$$\boxed{P = VI = I^2R = \frac{V^2}{R}}$$

Page No.
Date

10/4/23

Unit 1

Ohm's Law → The current passing through the circuit is directly proportional to voltage keeping the temperature constant

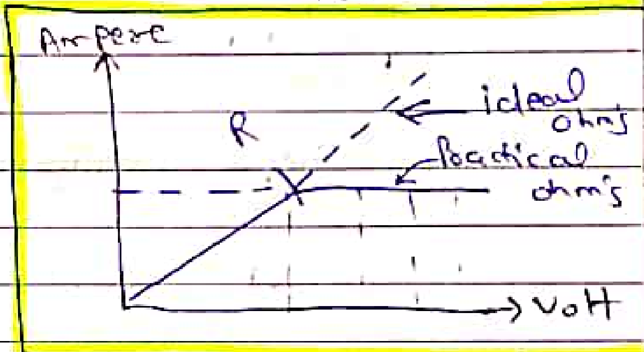
$$\boxed{\text{Current} \propto \text{voltage}}$$ ✓

$$\boxed{\text{Voltage} \propto \text{Current}}$$ ✗

Sources → batteries, generators etc.
Sink → R L C

$$\boxed{\begin{aligned} I &\propto V \\ V &= IR \end{aligned}}$$

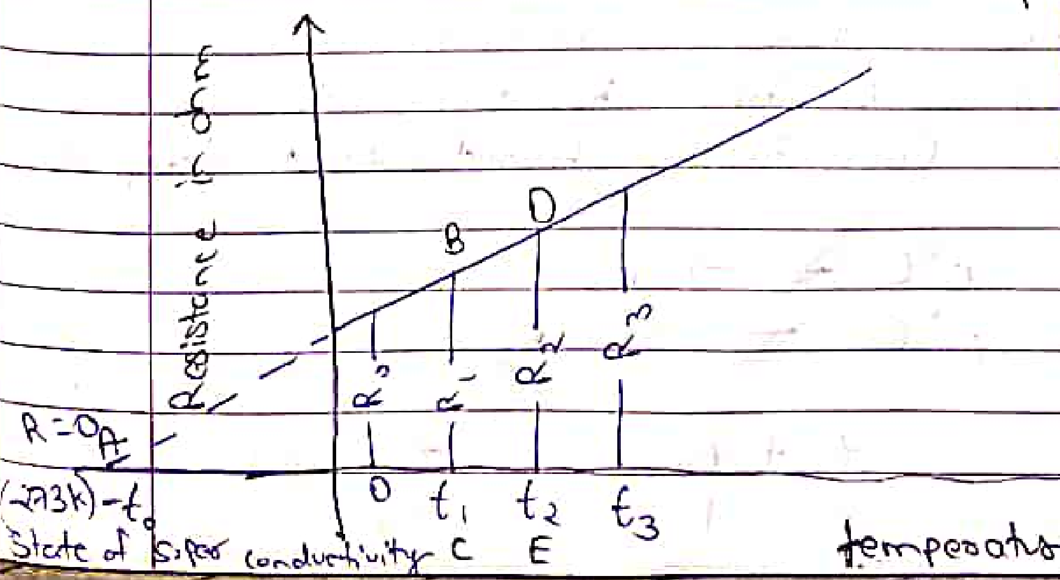
Thermal limit

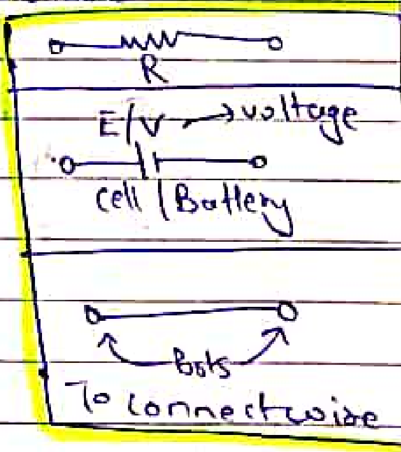


$$\boxed{R = \frac{\rho l}{A}}$$

→ ~~Rist~~ R is directly proportional to length of wire
→ R is ~~dir~~ inversely proportional to its area
→ ρ is constant that depend ~~upto~~ upon the material and is called specific resistance and resistivity

Resistance variation with temperature





Page No.	
Date	

→ for all pure metallic conductor Resistance ~~in~~ increase with increase in temperature.

→ for all non conductor materials the Resistivity / Resistance decrease with increase in temperature

$$\boxed{\text{slope of } ABC = \frac{R_1}{t_1 + t_0}}$$

$$\boxed{\text{Slope of } ADE = \frac{R_2}{t_2 + t_0}}$$

~~Slope~~ Slopes are equal

$$\frac{R_1}{t_1 + t_0} = \frac{R_2}{t_2 + t_0}$$

$$\boxed{\frac{R_2}{R_1} = \frac{t_2 + t_0}{t_1 + t_0}}$$

if R_1 & t_1 are known (Resistance at a particular temperature) is known then Resistance at t_2 can be ~~cal~~ calculated using the above formula

let R_0 be the Resistance at zero (0°C) and the conductor is heated to a temperature at t

$$0°C \longrightarrow R_0$$

$$t°C \longrightarrow R_t$$

$$\frac{R_t}{R_0} = \frac{t + t_0}{t_0 + 0} = \frac{t}{t_0} + 1$$

Page No.
Date

$$R_t = R_0 + \frac{t}{t_0} R_0$$

$$R_t - R_0 = \frac{t}{t_0} R_0$$

$$\boxed{\Delta R = \alpha R_0 t}$$ ← temperature

change in Resistance — temperature coefficient — Resistance at 0°C

Q) A coil of relay is made up of copper wire. At 20°C the resistance is 400 ohm; calculate the resistance of a coil at 80°C. The α of copper is $\boxed{0.0038}$ at 0°C. learn

