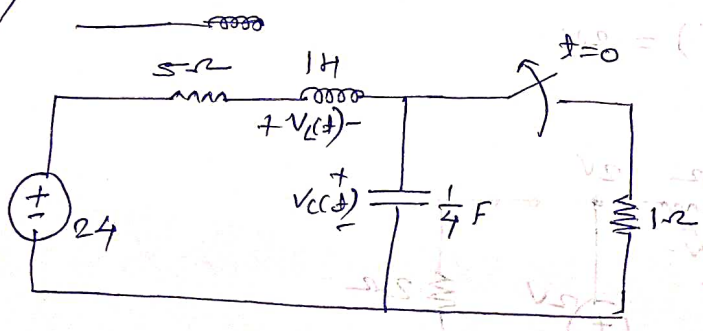
Transient analysis by laplace domain

(This is applicable for any circuit)





Q)



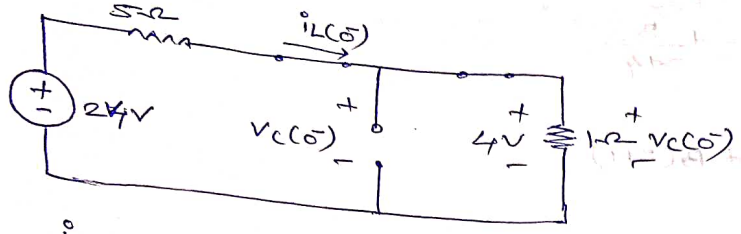
$V_L(t)$ & $V_C(t)$

Sol^n:- order of the ckt = 2

hence go for Laplace domain.

Sol^n:-

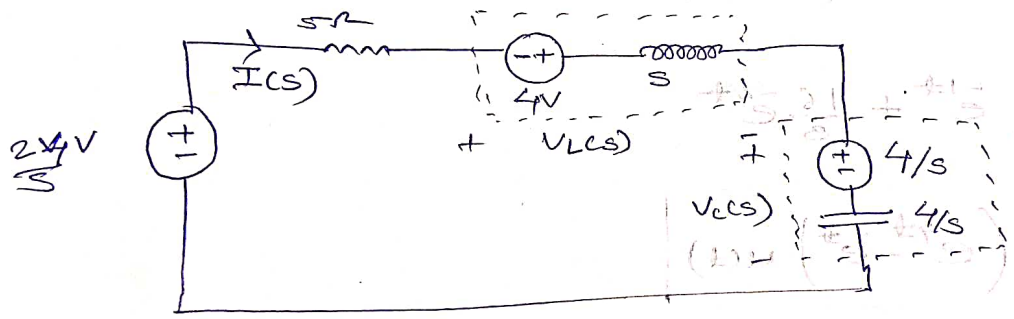
Step 01 :- $t = 0^-$, $L \to$ s.c. $C \to$ o.c.



$$i_L(0^-) = \frac{24}{6} = 4A$$

$$V_c(0^-) = 4 \times 1 = 4V$$

Step 02 :- convert the ckt into laplace domain ckt.



$$I(s) = \frac{\left(\frac{24}{s} + 4 - \frac{4}{s}\right)}{s + \frac{4}{s} + 5} = \frac{\left(\frac{20}{s} + 4s\right)}{s^2 + 5s + 4}$$

$$* \; V_L(s) = sI(s) - 4$$

$$= s\left(\frac{20 + 4s}{s^2 + 5s + 4}\right) - 4$$

$$= \frac{20s + 4s^2 - 4s^2 - 20s - 16}{s^2 + 5s + 4}$$

$$* \; V_L(s) = \frac{-16}{(s+1)(s+4)}$$

$$\frac{-16}{(s+1)(s+4)} = \frac{A}{s+1} + \frac{B}{s+4}$$

$$-16 = A(s+4) + B(s+1)$$

$s = -1$, $A = \frac{-16}{3}$

$s = -4$, $\frac{16}{3}$

$$V_L(s) = \frac{-16/3}{(s+1)} + \frac{16/3}{(s+4)}$$

$$= -\frac{16}{3} e^{-1t} + \frac{16}{3} e^{-4t}$$

$$\boxed{V_L(t) = \frac{16}{3}\left(e^{-4t} - e^{-t}\right) u(t)}$$

$$* \; V_c(s) = \frac{4}{s} + I(s) \times \frac{4}{s}$$

$$= \frac{4}{s} + \frac{(20+4s)}{(s+1)(s+4)} \times \frac{4}{s}$$

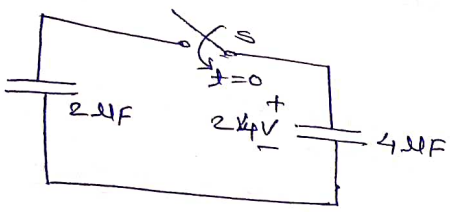
$$= \frac{4}{s} + \frac{80+16s}{s(s+1)(s+4)}$$

$$V_c(s) = \frac{4}{s} + \frac{A}{s} + \frac{B}{s+1} + \frac{C}{s+4}$$

$$= \frac{4}{s} + \frac{20}{s} - \frac{64/3}{(s+1)} + \frac{4/3}{s+4}$$

$$\boxed{V_c(t) = 4u(t) + 20u(t) - \frac{64}{3}e^{-t} + \frac{4}{3}e^{-4t}}$$

Q)



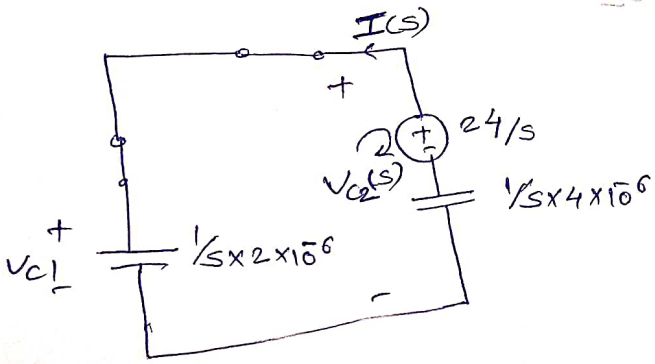
Sol^n:-

$t = 0^-$, SW → open

$V_{c1}(0^-) = 0V$

$V_{c2}(0^-) = 24V$

* Convert the ckt into laplace domain



$$I(s) = \frac{\frac{24}{s}}{\left(\frac{1}{s\times 2} + \frac{1}{s\times 4}\right)} = \left(\frac{24}{s}\right) \times \frac{1}{\left(\frac{2+1}{s\times 4}\right)}$$

$$= \frac{24}{\cancel{s}} \times \frac{4\cancel{s}}{3}$$

$$I(s) = \frac{24\times 4}{3} = 32\,A$$

$i(t) = 32\delta(t)$

KVL

$$V_{C2}(s) = \frac{24}{s} - \frac{1}{4s} I(s)$$

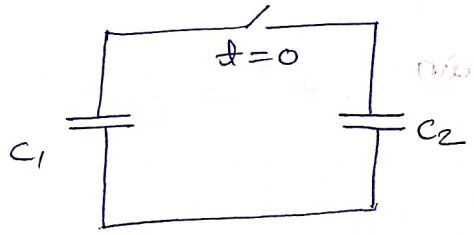
$$= \frac{24}{s} + 32 \times \frac{1}{4s}$$

$$= \frac{24}{s} + 8/s$$

$$V_{C2}(s) = \frac{32}{s}$$

$$\boxed{V_{C2}(t) = 32u(t)}$$

Q)

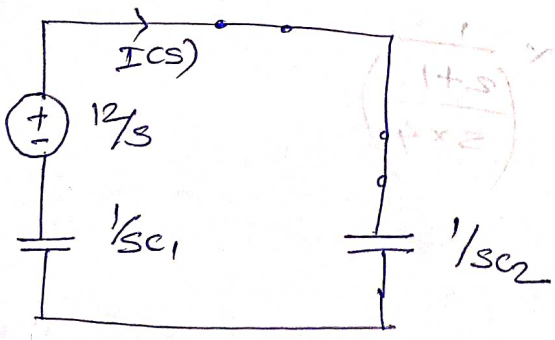


$V_{C1}(0^-) = 12V$

$V_{C2}(0^-) = 0V$

$\{ I(t) \text{ for } t>0 \}$

Sol^n:-



$$I(s) = \frac{12}{\frac{1}{sC_1} + \frac{1}{sC_2}}$$

$$= \frac{12 \times \cancel{\frac{1}{s}}}{\cancel{\frac{1}{s}}\left(\frac{1}{C_1} + \frac{1}{C_2}\right)} = \frac{12}{\left(\frac{C_1 + C_2}{C_1 C_2}\right)}$$

$$= 12 \times \frac{C_1 C_2}{C_1 + C_2}$$

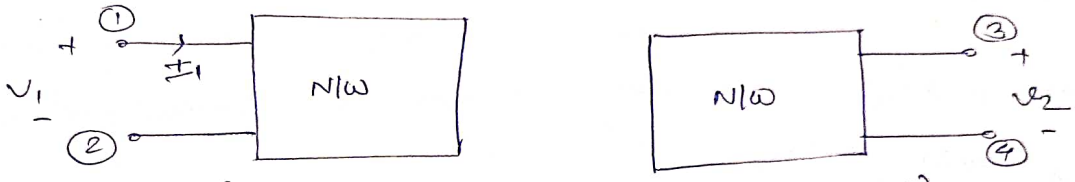
$$I(s) = 12 \times \underset{\text{const}}{K}$$

$$\boxed{i(t) = (12 \times K)\,\delta(t)}$$

Lect - 72

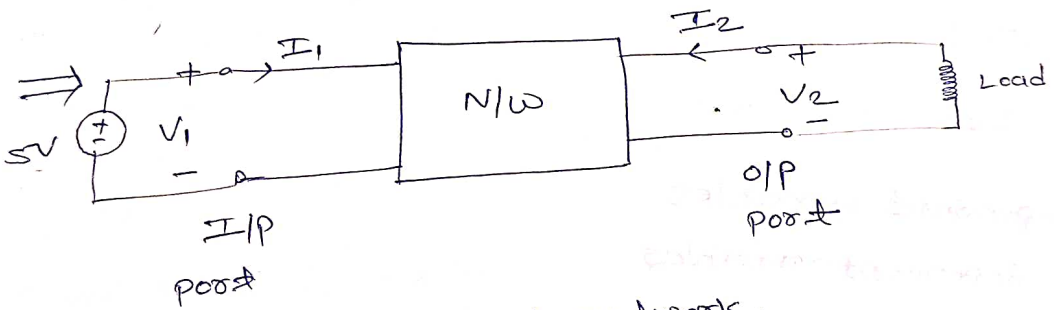
Two port Network

* Port :- It ~~is has~~ two terminal ~~device~~. in which the current Enters at one terminal and leaves at second terminal.



(one port Network) I/P port

(one port N/W) (O/P port)



Two port Network.

* $V_1, I_1 \rightarrow$ input ports variables
* $V_2, I_2 \rightarrow$ output ports variables.

The number of two port parameters $= {}^4C_2 = 6$

- Z-parameter
- Y- parameter
- ABCD - Parameter - Transmission line
- H - parameter
- G - parameter
- $(ABCD)^{-1}$ parameter.

* The two port N/w analysis is important for the designing of xmer, Transistor, amplifier & circuit models.

* In two port N/w at I/P & O/P port there must be a Electrical quantity as a variable like V_1 & I_1 Input port variable & V_2 & I_2 are output port variable.

* Z-parameters.

$$V_1 = Z_{11} I_1 + Z_{12} I_{12}$$

$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

.... Remember (Imp)

* $V_1 = f(I_1, I_2)$

$V_2 = f(I_1, I_2)$

V_1 & V_2 → Dependent variables

I_1 & I_2 → independent variables.

* If $I_1 = f(I_2)$ or $I_2 = f(I_1)$

Then Z-parameter does not exist

* $Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0}$ ⇒ Driving point Input impedance when $I_2 = 0$ A.

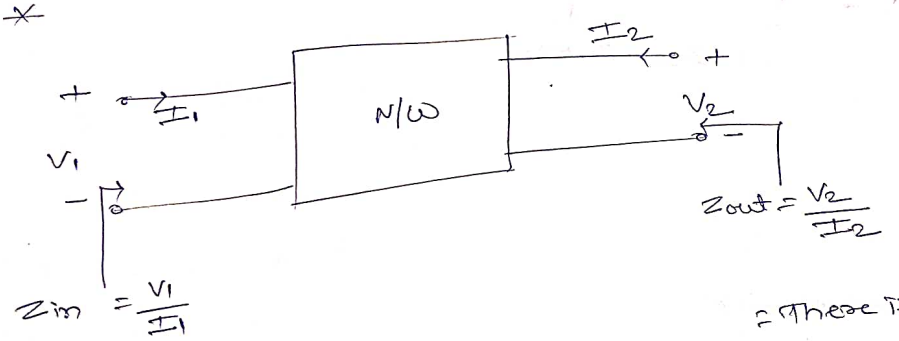
* $Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$ ⇒ output Transfer impedance when $I_2 = 0$ A.

$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0}$ → ~~output~~ Driving point output impedance when $I_1 = 0A$

$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$ → ~~output~~ Input transfer Impedance when $I_1 = 0A$

* These parameters are known as open ckt parameters.
* These impedances are known as conditional impedances.

*



∴ There is No condition.

∴ There is no condition here

$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} \neq Z_{in}$.

↓ Conditional Impedance

↓ unconditional Impedance

$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0} \neq Z_{out}$.

