(VED PRAKASH TIWARI)

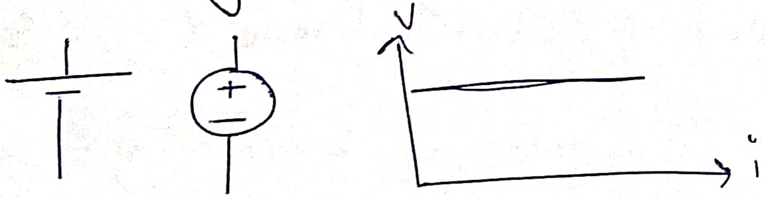
UNIT-1 Circuit / Network

↳ interconnection of various elements.

~~Circuit~~

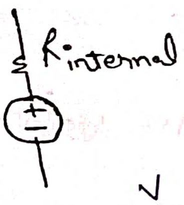
Source → Voltage Source
→ current source.

Ideal voltage source



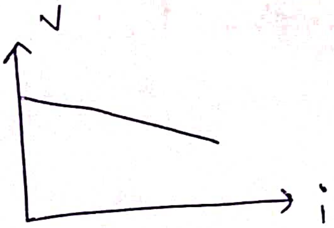
→ voltage across ideal voltage source remains constant ~~irrespective~~ irresponsible of current.

Practical voltage source

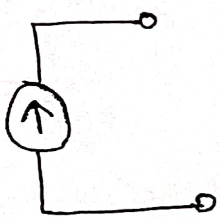


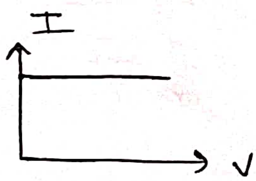
→ when current accross this increases, the voltage accross terminal decreases

$\boxed{I \uparrow \; V \downarrow}$

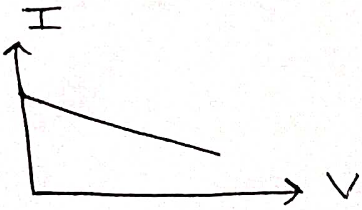


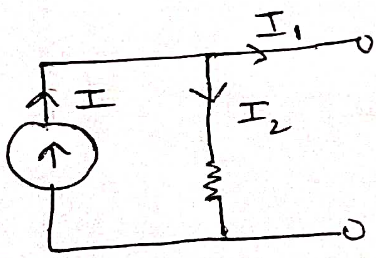
Ideal current source





practical current source





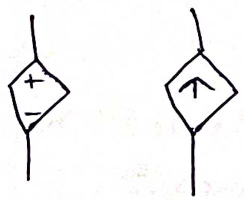
$\boxed{I_1 < I}$

→ these are independent source.

DEPENDENT SOURCE

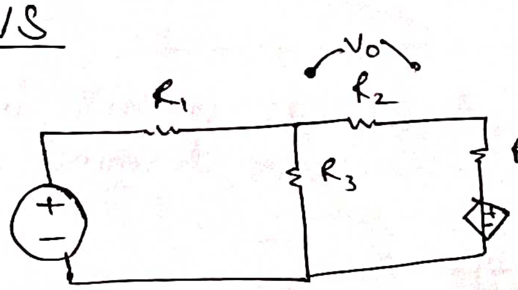
→ also "Controlled Sources"

→ Voltage controlled Voltage Source (VCVS)
→ current controlled Voltage Source (CCVS)
→ Current controlled current Source (CCCS)
→ Voltage controlled current Source (VCCS)



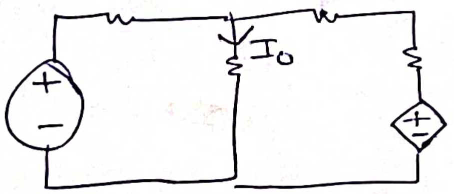
$\boxed{\text{Dependency: } KV_0, KI_0}$

VCVS



$5V_0$
↳ depends upon voltage across R_2.

CCVS



$3I_0$

Unilateral elements

→ it allows current flowing through both direcns
doesnot | without changing its characteristicks.

eg diode, BJT (bipolar junction transmitter)

Bilateral elements

→ it allows current flowing through both direcns.
without changing its characteristicks.

eg R, L, C

Active elements

if an element has an internal energy source that can drive the circuit is active element.

eg voltage source, semiconductor devices.

passive elements

if an ~~a~~ element ~~has~~ which dissipates or stores energy.

eg . R, L, C

LINEarity of Network

↳ compulsory ① Homogenity
② Superposition

→ if any element follow these then it ~~is~~ ~~be~~ follows linearity.