Sol) 20°C → 400 ohm
80°C → ?
$\alpha_0 = 0.0038$

$$\boxed{\alpha_{20} = \frac{1}{\frac{1}{\alpha_0} + t}} = \frac{1}{\frac{1}{0.0038} + 20} = 0.003533$$

$$R_{80°C} = R_{20}\left[1 + \alpha_{20}(t_2 - t_1)\right]$$

$$R_{80°C} = 400\left[1 + 0.003533\,(80 - 20)\right]$$

$$= 484.8\,\Omega$$

System

Electrical component when connected in a particular manner to perform a particular task is called a system.

In electrical term a **system** is called **circuit**.

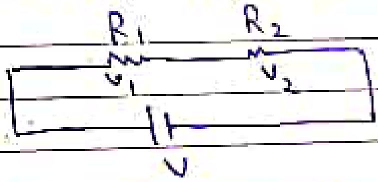
The different circuit are connected in the following 3 manner.

a) Series Connection

b) Parallel Connection

c) Series + Parallel Connection

a) Series Connection (Current Same)



$$R_{eff} = R_1 + R_2$$

$$V = IR$$

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

$$V = V_1 + V_2$$

$$\text{Power} = I^2 R = \frac{V^2}{R} = VI$$

$$\text{Power}_{battery} = VI$$

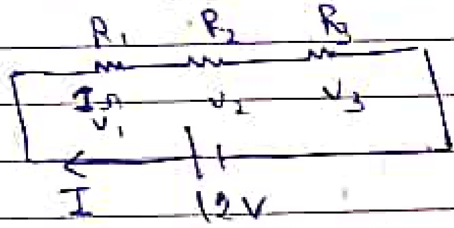
$$\text{Power}_{R_1} = I^2 R_1 \qquad \text{Power}_{R_2} = I^2 R_2$$

$$P_{battery} = P_{R_1} + P_{R_2}$$

a) The same current flow through all part of the circuit.
b) The applied voltage is equal to the ~~app~~ sum of ~~diff~~ voltage drops across different parts of the circuit.
c) Voltage drop & Power are additive
d) Resistance is additive.

Q) 3 Resistance are connected in series ~~in~~ through a 12 V battery. The value $R_1 = 1\,\Omega$ the voltage drop across the 2nd Resistance is 4 V
The power dissipated in the 3rd Resistance is 12 watts.
Find the value of R_1 R_2 R_3

Sol) Voltage drop $R_2 = 4V = V_2$



$R_{eff} = R_1 + R_2 + R_3$

$V = 12V$

$$I = \frac{12}{R_1 + R_2 + R_3}$$

$$\boxed{I = \frac{12}{1 + R_2 + R_3}}$$

$$\boxed{V_1 + V_2 + V_3 = 12}$$

$$\boxed{V_1 + V_3 = 8}$$

Power dissipated

$P = VI$

$12 = V_3 I$

$$\boxed{V_3 = \frac{12}{I}}$$

Now

$$\boxed{P = VI = I^2R = \frac{V^2}{R}}$$

Page No.
Date

$V_1 + V_3 = 8$

$\frac{I}{1} + \frac{12}{I} = 8$

$I^2 + 12 = 8I$

$I^2 - 8I + 12 = 0$

$I^2 - 6I - 2I + 12 = 0$

$I(I-6) - 2(I-6) = 0$

$$\boxed{I = 2,\ I = 6}$$

$I = 6$

$V_2 = IR_2$

$R_2 = \frac{4}{6}$

$\boxed{R_2 = \frac{2}{3}}$

$R_3 = \frac{P}{I^2} = \frac{12}{36} = \frac{1}{3}\ \Omega$

$\boxed{R_3 = \frac{1}{3}}$

$I = 2$

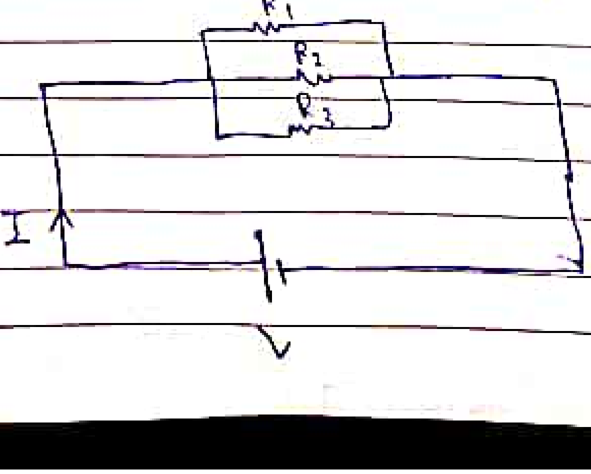
$4 = 2R_2$

$\boxed{R_2 = 2}$

$R_3 = \frac{12}{4} = 3\ \Omega$

$\boxed{R_3 = 3\ \Omega}$

b) Parallel connection (Potential same)