$V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \underbrace{\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}_{2\times 2}}_{\text{Z-parameter}} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$Z^{-1} = \frac{Adj(Z)}{det[Z]} = \frac{\begin{bmatrix} Z_{22} & -Z_{21} \\ -Z_{12} & Z_{11} \end{bmatrix}}{Z_{11} \times Z_{22} - Z_{12} \times Z_{21}}$$

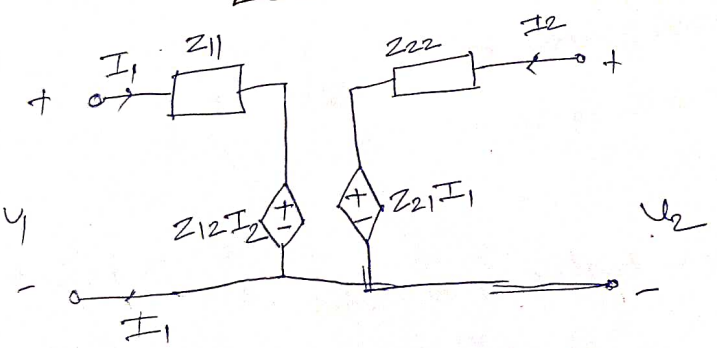
$$\boxed{Z^{-1} = Y}$$

* modeling of Z-parameter.

$V_1 = Z_{11} I_1 + Z_{12} I_2$

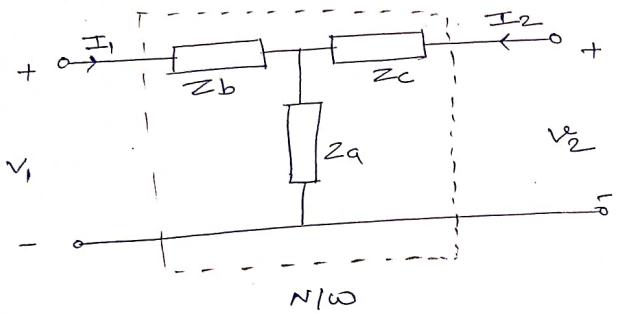
$V_2 = Z_{21} I_1 + Z_{22} I_2$

Lect-13



* $Z_{11} = Z_{22}$ — for symmetrical N/w
* $Z_{12} = Z_{21}$ → for reciprocal N/w

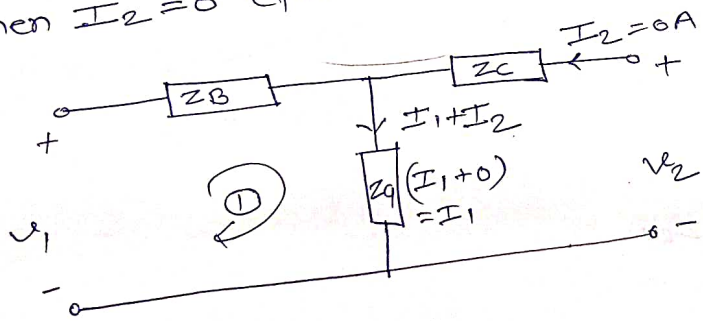
* Case I :-



$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

$$\begin{cases} V_1 = Z_{11} I_1 + Z_{12} I_2 \\ V_2 = Z_{21} I_1 + Z_{22} I_2 \end{cases}$$

when $I_2 = 0$ (port 02 is open ckt)



Applying KVL in loop ①

$$V_1 - I_1(Z_b) - I_1(Z_a) = 0$$

$$V_1 - (Z_a + Z_b) I_1 = 0$$

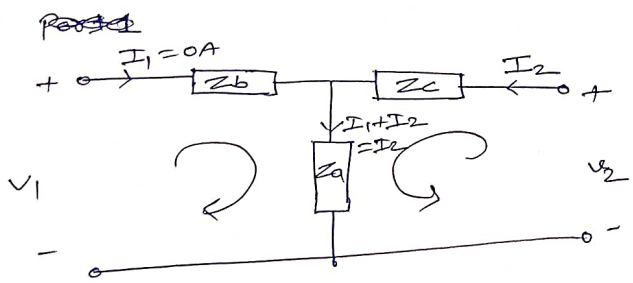
$$\boxed{\left.\frac{V_1}{I_1}\right|_{I_2=0} = Z_a+Z_b = Z_{11}}$$

* Apply KVL at ~~no~~ loop (2)

$V_2 = I_1 Z_a$

$$\boxed{\left.\frac{V_2}{I_1}\right|_{I_2=0} = Z_a = Z_{21}}$$

Case II when $I_1 = 0$



$V_1 = I_2 Z_a$

$$\boxed{\left.\frac{V_1}{I_2}\right|_{I_1=0} = Z_a = Z_{12}}$$

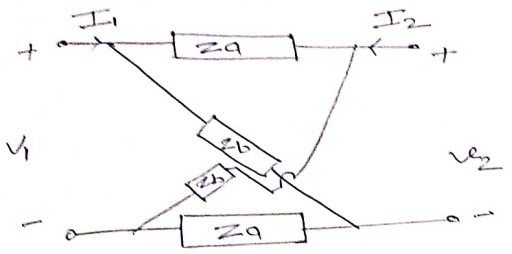
* $V_2 = I_2(Z_a+Z_c)$

$$\left.\frac{V_2}{I_2}\right|_{I_1=0} = (Z_a+Z_c) = Z_{22}$$

$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} = \begin{bmatrix} Z_a+Z_b & Z_a \\ Z_a & Z_a+Z_c \end{bmatrix}$$

--- Please Remember this.

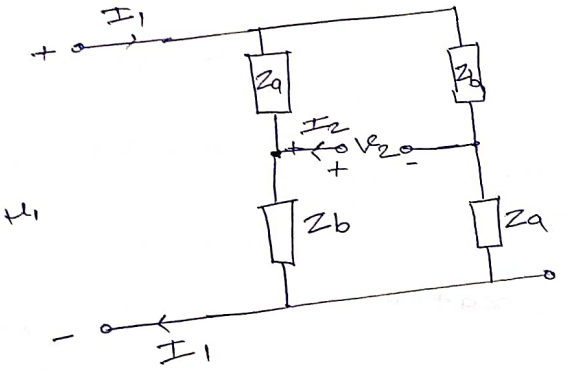
case-II (lattice N/w)



Za → series arm Impedance

Zb → diagonal Impedance

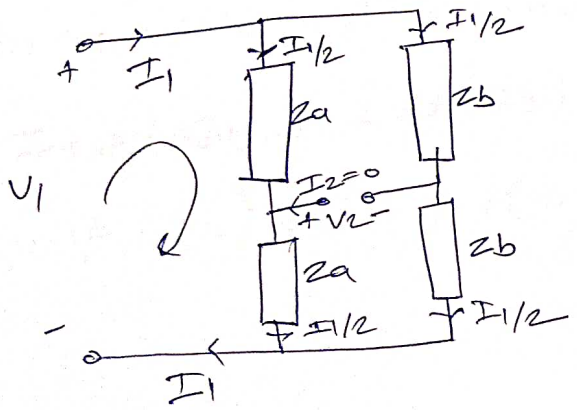
Sol^n:-



* $V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_2 I_2$

case-I :- when $I_2 = 0$



$$V_1 = \left(\frac{Z_a + Z_b}{2}\right) I_1$$

$$\boxed{\frac{V_1}{I_1} = \frac{Z_a + Z_b}{2} = Z_{11}}$$

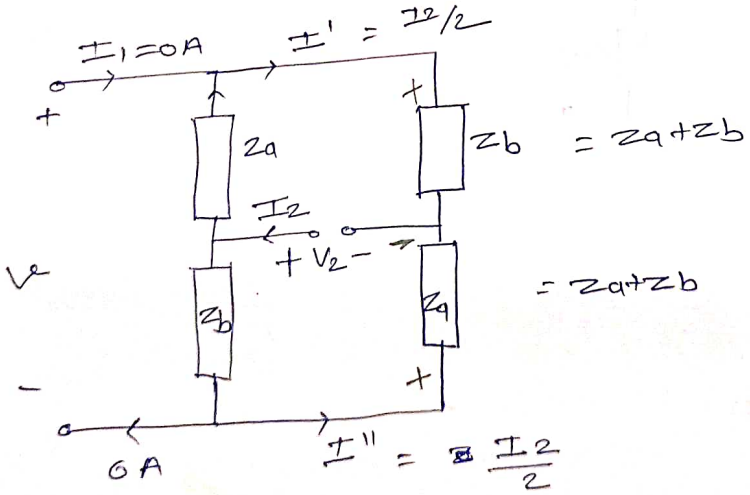
KVL in loop ②

$$V_2 - Z_a \times \frac{I_1}{2} + Z_b \times \frac{I_1}{2} = 0$$

$$V_2 = I_1 \left(\frac{Z_b - Z_a}{2}\right)$$

$$\boxed{\left.\frac{V_2}{I_1}\right|_{I_2=0} = -\left(\frac{Z_a - Z_b}{2}\right) = Z_{21}}$$

Case-II :- $I_1 = 0$



Apply KVL

$$V_1 + \frac{I_2}{2} \times Z_a - Z_b \times \frac{I_2}{2} = 0$$

$$\boxed{\left.\frac{V_1}{I_2}\right|_{I_1=0} = \frac{Z_b - Z_a}{2} = Z_{12}}$$

KVL in loop ②

$$-V_2 + Z_a \times \frac{I_2}{2} + \frac{I_2}{2} \times Z_b = 0$$

$$\boxed{\left.\frac{V_2}{I_2}\right|_{I_1=0} = \left(\frac{Z_a+Z_b}{2}\right) = Z_{22}}$$

$$[Z]_{lattice} = \begin{bmatrix} \left(\frac{Z_a+Z_b}{2}\right) & \left(\frac{Z_b-Z_a}{2}\right) \\ \left(\frac{Z_b-Z_a}{2}\right) & \left(\frac{Z_a+Z_b}{2}\right) \end{bmatrix}$$ Imp

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ii) Y- parameters

$$\left.\begin{aligned} I_1 &= f(V_1 \& V_2) \\ I_2 &= f(V_1 \& V_2) \end{aligned}\right\}$$ Independent variable

Dependent variable

* $I_1 = Y_{11} V_1 + Y_{12} V_2$

$I_2 = Y_{21} V_1 + Y_{22} V_2$

* for the existance of Y-parameters

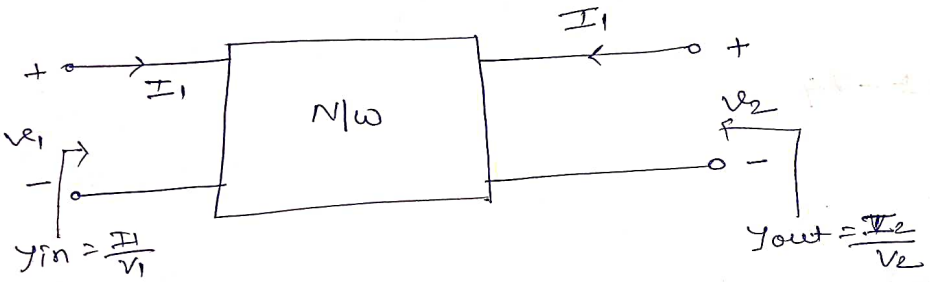
~~$I_2 \neq f(I_1)$ or $I_1 \neq f(I_2)$~~

$V_1 \neq f(V_2)$ or $V_2 \neq f(V_1)$

$$* \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$Y = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$$

* finding the Y-parameters.



Case-I :- when $V_2 = 0V$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0} = \text{I/p driving Admittance}$$

$$y_{21} \left.\frac{I_2}{V_1}\right|_{V_2=0} = \text{output transfer admittance}$$

$V_2 = $ S.C.

Case-II :-

when $V_1 = 0V$

$$y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0} = \text{output driving point admittance}$$

$y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0}$ = i/p transfer admittance when $V_1 = 0V$.

Y-parameter is also known as short ckt parameters

* Y-parameters are known as conditional Admittances.

* Y_{in} = I/p admittance

$= \frac{I_1}{V_1} \neq y_{11}$

This is a unconditional I/p admittance.

Y_{out} = o/p admittance

$= \frac{I_2}{V_2} \neq y_{22}$

unconditional o/p admittance

* Y- parameter in terms of Z-parameter and vice versa.

$y_{11} \neq \frac{1}{Z_{11}}$, $Y_{22} \neq \frac{1}{Z_{22}}$, $Y_{12} \neq \frac{1}{Z_{12}}$, $y_{21} \neq \frac{1}{Z_{21}}$

* $Y_{in} = \frac{I_1}{V_1} = \frac{1}{Z_{in}}$ ✓

$Y_{out} = \frac{I_2}{V_2} = \frac{1}{Z_{out}}$

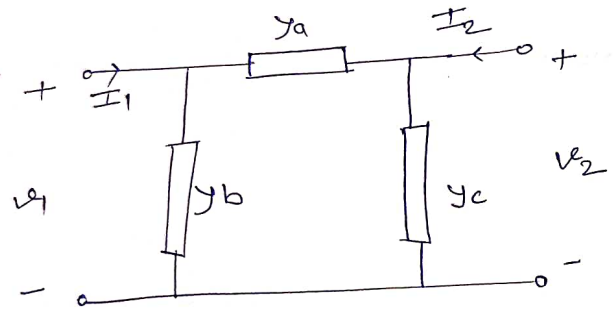
$$[Y] = [Z]^{-1} = \frac{\text{adj}[Z]}{\det[Z]}$$

or

$$[Z] = [Y]^{-1} = \frac{\text{adj}[Y]}{\det[Y]}$$

— This is not always true.