→ **HOMOGENITY** (Scaling property) or $f \to$ function

$$\boxed{f(ax) = a f(x)}$$ (homogenity or Scaling property)

eg

$f(x) = y = 7x$ ↳ yes, follows homogenity

$f(ax) = 7(ax) = a \cdot 7x = af(x)$

$$\boxed{f(ax) = af(x)}$$

(2) $f(x) = 3x^2$ → donot follows, homogenity

$f(ax) = 3a^2x^2 \neq af(x)$

→ **SUPER POSITION** (additive property)

$$\boxed{f(x_1+x_2) = f(x_1) + f(x_2)}$$

→ if we are applying 2 signal simultaneously, then effect must be sum of signal when applied solo.

eg

$f(x) = 7x$

$f(x_1+x_2) = 7x_1 + 7x_2$

$\Rightarrow f(x_1) + f(x_2)$

↳ Shows additive property

$f(x) = 3x^2$

$f(x_1+x_2) = 3(x_1+x_2)^2 \neq f(x_1) + f(x_2)$

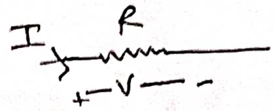
↳ do not shows additive prop.

→ if an element follow both if it follows both.

→ R, L & C as linear

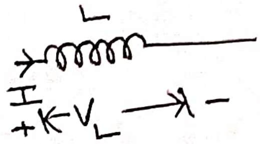
R:

$\boxed{V = IR}$ → this is linear eqn. & shows linearity of R



L:

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



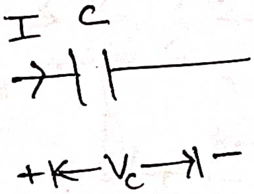
↳ this eqn. is non linear eqn.

↳ by this we cannot show L as linear

So, we apply another eqn,

$\boxed{\phi = LI}$ → it is a linear eqn.

C:



$$I = C\frac{dV_c}{dt}$$

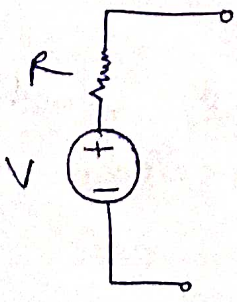
↳ non linear eqn.

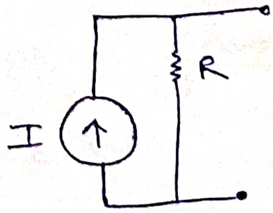
$$\Rightarrow V_c = \frac{1}{C}\int I \cdot dt$$

$\boxed{Q = CV}$ → it is a linear eqn.

Source transformation

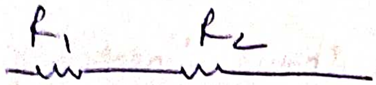
→ we can replace these connections if required. (R same in both case)



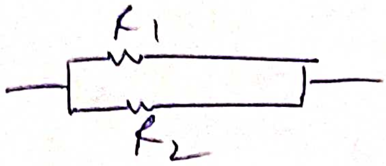


$\boxed{V = IR}$ → use this to find value.

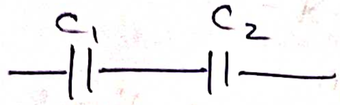
Series & // connection



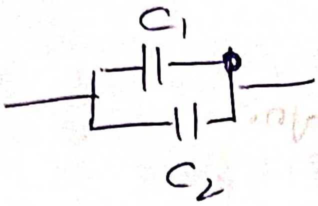
$R_{eq} = R_1 + R_2$



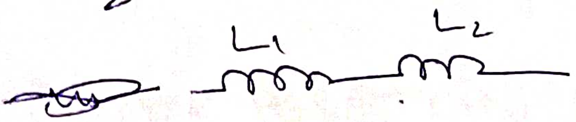
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$



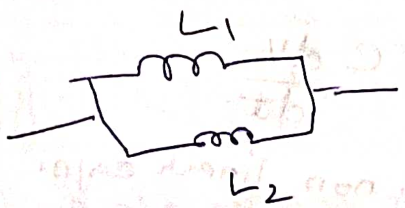
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$



$C_{eq} = C_1 + C_2$

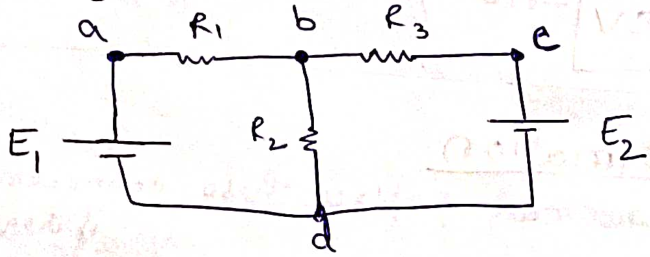


$L_{eq} = L_1 + L_2$



$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$

Loop analysis



node

↳ is equipotential point at which 2 or more elements are connected.