$$\boxed{\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$I_1 = \frac{V}{R_1} \qquad I_2 = \frac{V}{R_2} \qquad I_3 = \frac{V}{R_3}$$

$$I = I_1 + I_2 + I_3$$

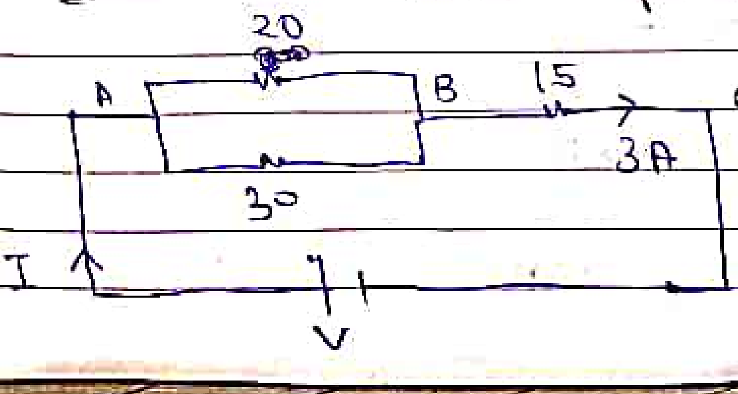
a) Same ~~vott~~ voltage appear all the branches of circuit
b) Each branch has its own individual current.
c) Branch current are additive

3) Series Parallel Circuit

Q) Two Resistances of 20 Ω & 30 Ω are placed at parallel to each other which is then placed in series with a 15 Ω resistor. The current through 15 Ω resistance is 3 Ampere. Find ~~The total~~ power consumed ~~to 20Ω & 30Ω resistor~~

1) The current through 20 Ω & 30 Ω resistor
2) The voltage across the hole circuit.
3) The total power consumed.

Sol)



$$R_{eff} = \frac{20 \times 30}{20+30} + 15$$

$$R_{eff} = \frac{20 \times 3\cancel{0}}{5\cancel{0}} + 15 = \frac{60}{5} + 15$$

$$\boxed{R_{eff} = 27\ \Omega}$$

$V = IR$

$V = 3 \times 27$

$\boxed{V = 81\ V}$ across the circuit

Power $= VI = 3 \times 81 = 243\ W$

$\boxed{\text{Power} = 243\ W}$

i) $V = IR$

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

$\cancel{I_{20} = \frac{81}{20}}$ $\quad$ $\cancel{I_{30} = \frac{81}{30}}$

$V_{AB} + V_{BC} = V$

$V_{AB} + 15 \times 3 = 81$

$\boxed{V_{AB} = 36\ V}$

$I_1 = \frac{36}{20} = 1.8A$

$I_2 = \frac{36}{30} = 1.2A$

Page No.
Date

Circuit Analysis and Energy Source

Energy source is a device that convert chemical, Mechanical, thermal or some oth other form of energy into electrical energy.

Energy convertor also known as load convert electrical energy into other form of energy (such as lamp heating element, electric Motor etc.)

While transmission from generator to load if the aptitude | Magnitude of voltage or current remains constant these are known as DC ~~Dis~~ (Direct current) circuit. If the voltage of current magnitude changes with time. they are known as alternating current circuit AC Ca circuit.

- The element which supply energy to network are known as active ~~source~~. element.
Example :- Battery, Solar cell, Wind Turbine

The component which desipiate or store energy are known as passive elements ex→ Resistor, capacitor, inductor.

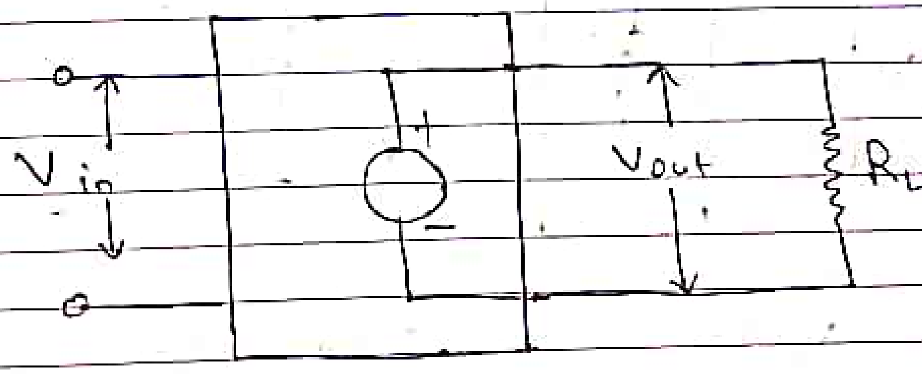
Parameter	Basic Relationship	VI characteristic	
R	$V = iR$	$V_R = Ri_R$	$i_R = \frac{V_R}{R}$
L	$\Psi = Li$	$V_L = L\frac{di_L}{dt}$	$i_L = \frac{1}{L}\int_{-\infty}^{t} V_L\, dt$

Page No.	
Date	

C $q = CV$ $v_c = \frac{1}{C}\int_{-\infty}^{t} i_c\, dt$ $i_c = C\frac{dv_c}{dt}$