π Network

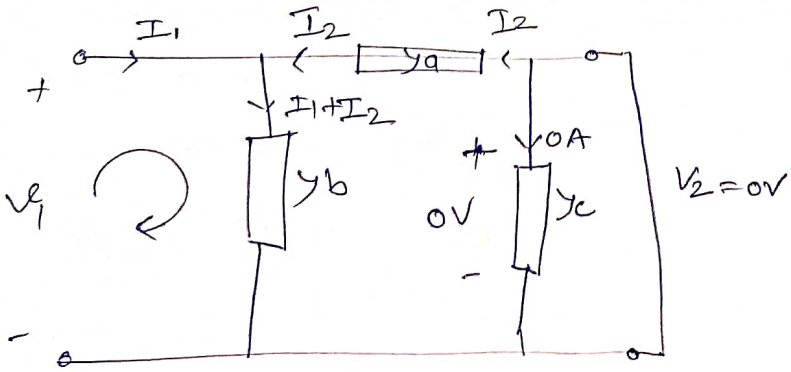


$$y_a = \frac{1}{Z_a}, \quad y_b = \frac{1}{Z_b}, \quad y_c = \frac{1}{Z_c}$$

Case-I

$$I_1 = y_{11}V_1 + y_{12}V_2$$

$$I_2 = y_{21}V_1 + y_{22}V_2$$



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$$V_1 = \left(\frac{I_1 + I_2}{y_b}\right) \quad --- (1)$$

$$\frac{I_1 + I_2}{y_b} + \frac{I_2}{y_a} = 0 \quad --- (2)$$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2 = 0V}$$

$$y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2 = 0V}$$

$$* \quad I_2\left(\frac{1}{y_a} + \frac{1}{y_b}\right) = \frac{-I_1}{y_b}$$

$$I_2\left(\frac{y_a + y_b}{y_a y_b}\right) = \frac{-I_1}{y_b}$$

$$I_2 = \frac{-I_1 \, y_a}{y_a + y_b}$$

$$* \quad V_1 = \frac{I_1}{y_b} - \frac{1}{y_b}\left(\frac{I_1 \times y_a}{y_a + y_b}\right)$$

$$\frac{V_1}{I_1} = \frac{1}{y_b}\left(1 - \frac{y_a}{y_a + y_b}\right)$$

$$= \frac{1}{y_a + y_b}$$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2 = 0V} = (y_a + y_b)$$

$$V_1 = \frac{I_1 + I_2}{y_b} \quad \text{---} \; (1)$$

$$V_1 = \frac{I_1}{y_b} + \frac{I_2}{y_b}$$

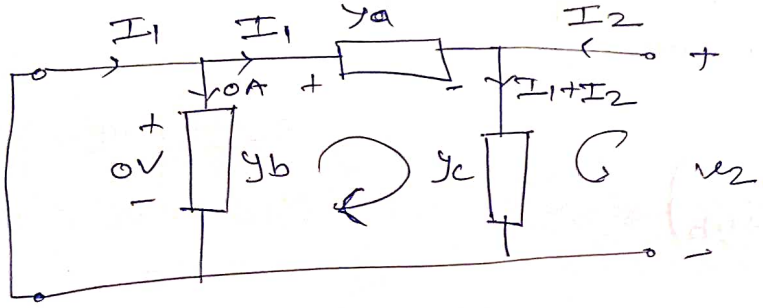
$$= \frac{-I_2(y_a + y_b)}{y_a y_b} + \frac{I_2}{y_b}$$

$$* \; V_1 = \frac{I_2}{y_b}\left(1 - \frac{(y_a + y_b)}{y_a}\right)$$

$$= \frac{I_2}{y_b}\left(\frac{y_a - y_a - y_b}{y_a}\right)$$

$$y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0} = (-y_a).$$

Case II :- when $V_1 = 0$



$$V_2 = \frac{I_1 + I_2}{y_c} \quad \text{---} \; (1)$$

$$-\frac{I_1}{y_a} - \left(\frac{I_1 + I_2}{y_c}\right) = 0 \quad \text{---} \; (2)$$

$$y_{12} = \frac{I_1}{V_2}\Big|_{V_1 = 0} = ?$$

$$y_{22} = \frac{I_2}{V_2}\Big|_{V_1 = 0} = ?$$

*

$$-I_1\left(\frac{1}{y_a} + \frac{1}{y_c}\right) = \frac{I_2}{y_c}$$

$$-I_1\left(\frac{y_a + y_c}{y_a y_c}\right) = \frac{I_2}{y_c}$$

$$\boxed{I_1 = \frac{-I_2 \times y_a}{y_a + y_c}}$$

* $$V_2 = \frac{-I_2 y_a}{y_c(y_a + y_c)} + \frac{I_2}{y_c}$$

$$= \frac{I_2}{y_c}\left(1 - \frac{y_a}{y_a + y_c}\right)$$

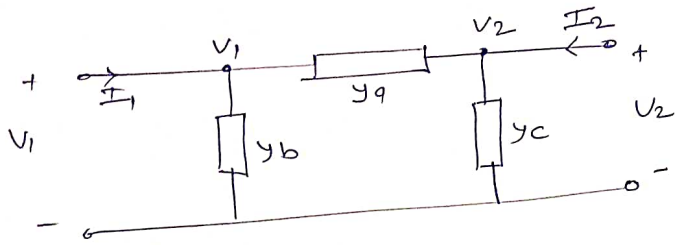
$$V_2 = \frac{I_2}{y_a + y_c}$$

$$\boxed{\frac{I_2}{V_2} = y_a + y_c}$$

* $y_{22} = \frac{I_2}{V_2}\Big|_{V_1=0} = (y_a + y_c)$

* $y_{12} = \frac{I_1}{V_2}\Big|_{V_1=0} = -y_a$

Easy method (Nodal)



Apply nodal at V_1

$$V_1(y_a + y_b) - V_2(y_a) = I_1 \quad -(1)$$

Nodal at V_2

$$V_2(y_a + y_c) - V_1(y_a) = I_2 \quad -(2)$$

$y_{11} = y_a + y_b$

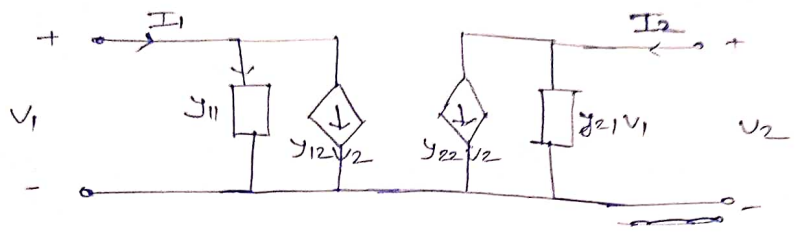
$y_{12} = -y_a$

$y_{21} = -y_a$

$y_{22} = y_a + y_c$

* $y_\pi = \begin{bmatrix} y_a+y_b & -y_a \\ -y_a & y_a+y_c \end{bmatrix}$

* model



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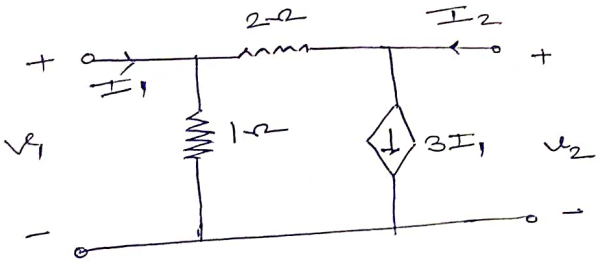
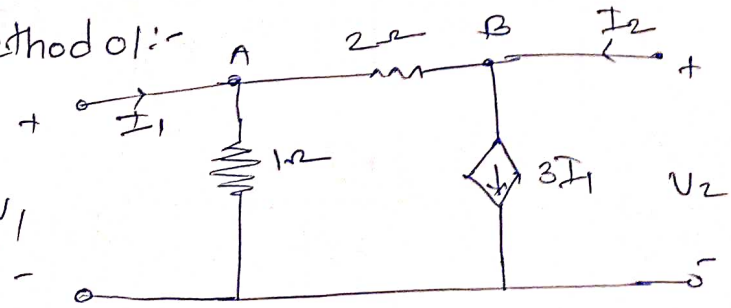
Q11)



$$[Z] = \begin{bmatrix} Z_1 & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

* $\begin{cases} V_1 = Z_{11}I_1 + Z_{12}I_2 \\ V_2 = Z_{21}I_1 + Z_{22}I_2 \end{cases}$

method 01:-



Applying KCL at node 'B'

$I_3 + 3I_1 = I_2$

$\boxed{I_3 = I_2 - 3I_1}$

Applying KCL at node 'A'

$I_4 = I_3 + I_1$ — (1)

$I_4 = I_2 - 3I_1 + I_1$

$= I_2 - 2I_1$ — (2)

* $V_1 = I_4 \times 1 = \underset{\substack{\downarrow \\ Z_{11} \\ = -2}}{-2I_1} + \underset{\substack{\downarrow \\ Z_{12} \\ = 1}}{I_2}$

*

$I_4 \times 1 + 2 \times I_3 - V_2 = 0$

$V_2 = (I_2 - 2I_1) + 2(I_2 - 3I_1)$

$= I_2 - 2I_1 + 2I_2 - 6I_1$

$V_2 = \underset{\substack{\downarrow \\ Z_{21} \\ = -8}}{-8I_1} + \underset{\substack{\downarrow \\ Z_{22} \\ = 3}}{3I_2}$

$$[Z] = \begin{bmatrix} -2 & 1 \\ -8 & 3 \end{bmatrix}$$

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Method-02 Nodal Analysis.

Applying Nodal at node V_1.

$$V_1\left(1+\frac{1}{2}\right)-V_2\left(\frac{1}{2}\right)=I_1$$

$$I_1 = \underset{y_{11}=3/2}{V_1\left(\frac{3}{2}\right)} - \underset{y_{12}=-\frac{1}{2}}{\frac{V_2}{2}}$$

* Applying nodal at node '2'

$$V_2\left(\frac{1}{2}\right)-\frac{V_1}{2} = I_2 - 3I_1 \quad \text{---} (2)$$

$$I_2 = 3I_1 - \frac{V_1}{2} + \frac{V_2}{2}$$

$$= 3\left(\frac{3V_1}{2}-\frac{V_2}{2}\right)-\frac{V_1}{2}+\frac{V_2}{2}$$

$$= V_1\left(\frac{9}{2}-\frac{1}{2}\right)+V_2\left(\frac{1}{2}-\frac{3}{2}\right)$$

$$I_2 = V_1(4)+V_2(-1)$$

$y_{21}=4,\ y_{22}=-1.$

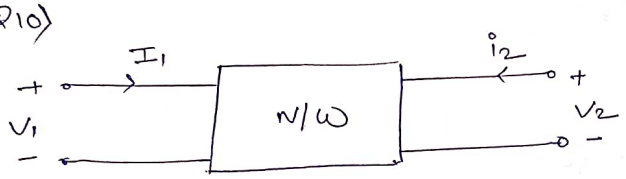
$$[Y]=\begin{bmatrix}3/2 & -1/2\\ 4 & -1\end{bmatrix}$$

$$[Z]=[Y]^{-1}=\frac{\text{Adj}[Y]}{|Y|}=\frac{\begin{bmatrix}-1 & 1/2\\ -4 & \frac{3}{2}\end{bmatrix}}{\left(-\frac{3}{2}+2\right)}$$

$$* [Z] = \frac{\begin{bmatrix} -1 & 1/2 \\ -4 & 3/2 \end{bmatrix}}{1/2}$$

$$[Z] = \begin{bmatrix} -2 & 1 \\ -8 & 3 \end{bmatrix}$$

Q10)



$$\begin{cases} i_1 = 2V_1 + V_2 \\ i_2 = V_1 + V_2 \end{cases}$$

$$[Y] = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$$

$$* [Z] = [Y]^{-1} = \frac{\text{adj}[Y]}{|Y|}$$

$$[Z] = \frac{\begin{bmatrix} 1 & -1 \\ -1 & 2 \end{bmatrix}}{2-1} = \begin{bmatrix} 1 & -1 \\ -1 & 2 \end{bmatrix}$$

$Z_{11} = 1$, $Z_{12} = -1$

$Z_{21} = -1$, $Z_{22} = 2$

* $V_1 = Z_{11}I_1 + Z_{12}I_2$

$V_2 = Z_{21}I_1 + Z_{22}I_2$

case-I $I_2 = 0$

~~Z11~~

$$Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0} = ?$$

$$Z_{21} = \frac{V_2}{I_1}\Big|_{I_2=0} = ?$$

$I_2 = 0$

$V_1 + V_2 = 0$

$$\boxed{V_1 = -V_2}$$

$i_1 = 2V_1 + -V_1$

$i_1 = V_1$

$$\left[\frac{V_1}{i_1}\Big|_{i_2=0} = 1 = Z_{11}\right]$$

$i_1 = 2V_1 + V_2$

$= -2V_2 + V_2$

$i_1 = -V_2$

$$\left[\frac{V_2}{i_1}\Big|_{i_2=0} = -1 = Z_{21}\right]$$

Case - II $\quad I_1 = 0$

$$Z_{12} = \frac{V_1}{I_2} = ?$$

$$Z_{22} = \frac{V_2}{I_2} = ?$$

$$2V_1 + V_2 = 0$$

$$\boxed{V_2 = -2V_1}$$

$$i_2 = V_1 + V_2$$

$$= \frac{-V_2}{2} + V_2 = \frac{V_2}{2}$$

$$\left[\left. \frac{i_2}{V_2} \right|_{i_1 = 0} = 2 = Z_{22} \right]$$

$$* \; i_2 = V_1 + V_2$$

$$i_2 = V_1 - 2V_1$$

$$= -V_1$$

$$\left[\left. \frac{V_1}{I_2} \right|_{i = 0} = -1 = Z_{12} \right]$$

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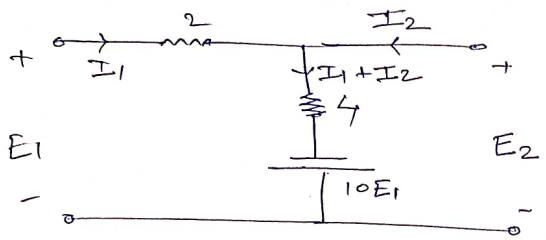
Q9)