eg: (a, b, c, d)

Junction

↳ is equipotential point where 3 or more than 3 elements are connected. (b, d) eg

Branch :- is that part of network which lies b/w 2 junctions.

eg: dab, ab, dcb

Loop :- any closed path in a circuit is a loop.

eg $\underbrace{\text{abda, bcdb}}_{\text{elementry loops}}$, acda

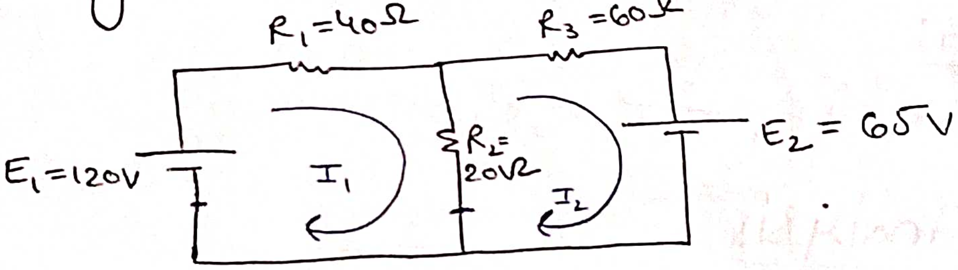
Mesh:

↳ elementry loops are called mesh.

eg abda, bcdb

Mesh analysis :-

Q).



by KVL loop 1:

$$-120 + 40I_1 + (I_1 - I_2)20 = 0 \quad -① $$

$$\cancel{2}\,4I_1 + 2I_1 - 2I_2 = \cancel{12}\,6$$

$$\boxed{3I_1 - I_2 = 6}$$

$$I_2 = 3I_1 - 6$$

by KVL Loop 2:

$$(I_2 - I_1)20 + 60I_2 + 65 = 0 \quad - ⑪$$

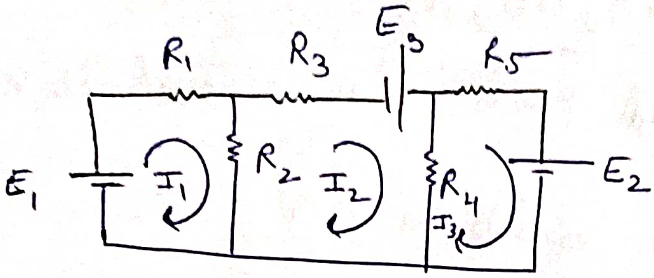
$$80I_2 - 20I_1 + 65 = 0$$

$$\boxed{16I_2 - 4I_1 + 13 = 0}$$

$I_1 = 4.38$

$I_2 = 7.14$

#



loop 1:

$$-E_1 + I_1R_1 + (I_1 - I_2)R_2 = 0$$

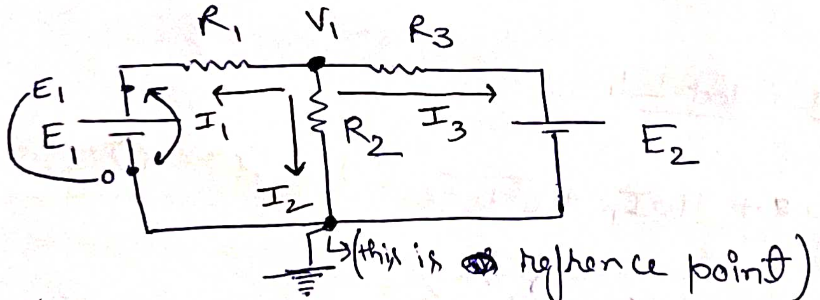
loop 2:

$$I_2R_3 - E_3 + (I_2 - I_3)R_4 + (I_2 - I_1)R_2 = 0$$

loop 3:

$$I_3R_5 + E_2 + (I_3 - I_2)R_4 = 0$$

Nodal Analysis



KCL

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_1 - E_1}{R_1} + \frac{V_1 - 0}{R_2} + \frac{V_1 - E_2}{R_3} = 0$$