These are board categories of source
(1) dependent source
(2) Independent source

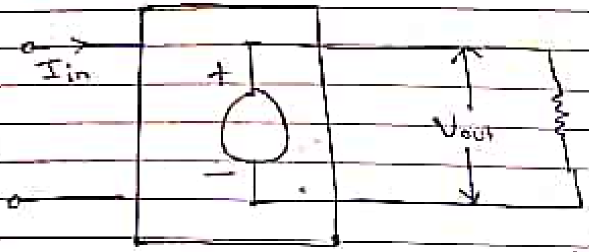
Dependent Source are the one which depend on ~~other~~ some Source quantity in the circuit which can either ~~w~~ be voltage or ~~cure~~ current
The relationship may be linear or Non ~~b~~ linear.
The are four board category ~~source~~ of dependent sources
i) ~~vo.~~ voltage dependent voltage source.



VDVS $V_{out} = K_1 V_{in}$

K_1 = constant

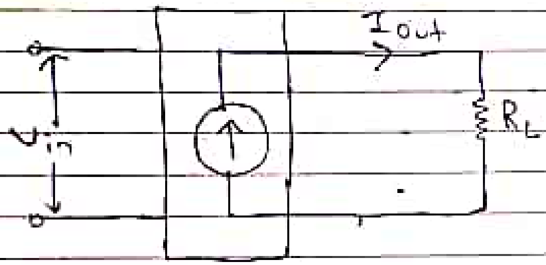
When the strength of voltage or current in the Source for any change in the connected Network



$V_{out} = K_2 I_{in}$

$K_2 \rightarrow$ ohms

<u>CDVS</u> like $V = RI$

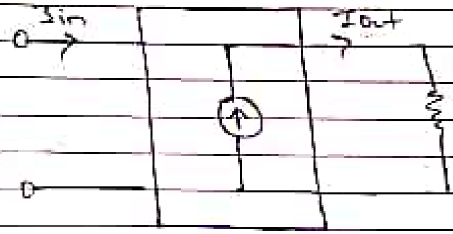


<u>VDCS</u> , $I_{out} = K_3 V_{in}$

K_3 in mho (Reversed Ohm)

$V = IR$

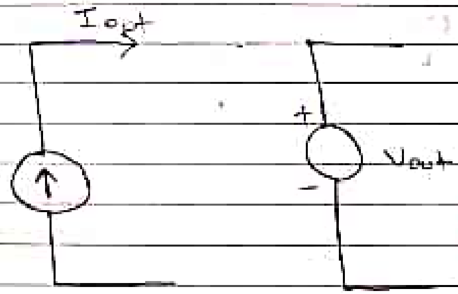
$I = \frac{V}{R}$



$I_{out} = K_4 I_{in}$ $K_4 =$ Constant

<u>CDCS</u>

Independent Source



The strength of voltage or current is not changed by any variation in the connected network

A Source is said to be independent if its value remain constant and is independent of any other ~~cont~~ quantity in the circuit

<u>Ideal and practical Sources</u>

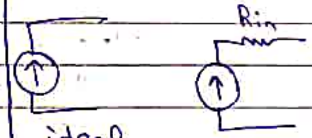
Elements that provide constant current and constant voltage with 0 ~~inter~~ internal resistance are called <u>Ideal Sources</u>

Practical Sources experienced a current or voltage drop because of internal resistance offered by them.

Note ideal & practical sources are dependent or independent both are possible

The current & voltage are coming from the ~~current~~ chemical reaction / energy, Mechanical, Thermal ~~[illegible]~~ process

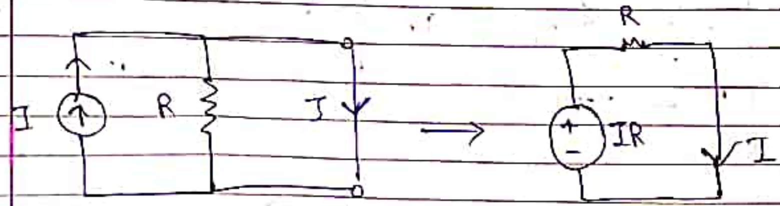
Example Phone charges convert 220 A to 5 A so it is convert with the help of K



ideal

At 0°C & −273 K it become resistance free & behaves like ideal

Source transformation



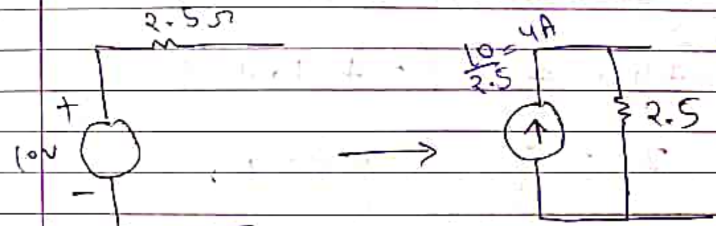
$\frac{V}{R}$

$\frac{IR}{R}$

I

CS →

Current Source convert into voltage Source

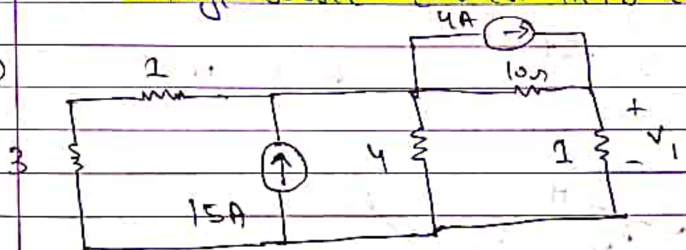


$\frac{10}{2.5} = 4A$

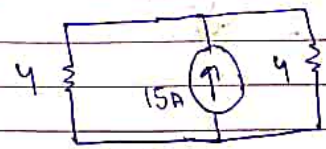
VS → CS

voltage Source convert into Current Source

Q)