Lec# - 77

* $E_1 = Z_1 I_1 + Z_{12} I_2$

$E_2 = Z_{21} I_1 + Z_{22} I_2$

Sol^n:-

* method 01:-

$$E_1 - I_1 \times 2 - 4(I_1 + I_2) + 10E_1 = 0$$

$$11E_1 = 6I_1 + 4I_2$$

$$E_1 = \frac{6}{11} I_1 + \frac{4}{11} I_2$$

$$Z_{11} = \frac{6}{11}, \quad Z_{12} = \frac{4}{11}$$

* $E_2 - 4(I_1 + I_2) + 10E_1 = 0$

$$E_2 = 4I_1 + 4I_2 - 10E_1$$

$$= 4I_1 + 4I_2 - 10\left(\frac{6}{11} I_1 + \frac{4}{11} I_2\right)$$

$$= I_1\left(4 - \frac{60}{11}\right) + I_2\left(4 - \frac{40}{11}\right)$$

$$\Rightarrow Z_{21} = \frac{11 \times 4 - 60}{11} = \frac{-16}{11}, \quad Z_{22} = \frac{4}{11}$$

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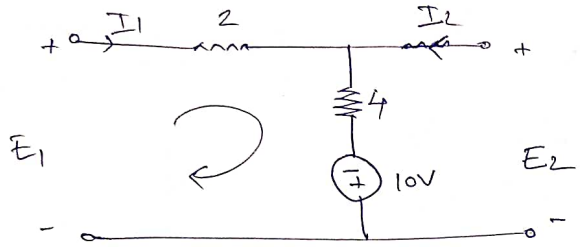
Note:- If $10E_1 \rightarrow 10V$



$$\boxed{E_1 = I_1 \times 2 + (I_1 + I_2) \times 4 - 10}$$

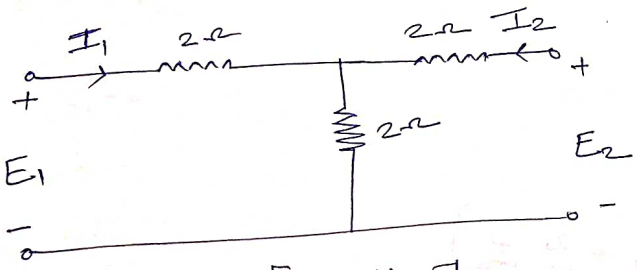
u can not get Z_{11} & Z_{12}

$$E_2 = (I_1 + I_2)4 - 10$$

u can not get Z_{21} or Z_{22}

Note:- If within the N/w there will be any independent source then you can not calculate Y & Z parameter.

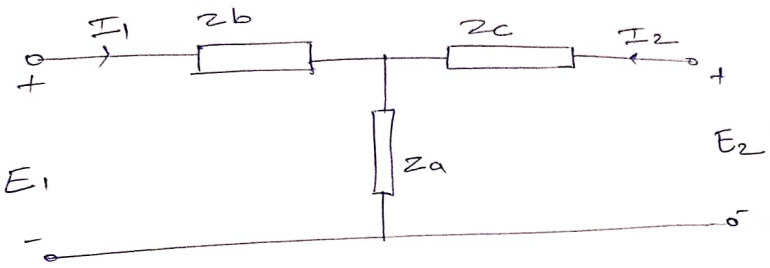
Q14)



calculate $[Y] = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$

* The N/w given is a standard T-N/w

$$[Z] = \begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix}$$



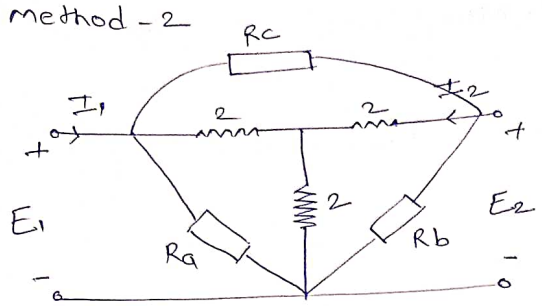
$$[Z] = \begin{bmatrix} Z_a+Z_b & Z_a \\ Z_a & Z_a+Z_b \end{bmatrix}$$

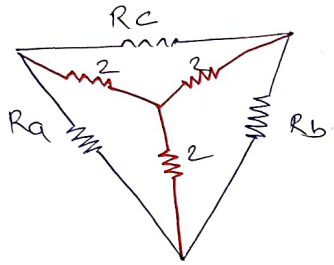
$$\Rightarrow [Y] = [Z]^{-1} = \frac{\text{Adj}\,[Z]}{|Z|} = \frac{\begin{bmatrix} 4 & -2 \\ -2 & 4 \end{bmatrix}}{16-4}$$

$$= \begin{bmatrix} \frac{1}{3} & -1/6 \\ -\frac{1}{6} & 1/3 \end{bmatrix}$$

$$\left\{ \begin{array}{l} y_{11} = y_{22} = \frac{1}{3} \\ y_{12} = y_{21} = -\frac{1}{6} \end{array} \right\}$$

Method - 2



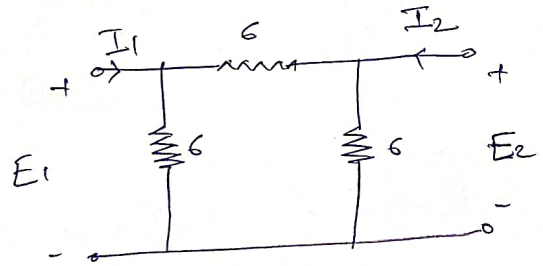


$$\Rightarrow R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{2}$$

$$= \frac{4+4+4}{2} = \frac{12}{2} = 6\Omega$$

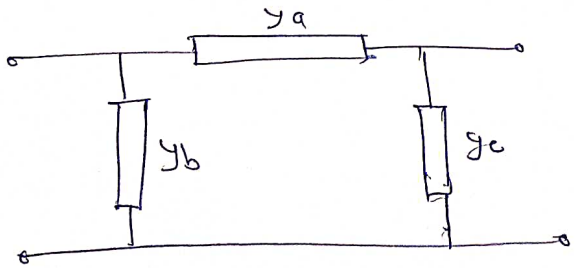
$$R_b = R_c = R_a = 6\Omega.$$

$\Rightarrow$



$$[y] = \begin{bmatrix} 12 & -6 \\ -6 & 12 \end{bmatrix}$$

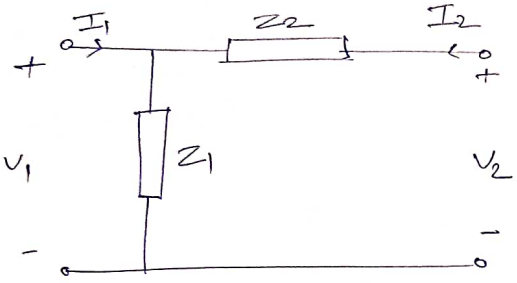
$\Rightarrow$



Q 7)

$$[Y] = \begin{bmatrix} 2/6 & -1/6 \\ -1/6 & 2/6 \end{bmatrix} = \begin{bmatrix} 1/3 & -1/6 \\ -1/6 & 1/3 \end{bmatrix}$$ //

Q7)

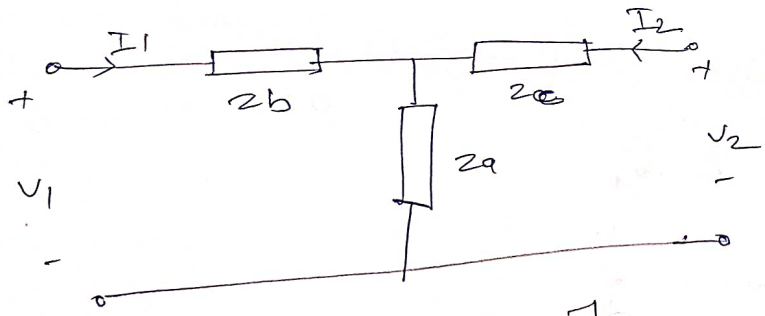


$$Z = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

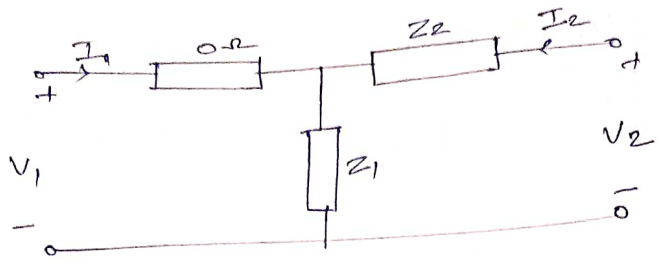
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

method - 1



$$[Z] = \begin{bmatrix} Z_a + Z_b & +Z_a \\ +Z_a & Z_a + Z_c \end{bmatrix}$$

⇒



$$[Z] = \begin{bmatrix} Z_1 & Z_1 \\ Z_1 & Z_1+Z_2 \end{bmatrix}$$

method 2:-

* $V_1 = (I_1 + I_2) Z_1$

$$V_1 = \underbrace{Z_1 I_1}_{Z_{11}} + \underbrace{Z_1 I_2}_{Z_{12}}$$

* $V_2 - I_2 Z_2 - (I_1 + I_2) Z_1 = 0$

$$V_2 = \underbrace{I_1 (Z_1)}_{Z_{21}} + \underbrace{I_2 (Z_1 + Z_2)}_{Z_{22}}$$

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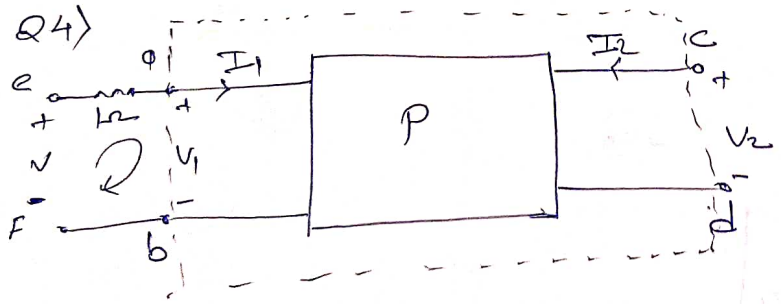
Q4)



Two port N/W defind → a & c
b & d

$$[Z]_{ij} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

$V_1 = f(I_1 \& I_2)$

$V_2 = f(I_1 \& I_2)$

* $V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

$V =$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

$$[Z]_{modified} = \begin{bmatrix} (Z_{11}+1) & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

* $V - I_1 \times 1 - V_1 = 0$

$V = V_1 + I_1$

$\boxed{V_1 = V - I_1}$

$V = Z_{11} I_1 + Z_{12} I_2 + I_1$

$\boxed{V = (Z_{11}+1) I_1 + Z_{12} I_2}$

Conclusion :-

if in a two port N/W a series Resistance is added at port 1 & 2 then modified Z parameter component changes as shown :

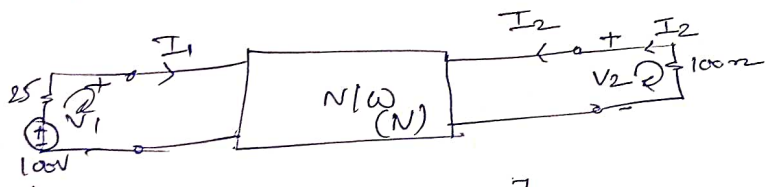
$$Z_{11}' = Z_{11} + (R) \text{ port } 01$$

$$Z_{12}' = Z_{12}$$

$$Z_{21} = Z_{21}$$

$$Z_{22} = Z_{22} + (R) \text{ port } 02$$

Q16)



Z_{in}

$$[Y] = \begin{bmatrix} 0.1\,S & -0.01\,S \\ 0.01\,S & 0.1\,S \end{bmatrix}$$

$\frac{V_2}{V_1} = ?$ (voltage gain)

$$I_1 = 0.1V_1 - 0.01V_2 \quad \text{--- (1)}$$

$$I_2 = 0.01V_1 + 0.1V_2 \quad \text{--- (2)}$$

$$V_2 + I_2 \times 100 = 0$$

$$\boxed{I_2 = \frac{-V_2}{100}}$$

-1 & 2

s shown below

$$* \quad \frac{-V_2}{100} = \cancel{0.01V_1} \; 0.01V_1 + 0.1V_2$$

$$V_2\left(-\frac{1}{100} - \frac{1}{10}\right) = \frac{1}{100} \times V_1$$

$$-\frac{2}{10} \times V_2 = \frac{1}{100} \times V_1$$

$$\frac{V_2}{V_1} = -\frac{10}{100} \times \frac{1}{2} = -\frac{1}{20}$$

$$V_2\left(\frac{1+10}{100}\right) = \frac{V_1}{100}$$

$$\left[\frac{V_2}{V_1} = \frac{-1}{11}\right]$$

$$\boxed{I_1 = ?}$$

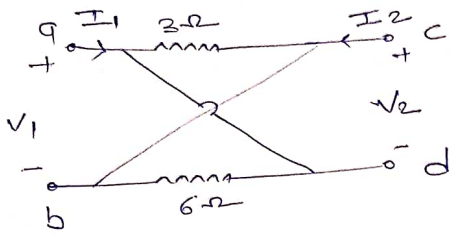
$$Z_{in} = \frac{100}{I_1}$$

$$100 - 25 \times I_1 + V_1 \quad --- (3)$$

$$V_2 = -100 I_2 \quad --- (4)$$

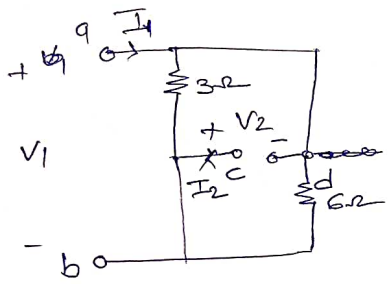
(Solve by yourself)