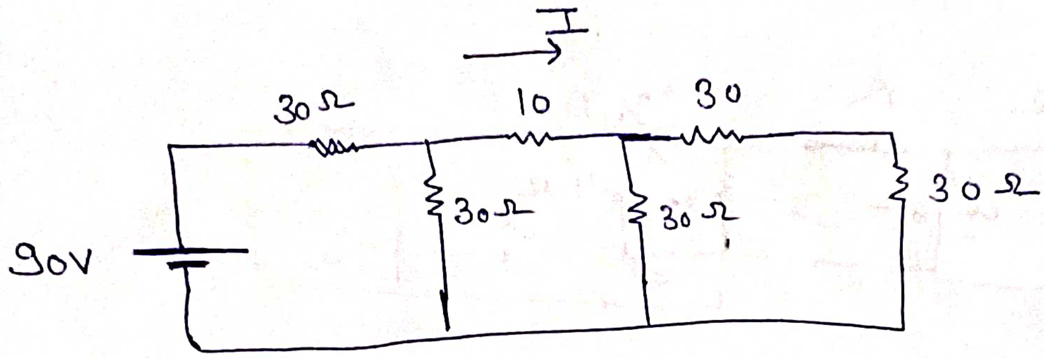
$$V_1 = \frac{490}{11}$$

$$I_1 = \frac{44.5 - 120}{40} \Rightarrow -1.88$$

$$I_2 = 2.27$$

$$I_3 = -0.39$$

Q2



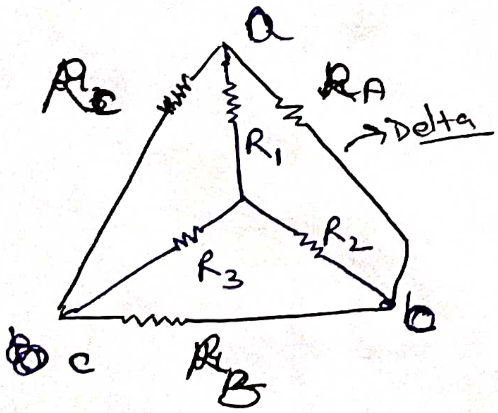
find I using Mesh analysis

Soln

$$i_{net} = \frac{90}{45} \Rightarrow 2$$

$$I = \frac{i_{net}}{2} = 1A$$

STAR-DELTA Transformation



$$R_1 = \frac{R_a R_c}{R_a + R_b + R_c}, \quad R_2 = \frac{R_a R_b}{R_a + R_b + R_c}$$

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

$$R_a = \frac{R_1R_2+R_2R_3+R_3R_1}{R_3}$$

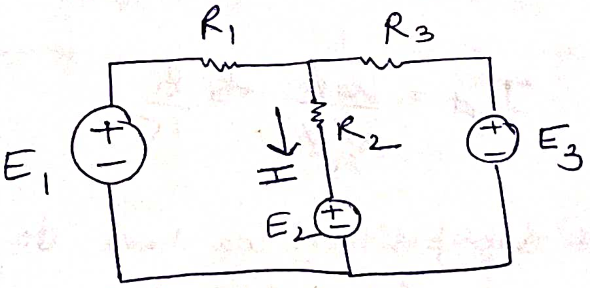
$$R_b = \frac{R_1R_2+R_2R_3+R_3R_1}{R_1}$$

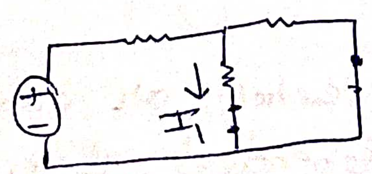
$$R_c = \frac{R_1R_2+R_2R_3+R_3R_1}{R_2}$$

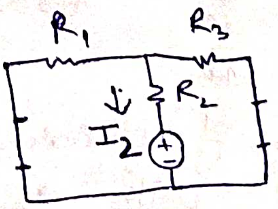
Network theorems

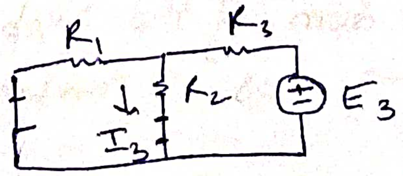
→ Super position theorem
→ thevenin's theorem, → Norton's theorem, → Maximum powertransfer theorem.

1. **Superposition theorem**:- in active linear bilateral network containing 2 or more sources, then combined effect of all source is always equal to summation of the individual sources on (all other off).



i) 

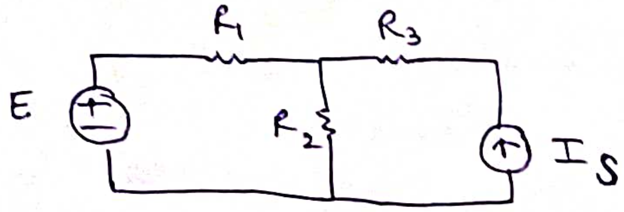
ii) 

iii) 