Sol) No resistance means Short circuit

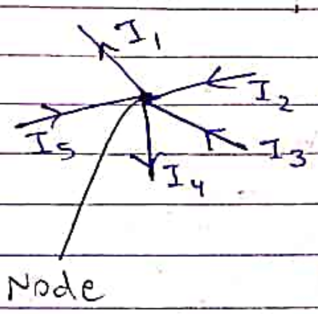


$R_{eq} = \frac{4 \times 4}{4+4} = 2\Omega$

KCL

$$\Sigma I = 0$$

$$\begin{pmatrix}\text{Sum of all} \\ \text{incoming current}\end{pmatrix} = \begin{pmatrix}\text{Sum of all} \\ \text{outgoing current}\end{pmatrix}$$



KVL In a closed Loop

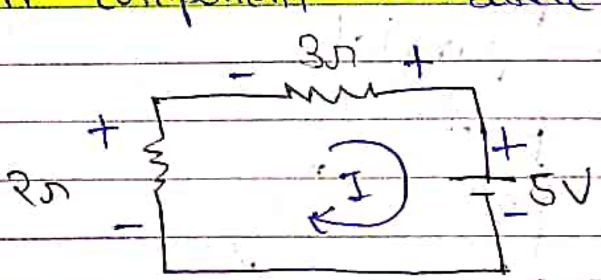
$$\Sigma V + \Sigma E = 0$$

According to Ohm's law $V = IR$

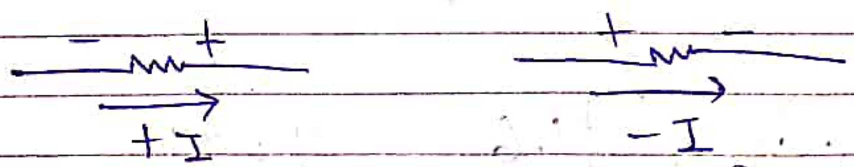
$$\boxed{\Sigma IR + \Sigma E = 0}$$

(1) Always consider clockwise current

(3) Same component → Different Terminal
Diff component → Same Terminal



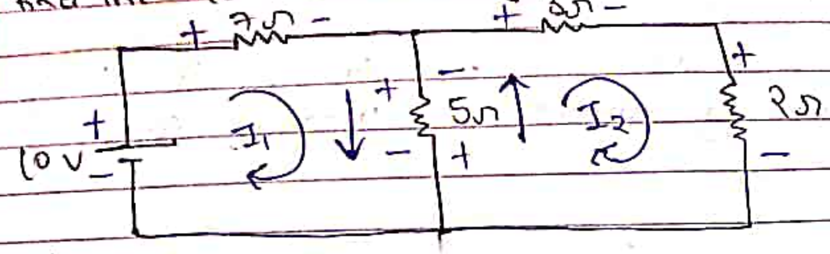
(4)



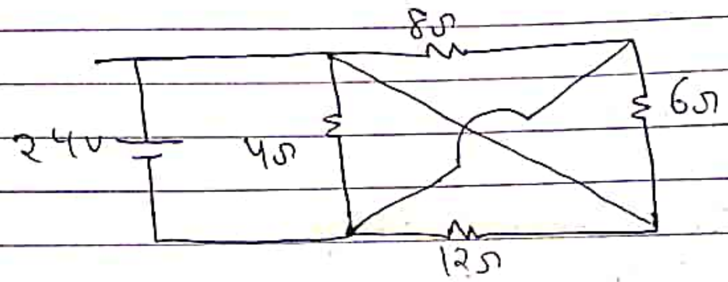
(5) अगर बहुत सारे voltage हो (battery) तो एक पकड़े बाकि को भूल जाए और sign convention दें

(6) एक wire में दो current जाते तो वह (+,−) sign ले जो loop आप ने consider करा है।

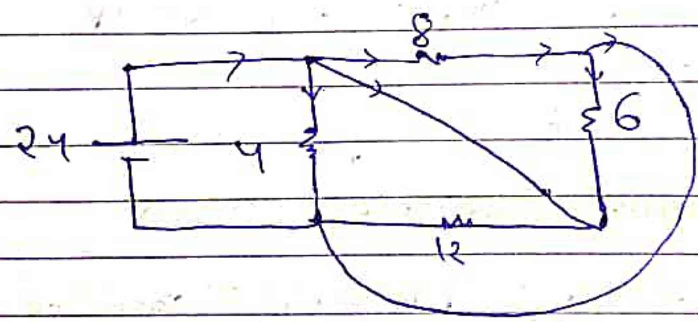
Q) Find the current through each loop



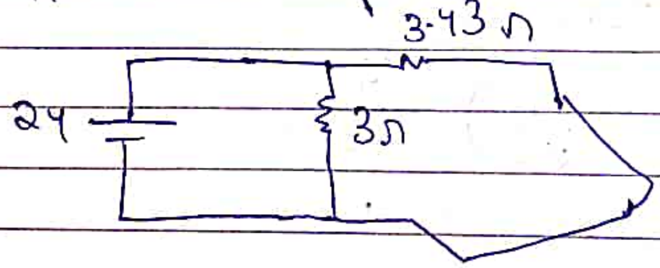
Q) Calculate battery current and effective resistance of the circuit