Q1)



$$Z_{parameter} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

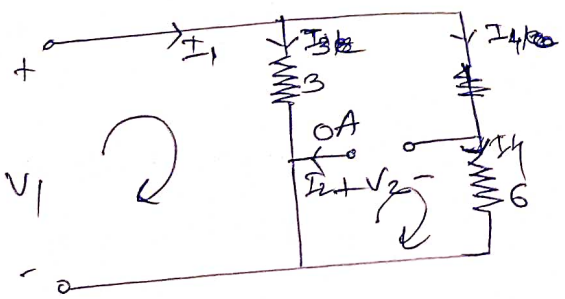
*



Case-I :- $I_2 = 0A$

$$Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0} = ?$$

$$Z_{21} = \frac{V_2}{I_1}\Big|_{I_2=0} = ?$$



$$I_3 = \frac{I_1 \times 6}{9} = \frac{2I_1}{3}$$

$$I_4 = \frac{I_1 \times 3}{9} = \frac{I_1}{3}$$

KVL ①

$$V_1 = 3I_3 = 3 \times \frac{2I_1}{3}$$

$$V_1 = 2I_1 + 0I_2$$

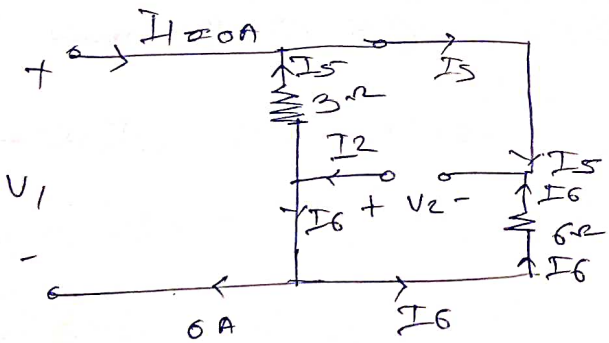
$$\left.\frac{V_1}{I_1}\right|_{I_2=0} = 2\Omega$$

KVL ②

$$-V_2 - I_4 \times 6 = 0$$

$$\left.\frac{V_2}{I_1}\right|_{I_2=0} = -2$$

Case - II when $I_1 = 0$



$$I_5 = \frac{I_2 \times 6}{9} = \frac{2I_2}{3}$$

$$I_6 = \frac{I_2 \times 3}{9} = \frac{I_2}{3}.$$

$$Z_{12} = \frac{V_1}{I_2} = ?$$

$$Z_{22} = \frac{V_2}{I_2} = ?$$

KVL in loop ①

$$V_1 + I_5 \times 3 = 0$$

$$V_1 = -I_5 \times 3$$

$$= \frac{-2 \times I_2}{\cancel{3}} \times \cancel{3}$$

$$V_1 = -2I_2$$

$$\boxed{\frac{V_1}{I_2} = -2\Omega}$$

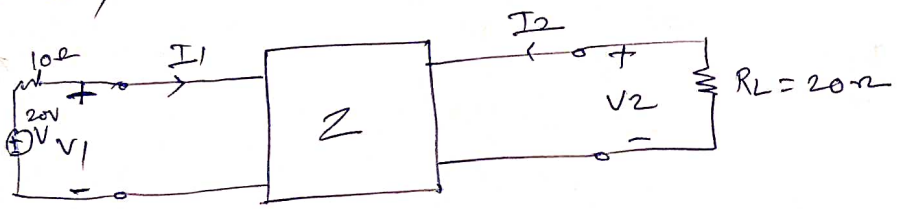
$$* \quad -V_2 + 6I_6 = 0$$

$$+V_2 = +6 \times \frac{I_2}{3}$$

$$V_2 = 2I_2$$

$$\frac{V_2}{I_2} = 2\Omega.$$

Q3)



$$[Z] = \begin{bmatrix} 40 & 60 \\ 80 & 100 \end{bmatrix}$$

Lect - 79

* The power dissipated in RL →

$$\boxed{P_{RL} = I_2^2 \times R_L} = [I_2^2 \times 20]$$

Solⁿ:-

$$V_1 = 40I_1 + 60I_2 \quad - (1)$$

$$V_2 = 80I_1 + 100I_2 \quad - (2)$$

$$20 = I_1 \times 10 + V_1 \quad - - (3)$$

$$[V_2 = -I_2 \times 20] \quad - - - (4)$$

* From eqⁿ (3) & (1)

$$20 - 10I_1 = 40I_1 + 60I_2$$

$$\boxed{50I_1 + 60I_2 = 20} \quad - - - (5)$$

* From eqⁿ (4) & (2)

$$-20I_2 = 80I_1 + 100I_2$$

$$50 \times (80I_1 + 120I_2 = 0 \quad - - - (6))$$

$$80 \times (50I_1 + 60I_2 = 20)$$

$$(120 \times 50 - 60 \times 80)I_2 = -20 \times 80$$

$$I_2 = \frac{-1600}{120 \times 50 - 60 \times 80} = -1.33 = -\frac{4}{3} A$$

$= \frac{16}{9} \times 20$

$(P_{RL} = 35.5W)$

* $P_{20V} = 20 \times I_1$ (D)

$I_2 = -\frac{4}{3}$.

$50 I_1 + 60\left(-\frac{4}{3}\right) = 20$

$50 I_1 = 100$

$I_1 = \frac{2}{1}$

$I_1 = 2A$

* $P_{20V} = 20 \times 2$

$= 40W$ (D).

Port ① power = ?

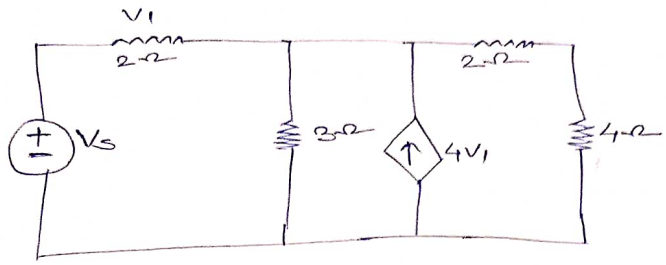
$P_{in} = V_1 \times I_1 = ?$

Port ② power

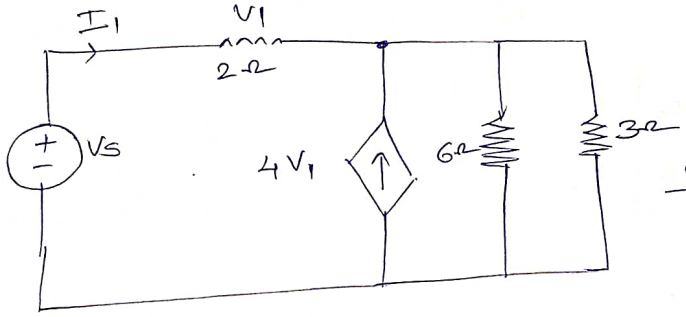
$P_{out} = V_2 \times I_2 = ?$

$P_{loss} = ?$

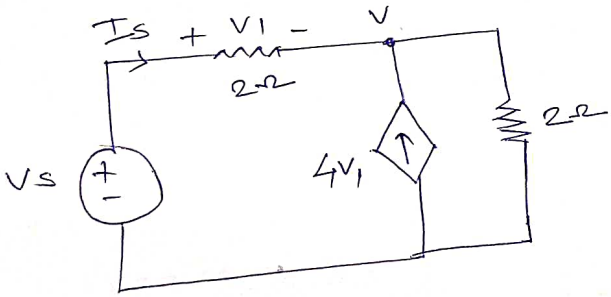
Q21)



$\boxed{Z_{in} = \frac{V_s}{I}}$ = test voltage approach.



$\frac{6 \times 3}{9} = 2\Omega$



$V\left(\frac{1}{2}\right) = 4V_1 + I_s$ — ①

$V_1 = 2I_s$ --- ②

$\frac{V}{2} = 9I_s$ --- ③

$V_s - 2I_s - V = 0$

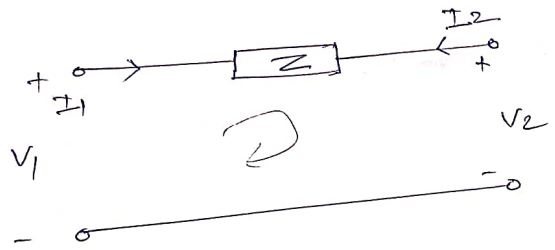
$V_s - 2I_s = V$ --- ④

$V_s - 2I_s = 18 I_s$

$V_s = 20 I_s$

$$\boxed{\frac{V_s}{I_s} = 20 = R_{in} = Z_{in}}$$

Q)



$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

* $V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

$V_1 = f(I_1 \& I_2)$

$V_2 = f(I_1 \& I_2)$

for the ~~e~~ Existance of Z parameter

$I_1 \neq f(I_2)$ or $I_2 \neq F(I_1)$

$I_1 = -I_2$

As Hence $I_1 = f(I_2)$

Hence 2-parameter will not exist.

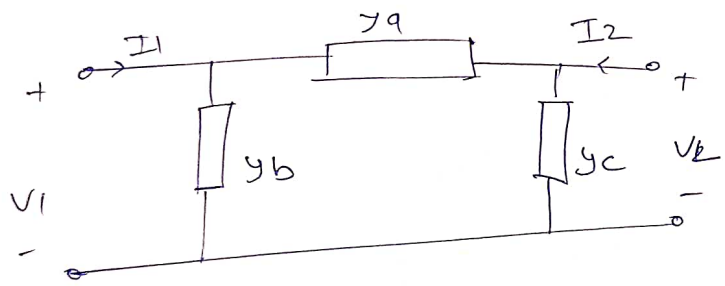
$$\left.\begin{matrix} I_1 \\ I_2 \end{matrix}\right\} = f(V_1 \& V_2)$$

$$I_1 = y_{11} V_1 + y_{12} V_2$$

$$I_2 = y_{21} V_1 + y_{22} V_2$$

$$\cancel{V_2}$$

$$V_1 =$$



$$[Y] = \begin{bmatrix} y_a + y_b & -y_a \\ -y_a & y_a + y_c \end{bmatrix}$$

$Z \to \infty \to$ o.c

$Y \to 0 \to$ o.c

$Z \to 0 \to$ s.c.

$Y \to \infty \to$ s.c

$$= \begin{bmatrix} y_a + 0 & -y_a \\ -y_a & y_a + 0 \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & -\frac{1}{2} \\ -\frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2 = 0}$$

$\Rightarrow V_1 = I_1 \times Z$

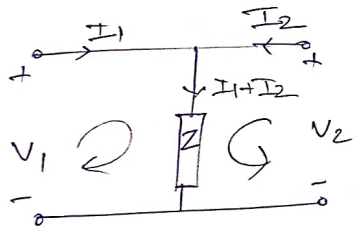
$$\frac{V_1}{I_1} = Z$$

$$\left[\frac{I_1}{V_1} = \frac{1}{Z}\right] = y_{11}$$

$* \; V_1 + I_2 Z = 0$

$$\boxed{\frac{I_2}{V_1} = \frac{-1}{Z}}$$

2)



$V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$

* KVL

$V_1 = I_1 Z + I_2 Z$

$V_2 = I_1 Z + I_2 Z$

$$\Rightarrow \begin{bmatrix} Z & Z \\ Z & Z \end{bmatrix} = [Z].$$

$* \; [Y] = [Z^{-1}] = \infty$

Y = parameter does not exist because $V_1 \neq f(V_2)$ & vice versa.

Here $V_1 = V_2$ i.e $V_1 = f(V_2)$

Hence [Y] parameter doesn't exist.

Lect - 80

iii) Hybrid (H) parameters

$V_1 = f(I_1, V_2)$

$I_2 = f(I_1, V_2)$

* $V_1 = h_{11} I_1 + h_{12} V_2$

$I_2 = h_{21} I_1 + h_{22} V_2$

* V_1 & I_2 are dependent variable.

I_1 & V_2 are independent variable

* For the existence of H-parameter

$I_1 \neq f(V_2)$, $V_2 \neq f(I_1)$

$$* \begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$[h] = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

$$[h]^{-1} = \frac{\text{Adj}[h]}{|h|} = \frac{\begin{bmatrix} h_{22} & -h_{12} \\ -h_{21} & h_{11} \end{bmatrix}}{h_{11} \times h_{22} - h_{12} \times h_{21}} = [g]$$

* Calculation of h - parameter.

Case-I :- $V_2 = 0V$

$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}$ = Impedance when $V_2 = 0$ $= \frac{1}{y_{11}}$

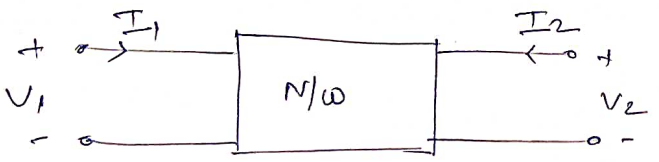
$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}$ = forward current gain when $V_2 = 0$ $= \frac{y_{21}}{y_{11}}$

Case II :- $V_1 = 0$

$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0A}$ = Admittance when $I_1 = 0A$ $= \frac{1}{Z_{22}}$

$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0A}$ = Reverse voltage gain when $I_1 = 0A$. $= \frac{Z_{12}}{Z_{22}}$

*



* Z- parameter

$V_1 = Z_{11}I_1 + Z_{12}I_2$

$V_2 = Z_{21}I_1 + Z_{22}I_2$

$I_1 = 0$

$I_2 = 0$

Y- Parameter

$I_1 = y_{11}V_1 + y_{12}V_2$

$I_2 = y_{21}V_1 + y_{22}V_2$

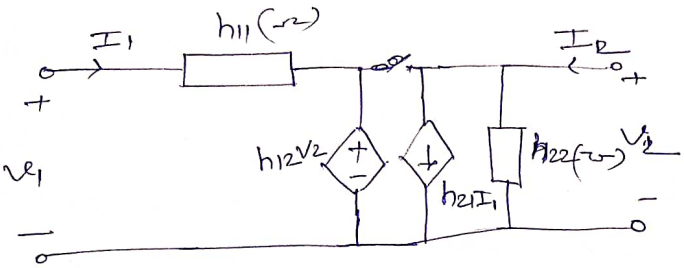
$V_1 = 0$

$V_2 = 0$

GARIMA NAGPUR

$$\left.\begin{aligned} Z_{12} &= \frac{V_1}{I_2} \\ Z_{22} &= \frac{V_2}{I_2} \end{aligned}\right\} I_1 = 0A$$

*



* Symmetrical $\longrightarrow$ Δh = Determinant = 1

Reciprocal $\longrightarrow$ $h_{21} = -h_{12}$

iv) g- parameter

* $I_1 = f(V_1, I_2)$

$V_2 = f(V_1, I_2)$

Just replace to get g- parameter from the eqn of h-parameter

$I \rightarrow V$ & $V \rightarrow I$.