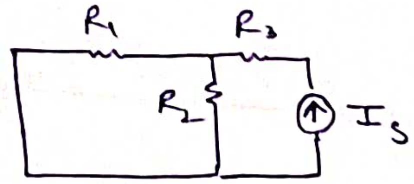
$$\boxed{I = I_1 + I_2 + I_3}$$

→ Current source → replace with open circuit
Voltage source → short circuit

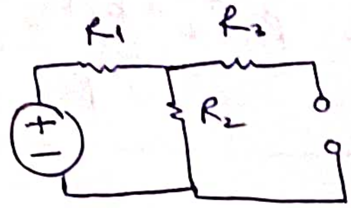
eg



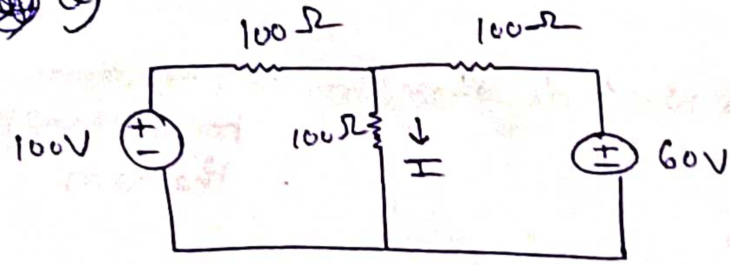
①



②

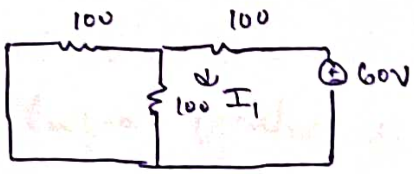


Q)

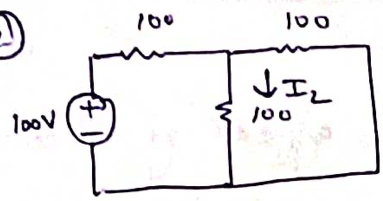


using superposition

①



②



$\frac{60}{150}$

$I_1 = \frac{60}{300}$

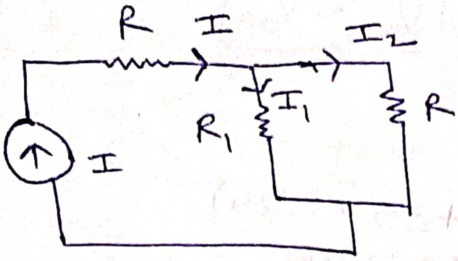
$I_2 = \frac{100}{300}$

$I_{net} = \frac{160}{300} \to \frac{8}{15}$

→ to verify the superposition, we have to show it by superposition & by one another method.

→ The response of network (voltage across or current through an element) with several independent sources can be obtained as the sum of the responses to sources taken one at a time as a consequence of circuit linearity.

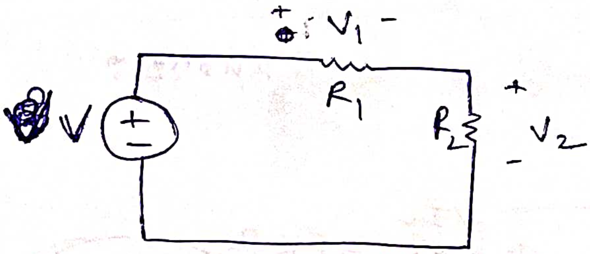
→ Current division rule :-



$$\boxed{I_1 = \left(\frac{1/R_1}{1/R_1 + 1/R_2}\right) I}$$

$$\boxed{I_2 = \left(\frac{1/R_2}{1/R_1 + 1/R_2}\right) I}$$

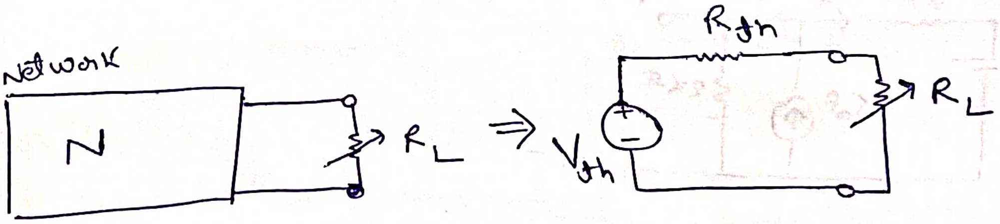
→ Voltage division rule :-



$$\boxed{V_1 = \left(\frac{R_1}{R_1+R_2}\right) V} \qquad \boxed{V_2 = \left(\frac{R_2}{R_1+R_2}\right) V}$$