Sol)

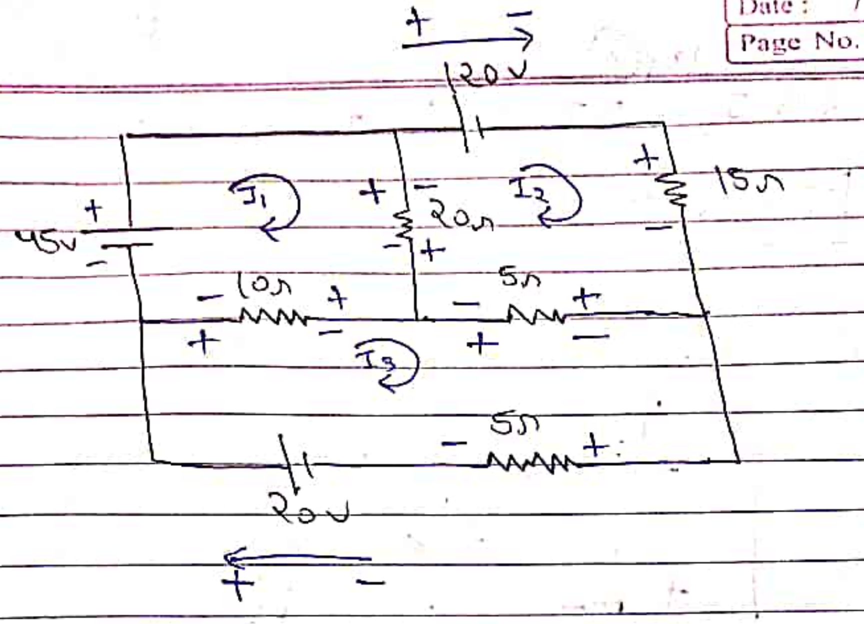


8, 6 are in parallel
4, 12 are in parallel



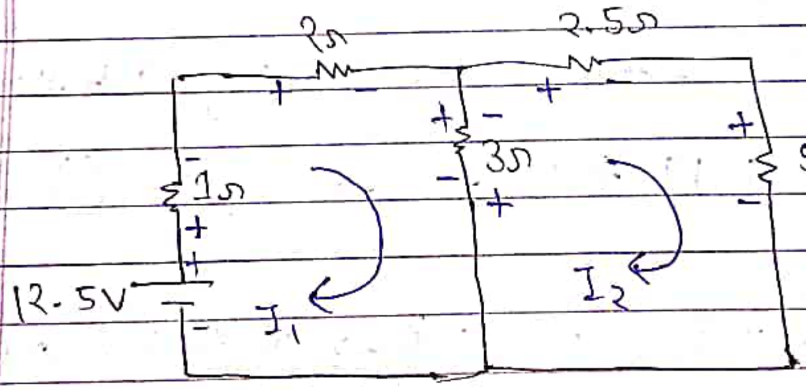
$I = \frac{24}{1.6}$

$\boxed{I = 15}$



Mesh analysis (KCL & KVL application)

Q) With the help of Mesh current Method find the current through 1Ω resistor & its direction



Sol) Step 1) Marking the different nodes & current with direction.

Apply KVL to Mesh loop (1)

$$12.5 - I_1 - 2I_1 - 3I_1 + 3I_2 = 0$$

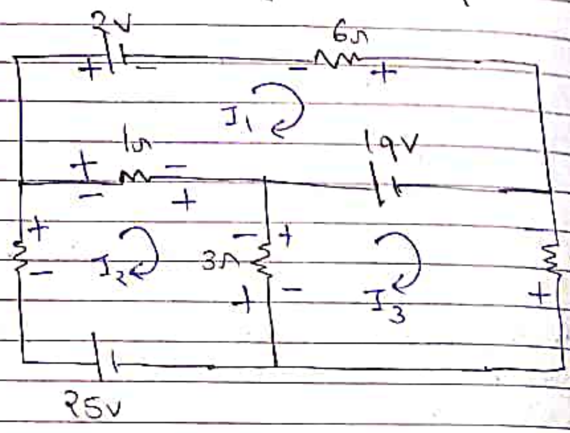
Date: / /
Page No.

loop (2)

$$-2.5I_2 - 5I_2 - 3I_2 + 3I_1 = 0$$

$$\boxed{I_1 = 2.43\,A}$$

Q) Find current through all loops



Sol) ignore वाली battery after taking 2 battery

loop (1)

$$-2 + 6I_1 + 19 + I_1 - I_2 = 0 \quad — (1)$$

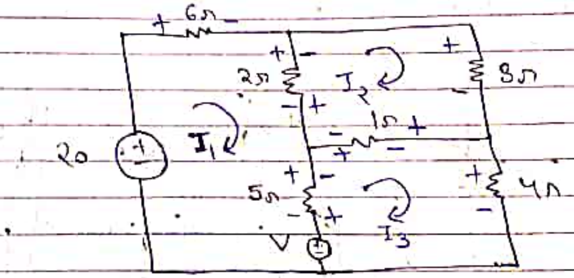
loop (2)

$$2I_2 + I_2 + 3I_2 - I_1 - 3I_3 + 25 = 0 \quad — (2)$$

loop (3)

Date: / /
Page No.