* $I_1 = g_{11}V_1 + g_{12}I_2$

$V_2 = g_{12}V_1 + g_{22}I_2$

* I_1 & V_2 are Dependent variable

V_1 & I_2 $\rightarrow$ Independent variable

* for existance of g-parameter

$V_1 \neq f(I_2)$ & $I_2 \neq f(V_1)$

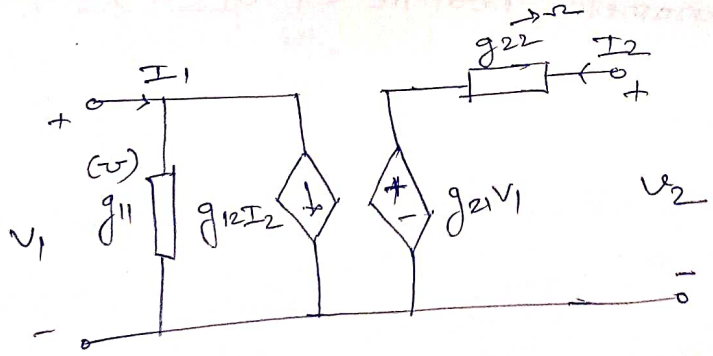
$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

$$[g] = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}$$

$$[g]^{-1} = [h] = \frac{\text{adj}[g]}{\Delta g} = \frac{\begin{bmatrix} g_{22} & -g_{12} \\ -g_{21} & g_{11} \end{bmatrix}}{(g_{11} \times g_{22} - g_{21} \times g_{12})}$$

$g_{11} \neq \frac{1}{h_{11}}$, $g_{12} \neq \frac{1}{h_{12}}$, $g_{21} \neq \frac{1}{h_{21}}$, $g_{22} \neq \frac{1}{h_{22}}$

*



Model of g-parameter

symetrical → $\Delta g = 1$

reciprocal → $g_{21} = -g_{12}$

Lect - 81

V) ABCD parameter

* It is ~~also~~ used for transient analysis of T lines.

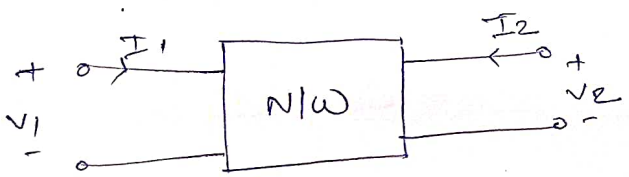
* Hence it is also known as Transmission parameter.

* $\left\{ \begin{array}{l} V_1 = f(V_2, I_2) \\ I_1 = f(V_2, I_2) \end{array} \right\}$

Dependent variable — Independent variable.

* as V_1 & I_1 are the variables of single port hence the electrical modeling of ABCD parameter is not possible.

* $$\boxed{\begin{array}{l} V_1 = AV_2 - BI_2 \\ I_1 = CV_2 - DI_2 \end{array}}$$



* Case-I $V_2 = 0$

$B = -\frac{V_1}{I_2} \Rightarrow \Omega$

$D = \frac{+I_1}{I_2} \Rightarrow$ (unitless)

Case - II $I_2 = 0$

$$A = \frac{V_1}{V_2} = \text{unitless}$$

$$C = \frac{I_1}{V_2} \Rightarrow (\text{Semen's } \mho)$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

$$[ABCD] = [T] = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

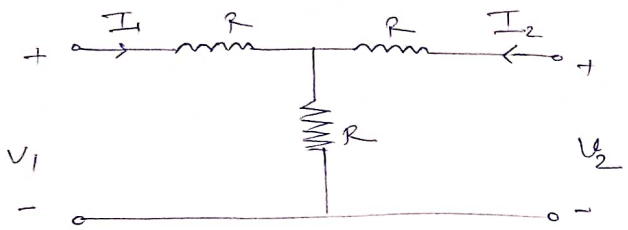
* Symmetrical $\rightarrow \Delta ABCD = 1 = AD - CB$

Reciprocity $\rightarrow \boxed{A = D}$

Lect - 82

Problems on h, g, & ABCD parameter

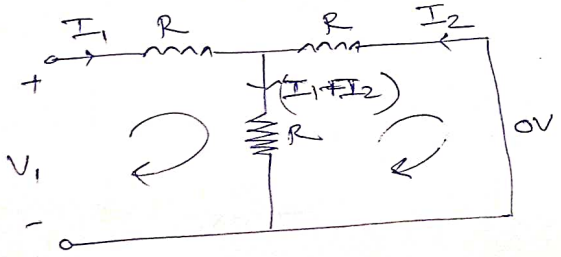
Q18)



h_{21}

$$* \begin{cases} V_1 = h_{11} I_1 + h_{12} V_2 \\ I_2 = h_{21} I_1 + h_{22} V_2 \end{cases}$$

Case-I :- $V_2 = 0V$



$$\left.\frac{V_1}{I_1}\right|_{V_2=0} = R + \frac{R}{2} = \frac{3R}{2} = h_{11}$$

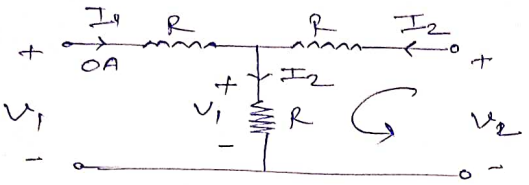
$$(I_1 + I_2) R + I_2 R = 0$$

$$I_1 R + I_2 (2R) = 0$$

$$I_2 \times 2R = -I_1 \times R$$

$$\left.\frac{I_2}{I_1}\right|_{V_2=0} = \frac{-R}{2R} = -\frac{1}{2} = h_{21}$$

Case-II when $I_1 = 0$



$$V_2 - I_2(R+R) = 0 \quad -(1)$$

$$\left.\frac{V_2}{I_2}\right|_{I_1=0} = 2R = h_{22}.$$

$$*V_1 = I_2 \times R \quad -(2)$$

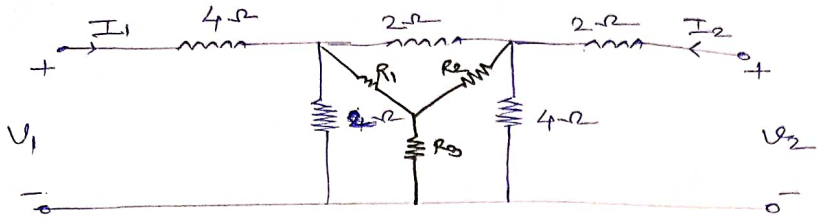
$$V_2 = 2V_1$$

$$\boxed{\left.\frac{V_1}{V_2}\right|_{I_1=0} = \frac{1}{2} = h_{12}}$$

$$[Z] = \begin{bmatrix} 2R & R \\ R & 2R \end{bmatrix}$$

$$[Y] = [Z]^{-1}$$

Q)

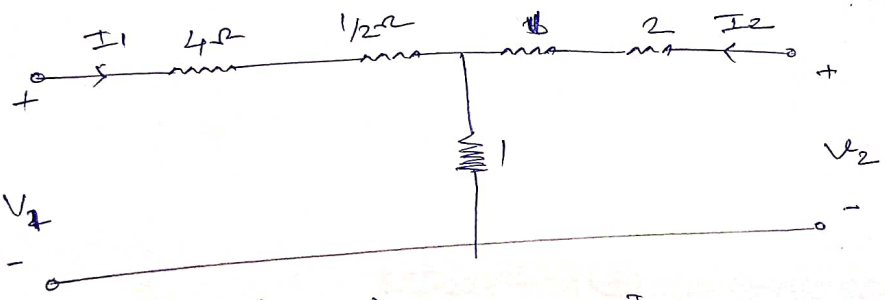


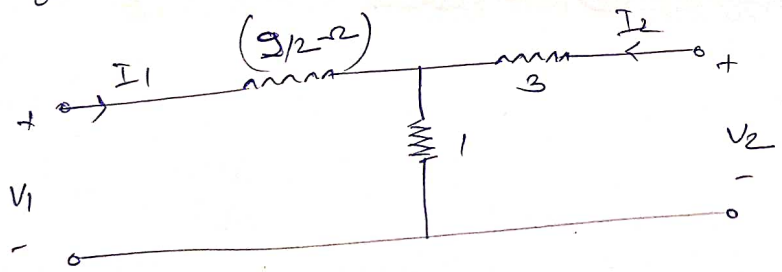
$$\begin{cases} V_1 = h_{11} I_1 + h_{12} V_2 \\ I_2 = h_{21} I_1 + h_{22} V_2 \end{cases}$$

$$\Rightarrow R_1 = \frac{2\times 2}{8} = \frac{4}{8} = \frac{1}{2}\,\Omega$$

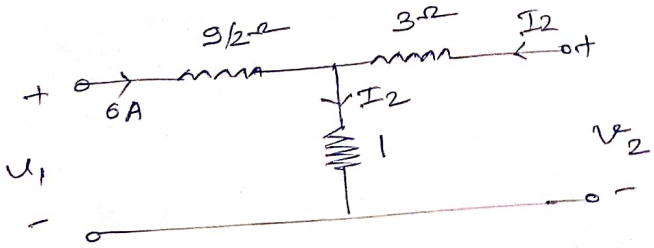
$$R_2 = \frac{4\times 2}{8} = 1\,\Omega$$

$$R_3 = \frac{2\times 4}{8} = 1\,\Omega$$





case-I $I_1 = 0A$



$V_1 = I_2 \times 1$ — ①

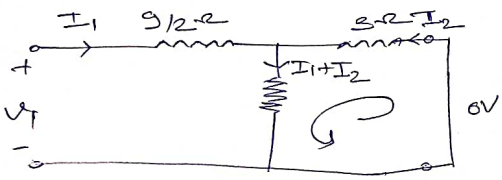
$V_2 = I_2(4)$ - - ②

$\frac{V_2}{I_2} = 4$ or $\left.\frac{I_2}{V_2}\right|_{I_1=0A} = \frac{1}{4} = h_{22}$

$V_1 = I_2 \times 1$

$\left.\frac{V_1}{V_2}\right|_{I_1=0} = \frac{I_2}{4I_2} = \frac{1}{4} = h_{12}.$

Case-II $V_2 = 0$



$I_2 \times 3 + (I_1+I_2) \times 1 = 0$

$I_1 + 4I_2 = 0$

$\left.\frac{I_2}{I_1}\right|_{V_2=0} = -\frac{1}{4} = h_{21}$

$* \; V_1 = I_1 \times \frac{9}{2} + I_1 \times 1 + I_2 \times 1$

$= I_1\left(\frac{9}{2}+1\right) + I_2$

$= I_1\left(\frac{9}{2}+1\right) - \frac{1}{4}\Big)$

$= I_1\left(\frac{18+4-1}{4}\right)$

$$\left.\frac{V_1}{I_1}\right|_{V_2=0} = \frac{21}{4} = h_{11}.$$

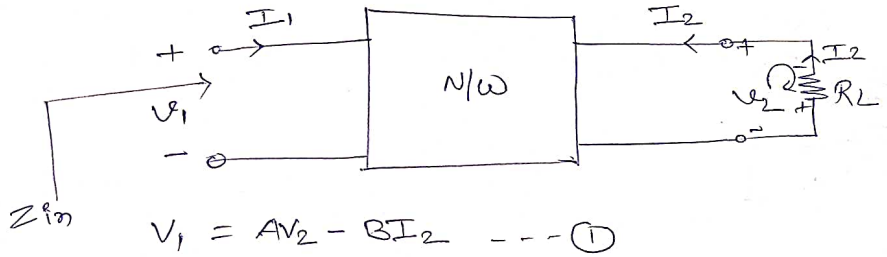
Q) A two port N/W is represented by

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}.$$

If port 2 is terminated by R_L,

The input impedance seen at port 1 will be

Sol:-



$$V_1 = AV_2 - BI_2 \quad ---(1)$$

$$I_1 = CV_2 - DI_2 \quad ---(2)$$

Now

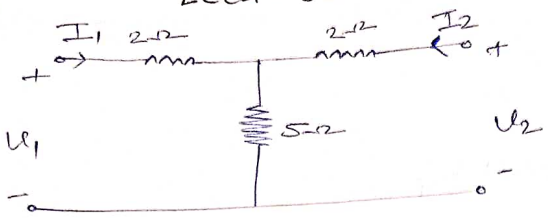
$$Z_{in} = \frac{V_1}{I_1}$$

$$* \; V_2 = -I_2 R_L \quad ---(3)$$

$$\frac{V_1}{I_1} = \frac{AV_2 - BI_2}{CV_2 - DI_2}$$

$$\frac{V_1}{I_1} = \frac{-AR_L I_2 - BI_2}{-CR_L I_2 - DI_2} = \frac{+(AR_L + B)}{+(CR_L + D)} = \frac{AR_L + B}{CR_L + D} = Z_{in}.$$

Q) Lect- 83



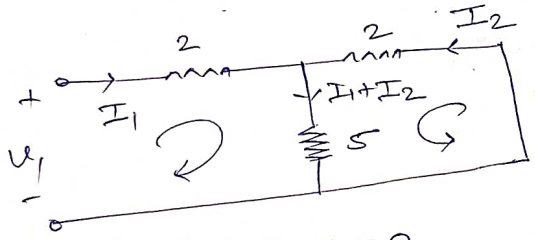
$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

find 'B' = ?