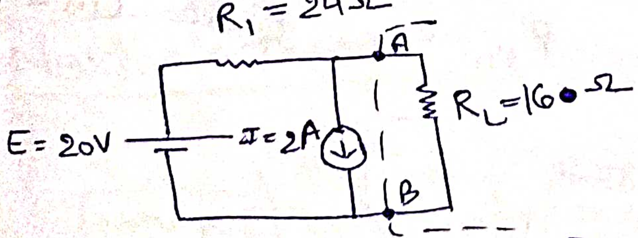
② Thevenin's theorem :-

Network



complex network

(current, voltage & power of R_L)

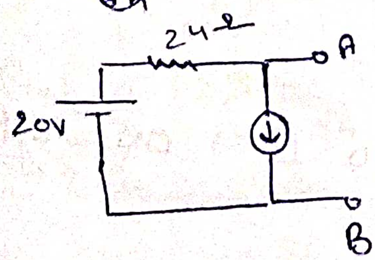


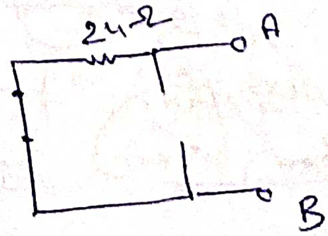
① R_{th}

→ inactive all the sources

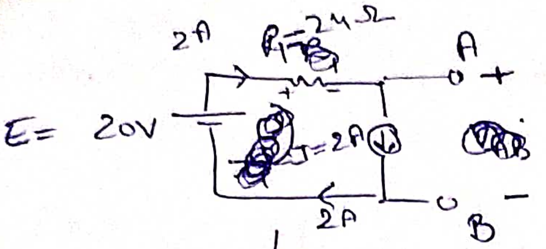
→ $R_{AB} = R_{th}$

R_{th}





$R_{AB} = 24\Omega \Rightarrow \boxed{R_{th} = 24\Omega}$



↳ Series cicuit
→ current same

V_{th}

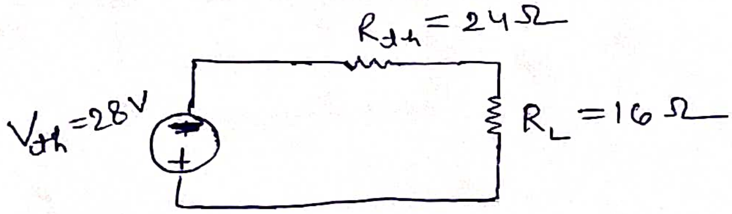
→ V_{AB} across A B

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

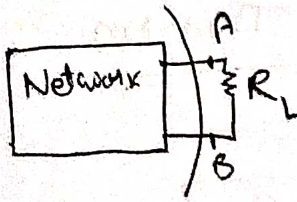
$V_{AB} = +20 - 2(24)$

$= -28$ Volt.

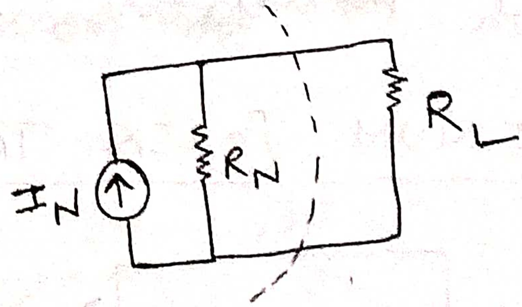
$\boxed{V_{th} = 28V}$



③ Norton's theorem



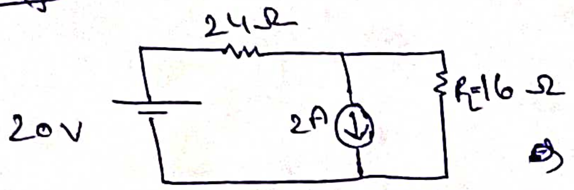
$\Rightarrow$

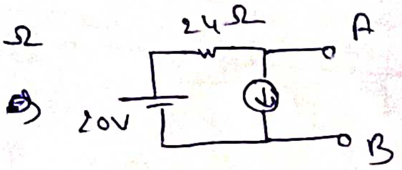


i) R_N ii) I_N (Short circuit AB, current in AB = I_N)

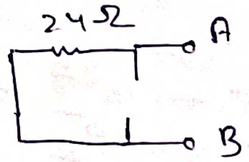
↳ same as R_{th}

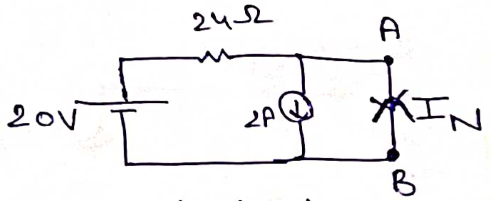
eg





$R_N = R_{th} = 24\Omega$

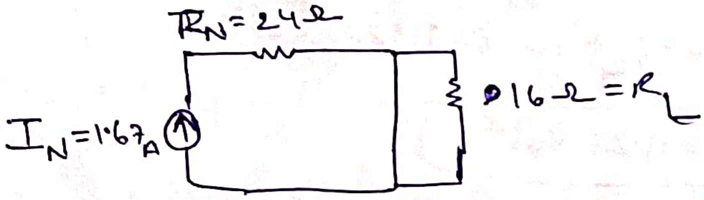


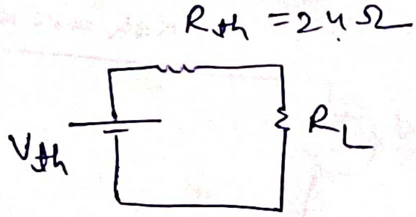


by superposition,

$I_N = 2 - \frac{20}{24} \Rightarrow 7/6\ A \Rightarrow 1.67\ A$

Nortons equivalent





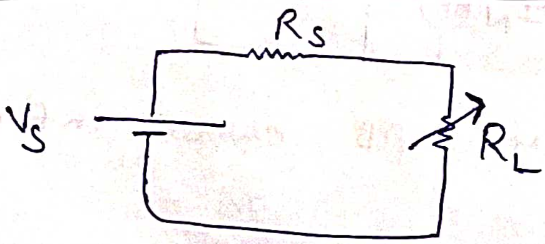
$V_{th} = I_N R_{th}$

$= I_N R_N = 7/6 \times 24 \Rightarrow 28\ V$

→ Thevenin & Norton circuit are dual circuit

→ $R_N = R_{th}$

④ MAXIMUM POWER TRANSFER Theorem



if $\boxed{R_L = R_S}$

Power delivered to R_L will be Maximum.

Proof:

I^2R

$$P_{R_L} = I^2 R_L$$

$$\Rightarrow \frac{V_S^2}{(R_L+R_S)^2} R_L$$

$$\frac{dP_L}{dR_L} = V_S^2 \left(\frac{(R_L+R_S)^2 - R_L 2(R_L+R_S)}{(R_L+R_S)^4} \right)$$

$$\Rightarrow \frac{V_S^2}{(R_L+R_S)^4} \times (R_L+R_S)\,(R_L+R_S-2R_L)$$

$$\Rightarrow \frac{V_S^2}{(R_L+R_S)^3} (R_S - R_L)$$

for maxima,

$$\boxed{R_L = R_S}$$

$$\boxed{(P_L)_{max} = \frac{V_S^2}{(2R_S)^2} R_S \Rightarrow \frac{V_S^2}{4R_S}}$$

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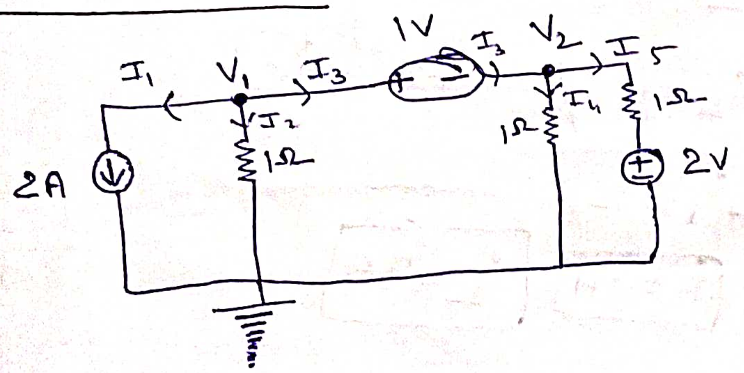
5 → Jan 2021

Super node

→ $\boxed{\text{Ignore}}$



$$I_1 + I_2 + I_3 = 0$$

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

$$I_3 = I_4 + I_5$$

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

$\boxed{V_1 - V_2 = 1}$

$\rightarrow 2 + \frac{V_1 - 0}{1} + \frac{V_2 - 0}{1} + \frac{V_2 - 2}{1} = 0$

$2V_2 + V_1 = 0$ & $V_1 - V_2 = 1$

$3V_2 + 1 = 0$

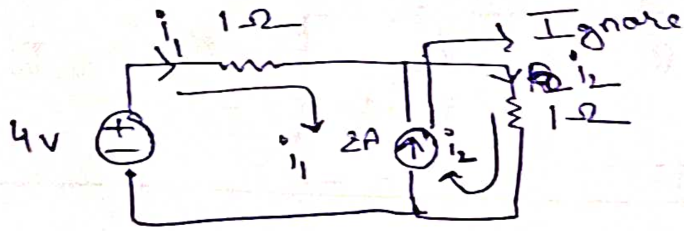
$\boxed{V_2 = -1/3}$ $\boxed{V_1 = 2/3}$