Sol^n:- $V_1 = AV_2 - BI_2$

$I_1 = CV_2 - DI_2$

case I $V_2 = 0$



$$I_2(7) + I_1 5 = 0$$

$$\left.\frac{I_1}{I_2}\right|_{V_2=0} = \frac{-7}{5}$$

$$D = \frac{-I_1}{I_2} = \frac{7}{5}$$

$$* V_1 = 7I_1 + 5I_2$$

$$= 7 \times \left(\frac{-7}{5} \times I_2\right) + 5I_2$$

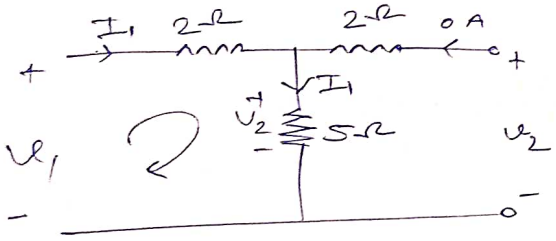
$$\frac{V_1}{I_2} = \frac{-7 \times 7}{5} + 5$$

$$-\frac{V_1}{I_2} = \frac{7 \times 7}{5} - 5$$

$$= \frac{49 - 25}{5}$$

$$B = 4.8\ \Omega$$

case-II $I_2 = 0$



$$V_2 = I_1 \times 5$$

$$C = \frac{I_1}{V_2} = \frac{1}{5}\ \mho$$

$$* \quad V_1 - V_2 = I_1 \times 2$$

$$V_1 = V_2 + 2I_1$$

$$V_1 = V_2 + 2 \times \frac{V_2}{5}$$

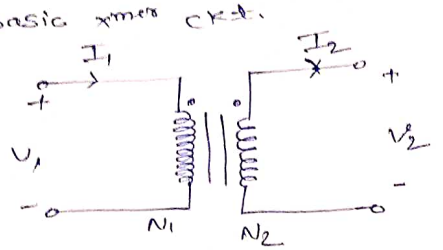
$$V_1 = V_2\left(1 + \frac{2}{5}\right)$$

$$V_1 = V_2\left(7/5\right)$$

$$\frac{V_1}{V_2} = \frac{7}{5} = A$$

Transformers.

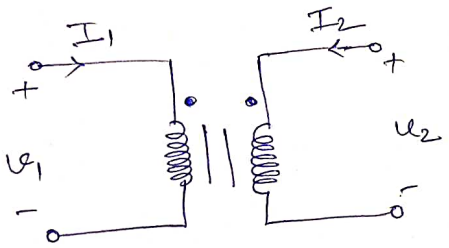
* Basic xmer ckt.



$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = 'a'$$

$$\frac{I_2}{I_1} = \frac{N_1}{N_2} = n = 'a' \Rightarrow \text{Turns ratio}$$

* transformer represented as a two port N/W in N/W theory.



$$\frac{V_1}{V_2} = n = \frac{N_1}{N_2} \rightarrow V_1 = nV_2 \quad - (1)$$

$$-\frac{I_2}{I_1} = n = \frac{N_1}{N_2} \rightarrow I_2 = -nI_1 \quad - (2)$$

or

$$I_1 = \frac{-I_2}{n}.$$

$V_1 = f(V_2) \longrightarrow$ Y-parameter will never exist.

$I_1 = f(I_2) \longrightarrow$ Z parametre will never exist.

* h parameter

$V_1 = h_{11} I_1 + h_{12} V_2 \Rightarrow V_1 = \underset{h_{11}}{0} \times I_1 + \underset{h_{12}}{n} V_2$

$I_2 = h_{21} I_1 + h_{22} V_2 \Rightarrow I_2 = \underset{h_{21}}{-n} I_1 + \underset{h_{22}}{0} V_2$

$$[h] = \begin{bmatrix} 0 & n \\ -n & 0 \end{bmatrix}$$

$h_{21} = -h_{12}$

$-n = -n \Rightarrow$ reciprocal ckt.

$\Delta h = 1$

$= n^2 \neq 1$

hence it is a asymmetrical circuit.

* ABCD - parameter

$V_1 = AV_2 - BI_2 \longrightarrow \underset{A}{n} V_2 - \underset{B}{0} I_2$

$I_1 = CV_2 - DI_2 \longrightarrow \underset{C}{0} V_2 + \underset{D}{I_2 \times \frac{1}{n}}$

$$[ABCD] = \begin{bmatrix} n & 0 \\ 0 & 1/n \end{bmatrix}$$

$\Delta T = n \times \frac{1}{n} - 0$

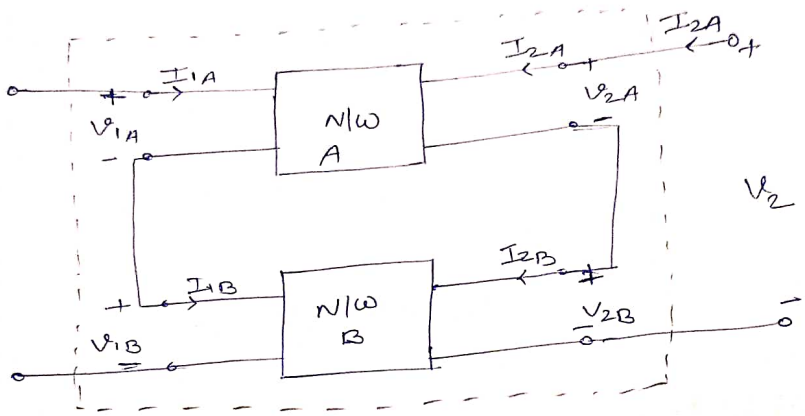
$\Delta T = 1 \rightarrow$ reciprocal ✓

$A \neq D \rightarrow$ Asymmetrical.

Lect - 84

Interconnection

i) Series Interconnections.



$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

Sol:- proof that $[Z] = [Z]_A + [Z]_B$

$$\left.\begin{cases} V_{1A} = Z_{11A} I_{1A} + Z_{12A} I_{2A} \\ V_{2A} = Z_{21A} I_{1A} + Z_{22A} I_{2A} \end{cases}\right\} N/W\ A$$

$$\left.\begin{cases} V_{1B} = Z_{11B} I_{1B} + Z_{12B} I_{2B} \\ V_{2B} = Z_{21B} I_{1B} + Z_{22B} I_{2B} \end{cases}\right\} N/W\ B$$

$$* \begin{bmatrix} V_1 = Z_{11} I_1 + Z_{12} I_2 \\ V_2 = Z_{21} I_1 + Z_{22} I_2 \end{bmatrix}$$

$* \; V_1 = V_{1A} + V_{1B}$

$V_2 = V_{2A} + V_{2B}$

$I_1 = I_{1A} + I_{1B}$

$I_2 = I_{2A} + I_{2B}$

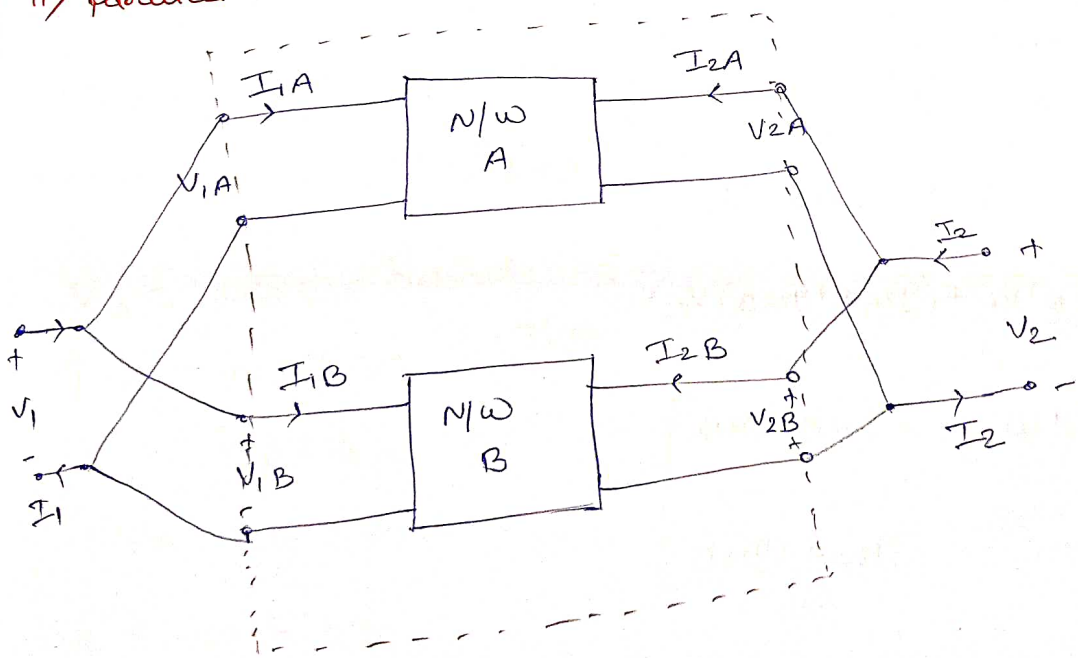
$* \; V_1 = (Z_{11A} + Z_{11B}) I_1 + (Z_{12A} + Z_{12B}) I_2$

$V_2 = (Z_{21A} + Z_{21B}) I_1 + (Z_{22A} + Z_{22B}) I_2$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11A} + Z_{11B} & Z_{12A} + Z_{12B} \\ Z_{21A} + Z_{21B} & Z_{22A} + Z_{22B} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$[Z_A] + [Z_B] = [Z]$ //

ii) parallel connection



$$[Y] = [Y$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$[Y] = [Y]_A + [Y]_B$$

$$* \; I_{1A} = y_{11A} V_{1A} + y_{12A} V_{2A}$$

$$I_{2A} = y_{21A} V_{1A} + y_{22A} V_{2A}$$

$$* \; I_{1B} = y_{11B} V_{1B} + y_{12B} V_{2B}$$

$$I_{2B} = y_{21B} V_{1B} + y_{22B} V_{2B}$$

$$* \; I_1 = I_{1A} + I_{1B}$$

$$I_2 = I_{2A} + I_{2B}$$

$$* \; V_1 = V_{1A} + V_{1B}$$

$$V_2 = V_{2A} + V_{2B}$$

$$* \; I_1 = (y_{11A} + y_{11B}) V_1 + (y_{12A} + y_{12B}) V_2$$

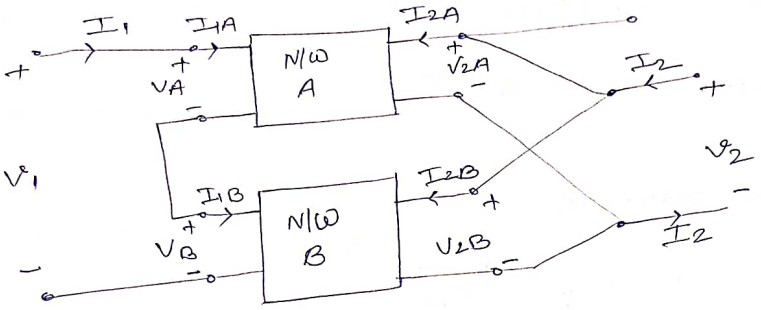
$$I_2 = (y_{21A} + y_{21B}) V_1 + (y_{22A} + y_{22B}) V_2$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11A} + y_{11B} & y_{12A} + y_{12B} \\ y_{21A} + y_{21B} & y_{22A} + y_{22B} \end{bmatrix}$$

$$[Y] = [Y]_A + [Y]_B$$

Lect-85

iii) Series & parallel Interconnection



$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$[h] = [h]_A + [h]_B$$

$* \; V_{1A} = h_{11A} I_{1A} + h_{12A} V_{2A}$

$I_{2A} = h_{21A} I_{1A} + h_{22A} V_{2A}$

$* \; V_{1B} = h_{11B} I_{1B} + h_{12B} I_{2B}$

$I_{2B} = h_{21B} I_{1B} + h_{22B} V_{2B}$

$* \; V_1 = V_{1A} + V_{1B}$

$I_{1A} = I_{1B} = I_1$

$V_2 = V_{2A} = V_{2B}$

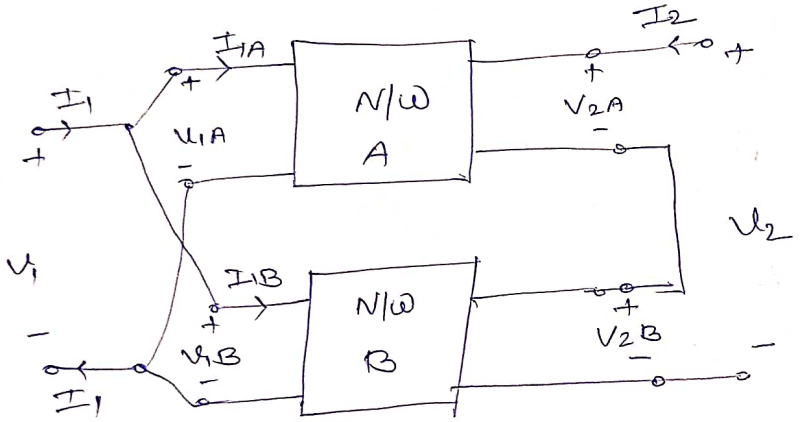
$I_2 = I_{2A} = I_{2B}$

* $V_1 = (h_{11A} + h_{11B}) I_1 + (h_{12A} + h_{12B}) V_2$.