$I_4 = -1/3$ $I_5 = -7/3$

$\boxed{I_3 = -8/3 \, A}$

$P_{(1V)} = (1)\, 8/3 \Rightarrow 8/3 \, W$

Super Mesh



$-4 + i_1 + i_2 = 0$

$i_1 + i_2 = 4$ & $i_1 + 2 = i_2$

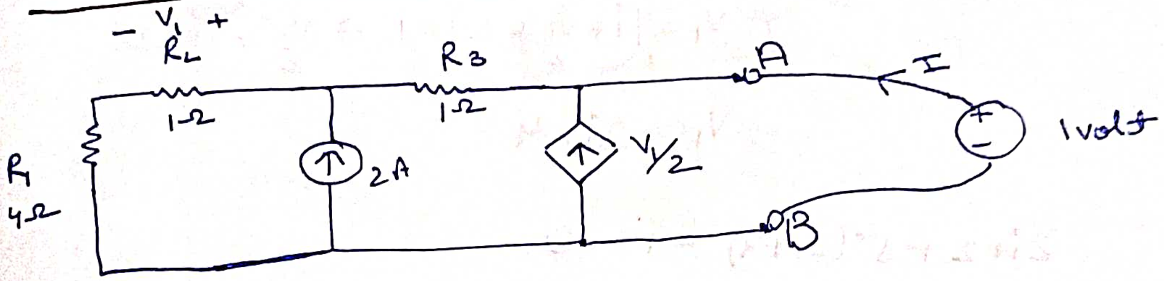
$2i_1 = 2$

$\boxed{i_1 = 1A}$ $\boxed{i_2 = 3A}$

$\eta = \frac{P_{R_L}}{P_{R_L}+P_{R_S}} \times 100 \Rightarrow 50\%$ (in Maximum power Transfer theorem)

↳ efficiency of system

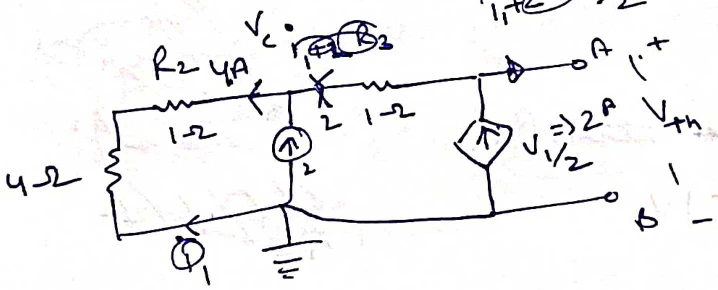
Thevenin's / Norton's (with Dependent source)



R_{th}

$R_{AB} = \frac{1}{I} = R_{th}$

V_{th}



$V_1 = R_2 i_1$

$\frac{V_c}{5} - 2 - \frac{V_1}{2} = 0$

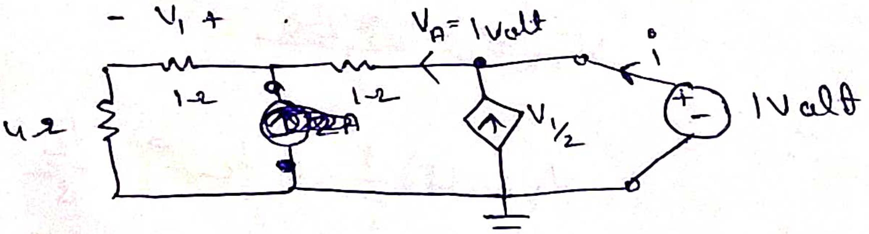
$V_1 = \frac{1}{5} \times V_c \Rightarrow \frac{V_c}{5}$

$\frac{V_c}{10} = 2 \Rightarrow \boxed{V_c = 20}$

$V_{th} = 2+4+4(4)$

$\boxed{V_{th} = 22 \text{ Volt}}$

R_{th}



$$R_{AB} = \frac{1}{i}$$

$$V_1 = V_A\left(\frac{1}{6}\right) \Rightarrow \frac{V_A}{6} \Rightarrow \frac{1}{6}$$

$$\frac{V_A - 0}{6} - \frac{V_1}{2} - i = 0$$

$$\frac{1}{6} - \frac{1}{12} - i = 0 \Rightarrow i = \frac{1}{12}$$

$$R_{AB} = \frac{1}{i} \Rightarrow \frac{1}{1/12} \Rightarrow 12\,\Omega$$