* $I_2 = (h_{21A} + h_{21B}) I_1 + (h_{22A} + h_{22B}) V_2$.

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11A} + h_{11B} & h_{12A} + h_{12B} \\ h_{21A} + h_{21B} & h_{22A} + h_{22B} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

iv) parallel & series connection.



$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

$$[g] = [g]_A + [g]_B$$

* $V_1 = V_{1A} = V_{1B}$

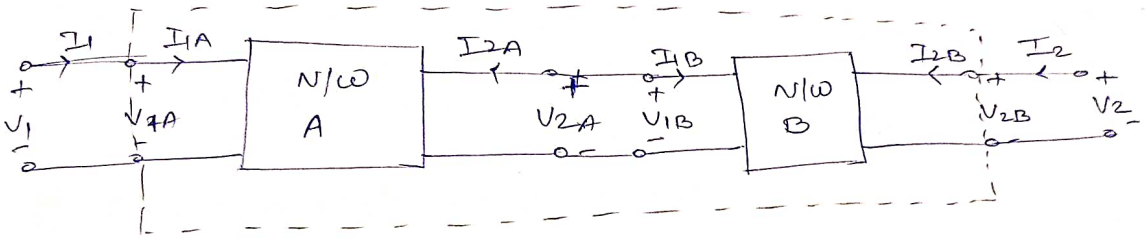
$I_1 = I_{1A} + I_{1B}$

$V_2 = V_{2A} + V_{2B}$

$I_{2A} = I_{2B} = I_2$

* $[g] = \begin{bmatrix} g_{11A} + g_{11B} & g_{12A} + g_{12B} \\ g_{21A} + g_{21B} & g_{22A} + g_{22B} \end{bmatrix}$ please try to drive yourself.

v) Cascade connection



$$[ABCD] = [ABCD]_A \cdot [ABCD]_B$$

* $V_{1A} = A_A V_{2A} - B_A I_{2A}$

$I_{1A} = C_A V_{2A} - D_A I_{2A}$

* $V_{1B} = A_B V_{2B} - B_B I_{2B}$

$I_{1B} = C_B V_{2B} - D_B I_{2B}$

* $\begin{cases} V_1 = V_{1A} \\ I_1 = I_{1A} \end{cases}$

$\begin{cases} V_{2A} = V_{1B} \\ I_{2A} = -I_{1B} \end{cases}$

$$\begin{cases} V_2 = V_{2B} \\ I_2 = I_{2B} \end{cases}$$

$$\begin{bmatrix} V_{1A} \\ I_{1A} \end{bmatrix} = \begin{bmatrix} A_A & B_A \\ C_A & D_A \end{bmatrix} \begin{bmatrix} V_{2A} \\ -I_{2A} \end{bmatrix} \quad \cdots (1)$$

$$* \begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

$$* \begin{bmatrix} V_{1B} \\ I_{1B} \end{bmatrix} = \begin{bmatrix} A_B & B_B \\ C_B & D_B \end{bmatrix} \begin{bmatrix} V_{2B} \\ -I_{2B} \end{bmatrix}$$

$$\begin{bmatrix} V_{2A} \\ -I_{2A} \end{bmatrix} = \begin{bmatrix} A_B & B_B \\ C_B & D_B \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

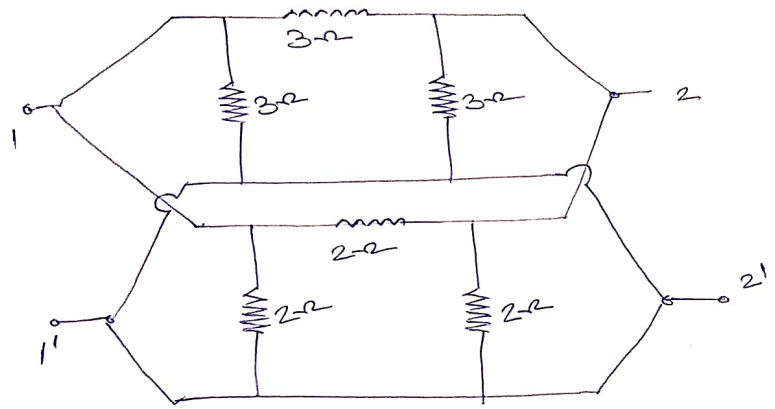
$$\begin{bmatrix} V_{1A} \\ I_{1A} \end{bmatrix} = \begin{bmatrix} A_A & B_A \\ C_A & D_A \end{bmatrix} \begin{bmatrix} A_B & B_B \\ C_B & C_B \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_A & B_A \\ C_A & D_A \end{bmatrix} \begin{bmatrix} A_B & B_B \\ C_B & C_B \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

GARIMA NAGPUR

Lect- 86

Q)

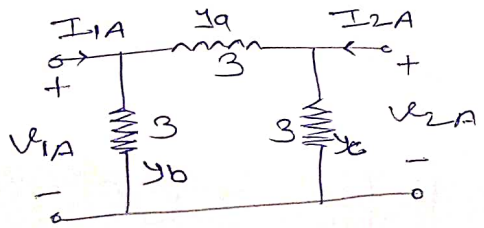


$[h_{22} = ?]$

* It is a parallel Interconnection

$$[Y] = [y]_A + [y]_B$$

* Network A

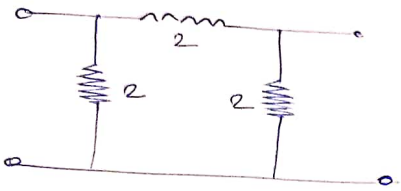


$$[Y]_A = \begin{bmatrix} y_a + y_b & -y_a \\ -y_a & y_a + y_c \end{bmatrix}$$

$$= \begin{bmatrix} \frac{1}{3} + \frac{1}{3} & -\frac{1}{3} \\ -\frac{1}{3} & \frac{1}{3} + \frac{1}{3} \end{bmatrix}$$

$$[Y]_A = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} \\ -\frac{1}{3} & 2/3 \end{bmatrix}$$

Network B



$$[Y]_B = \begin{bmatrix} \frac{1}{2}+\frac{1}{2} & -\frac{1}{2} \\ -\frac{1}{2} & \frac{1}{2}+\frac{1}{2} \end{bmatrix}$$

$$= \begin{bmatrix} 1 & -1/2 \\ -1/2 & 1 \end{bmatrix}$$

Total

$$[Y] = \begin{bmatrix} \frac{2}{3}+1 & -\frac{1}{3}-\frac{1}{2} \\ -\frac{1}{3}-\frac{1}{2} & \frac{2}{3}+1 \end{bmatrix} = \begin{bmatrix} \frac{5}{3} & \frac{-5}{6} \\ \frac{-5}{6} & \frac{5}{3} \end{bmatrix}$$

$$* \left\{ \begin{aligned} I_1 &= \frac{5}{3}V_1 - \frac{5}{6}V_2 \\ I_2 &= \frac{-5}{6}V_1 + \frac{5}{3}V_2 \end{aligned} \right\}$$

$$V_1 = h_{11} I_1 + h_{12} V_2$$

$$I_2 = h_{21} I_1 + h_{22} V_2$$

$\longrightarrow$ h-parameter

case-I $\quad I_1 = 0$

$$0 = \frac{5}{3} V_1 - \frac{5}{6} V_2$$

$$\frac{5}{6} V_2 = \frac{5}{3} V_1$$

$$\boxed{V_2 = 2V_1}$$

$$\boxed{\left.\frac{V_1}{V_2}\right|_{I_1=0} = \frac{1}{2} = h_{12}}$$

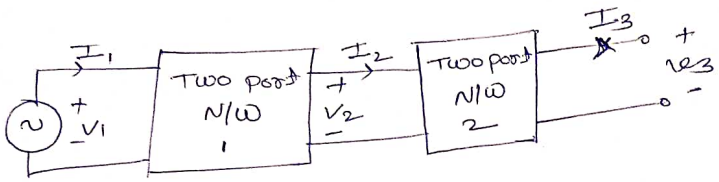
$$* \quad I_2 = \frac{-5}{6} \times \left(\frac{V_2}{2}\right) + \frac{5}{3} V_2$$

$$= V_2 \left(\frac{5}{3} - \frac{5}{12}\right)$$

$$I_2 = V_2 \left(\frac{20-5}{12}\right)$$

$$\left.\frac{I_2}{V_2}\right|_{I_2=0} = \frac{15}{12} = h_{22} = \cancel{1.255}\ 1.255$$

Q) Two passive networks are connected in cascade, Voltage source in connected at port 1



$$V_1 = A_1 V_2 + B_1 I_2$$

$$I_1 = C_1 V_2 + D_1 I_2$$

$$V_2 = A_2 V_3 + B_2 I_3$$

$$I_2 = C_2 V_3 + D_2 I_3$$

* If the therenin eq^n ckt at port 3 consist of voltage source V_T & an impedance Z_T, then.

V_T & Z_T = ?

Sol^n:-

$$[ABCD] = [ABCD]_1 [ABCD]_2$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} V_3 \\ I_3 \end{bmatrix}$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_1 A_2 + B_1 C_2 & A_1 B_2 + B_1 D_2 \\ C_1 A_2 + D_1 C_2 & C_1 B_2 + D_1 D_2 \end{bmatrix} \begin{bmatrix} V_3 \\ I_3 \end{bmatrix}$$

* $V_{th} \rightarrow$ at port '3' $\rightarrow$ O.C $\rightarrow I_3 = 0A$

$$V_3 \Big|_{I_3=0} = V_{th} \quad \Rightarrow$$

$$V_1 = (A_1A_2 + B_1C_2) \times V_3 + (A_1B_2 + B_1D_2) I_3$$

$$V_1 = (A_1A_2 + B_1C_2) V_3$$

$$\boxed{V_{th} = \frac{V_1}{A_1A_2 + B_1C_2}}$$

For the calculation of R_{th}

Lect - 87

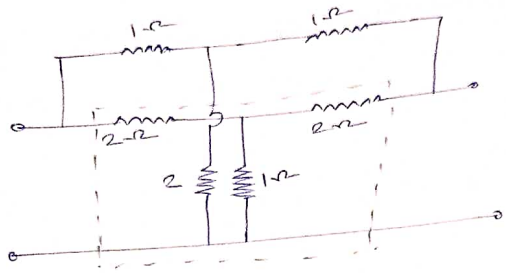
Apply test voltage approach in V_3

$$R_{th} = \frac{V_3}{I_3} = \frac{V_3}{-I_3}\Big|_{V_1=0}$$

$$V_1 = (A_1A_2 + B_1C_2) V_3 + (A_1B_2 + B_1D_2) I_3$$

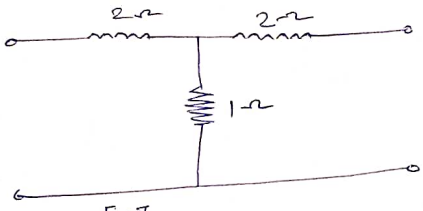
$$\frac{-V_3}{I_3} = R_{th} = Z_{th} = Z_T = \left(\frac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}\right)$$

Q)

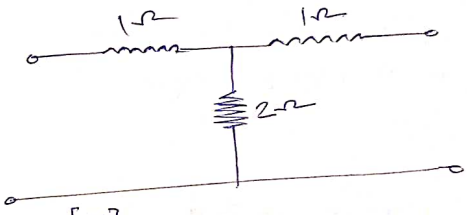


Find [Y] parameters

[Z] parameter.



$[Z]_1$



$[Z]_2$

* here two N/w are connected in parallel.

$$[Z]_1 = \begin{bmatrix} 3 & 1 \\ 1 & 3 \end{bmatrix}$$

$$[Z]_2 = \begin{bmatrix} 3 & 2 \\ 2 & 3 \end{bmatrix}$$

$$[Y]_1 = [Z]_1^{-1}$$

$$[Y]_1 = \frac{\begin{bmatrix} 3 & -1 \\ -1 & 3 \end{bmatrix}}{8}$$

$$= \begin{bmatrix} \frac{3}{8} & -\frac{1}{8} \\ -\frac{1}{8} & \frac{3}{8} \end{bmatrix}$$

$$[Y]_2 = [Z]_2^{-1}$$

$$[Y]_2 = [Z]^{-1} = \frac{\begin{bmatrix} 3 & -2 \\ -2 & 3 \end{bmatrix}}{5}$$

$$[Y]_2 = \begin{bmatrix} \frac{3}{5} & -\frac{2}{5} \\ -\frac{2}{5} & \frac{3}{5} \end{bmatrix}.$$

$$* \; [Y] = [Y_1] + [Y_2]$$

$$= \begin{bmatrix} \frac{3}{8} + \frac{3}{5} & -\left(\frac{1}{8} + \frac{2}{5}\right) \\ -\left(\frac{1}{8} + \frac{2}{5}\right) & \left(\frac{3}{8} + \frac{3}{5}\right) \end{bmatrix}$$

$$[Y] = \begin{bmatrix} 0.975 & -0.525 \\ -0.525 & 0.975 \end{bmatrix} = \begin{bmatrix} \frac{39}{40} & -\frac{21}{40} \\ -\frac{21}{40} & \frac{39}{40} \end{bmatrix}$$

$$[Z] = [Z_1] + [Z_2] \quad \times \quad \text{Not in parallel.}$$

$$[Z] = [Y]^{-1} = \frac{\begin{bmatrix} 39/40 & 21/40 \\ 21/40 & 39/40 \end{bmatrix}}{\left(\frac{39 \times 39}{40 \times 40} - \frac{21 \times 21}{40 \times 40}\right)} = \frac{\begin{bmatrix} 39/40 & 21/40 \\ 21/40 & 39/40 \end{bmatrix}}{0.95 - 0.27}$$