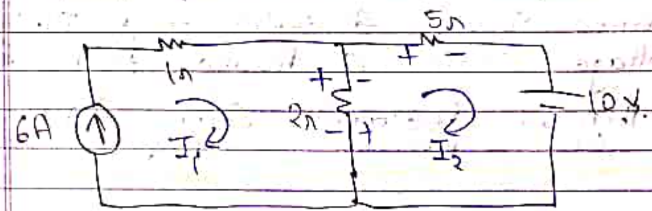
Q) By Mesh analysis find an unknown Emf V in the network which causes the Mesh current I_1 to be zero



Sol) loop I_1

$$20 - 6I_1 - 2I_1 - 5I_1 - V + 5I_3 + 2I_2 = 0$$

Q) By Mesh analysis find the current 2Ω resistor in circuit



Sol) $\boxed{I_1 = 6 \text{ given}}$

loop (2)

$$-2I_2 + 2I_1 - 5I_2 - 10 = 0$$

$$I_2 = 0.285\,A$$

Current through 2Ω resistor

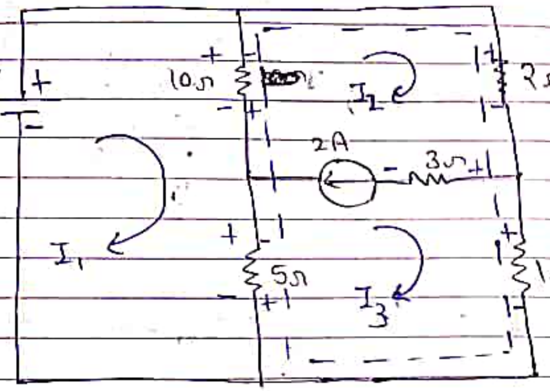
$$I_1 - I_2 = 6 - 0.285$$

$$= 5.71\,A$$

Date: / /
Page No.

Super Mesh

① Find the current through 5Ω resistor in the circuit.



Sol)

{Current Source के series में R आता है}
{Voltage Source के Parallel में R आता है}

they are ~~Redundant~~ Redundant इनको हटाओ R को

3Ω resistor become Redundant

Now $I_2 + 2 = I_3$ ✗

~~I_2~~ $I_2 - I_3 =$

$$\boxed{I_2 - I_3 = 2}$$

loop ①

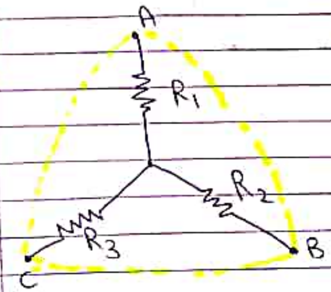
$$50 - 10I_1 - 5I_1 + 10I_2 + 5I_3 = 0$$

Date: / /
Page No.

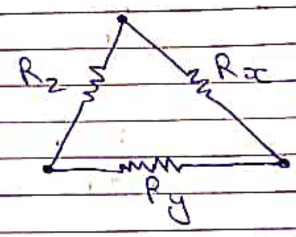
apply KVL to Super mesh

$$-2I_2 - I_3 - 5I_3 + 5I_1 - 10I_2 + 10I_1 = 0$$

Star Delta Transfor



Star



Delta

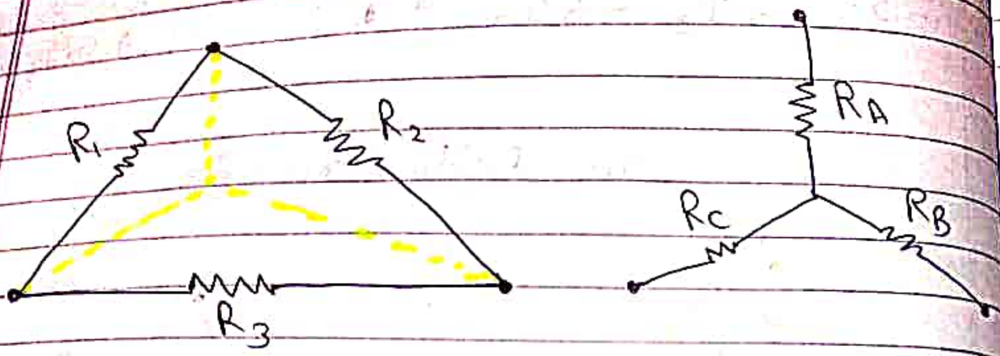
$$R_x = \frac{R_1R_2 + R_2R_3 + R_1R_3}{R_3}$$

$$R_y = \frac{R_1R_2 + R_2R_3 + R_1R_3}{R_1}$$

$$R_z = \frac{R_1R_2 + R_2R_3 + R_1R_3}{R_2}$$

Date : / /
Page No.:

Delta to Star



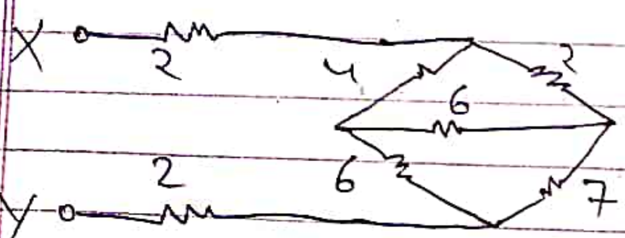
Sol)

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

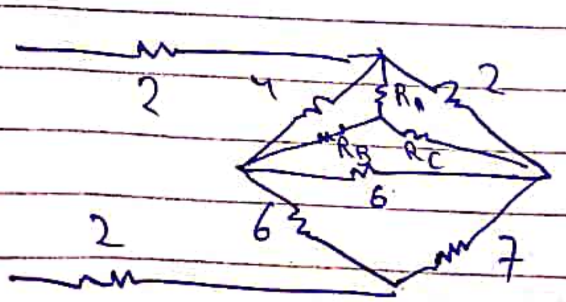
$$R_B = \frac{R_2 \times R_3}{R_1 + R_2 + R_3}$$

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

Q) Find the equivalent Resistance b/w the terminals X and Y in the network.



Sol)



$R_A = \frac{8}{12} = 0.6$

$R_B = \frac{24}{12} = 2$

$R_C = \frac{12}{12} = 1$

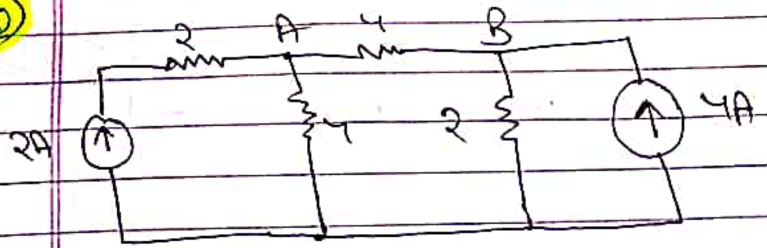
Current come at Node taken current +ve
current going out from Node taken -ve

Date : / /
Page No.

Nodal Analysis (only KCL use)

$V = IR$ $\quad I = \frac{V}{R} = \frac{V_2 - V_1}{R}$

Q)



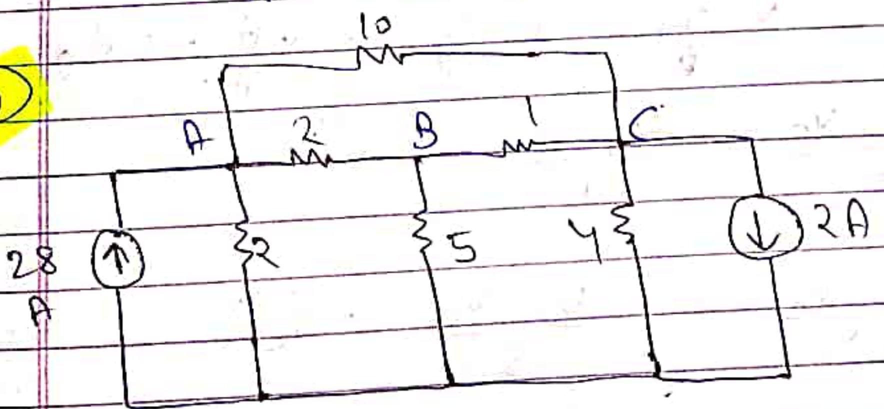
Sol) KCL at node A

$$2 = \frac{V_A}{4} + \frac{V_A - V_B}{4} \quad — ①$$

KCL at node B

$$4 = \frac{V_B}{2} + \frac{V_B - V_A}{4} \quad — ②$$

Q)



Sol) three Node A, B, C

at A

$$28 = \frac{V_A}{2} + \frac{V_A - V_B}{2} + \frac{V_A - V_C}{10} \quad — ①$$

Date : / /
Page No.

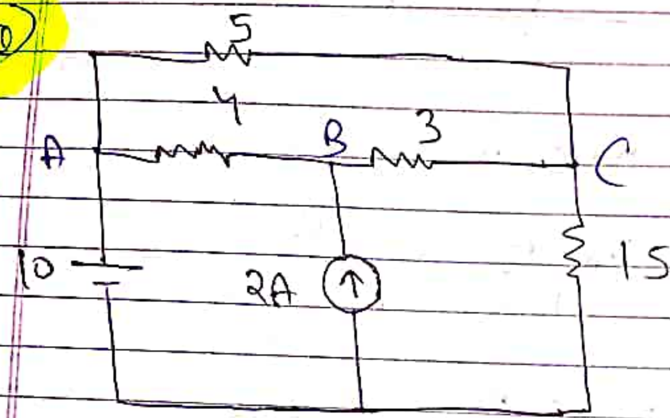
At C

$$-2 = \frac{V_C - V_A}{10} + \frac{V_C - V_B}{1} + \frac{V_C}{4} \quad \text{---} (2)$$

At B

$$0 = \frac{V_B - V_A}{2} + \frac{V_B}{5} + \frac{V_B - V_C}{1} \quad \text{---} (3)$$

Q)



Sol) A, B, C are Nodes

at A $\quad V = IR \quad I = \frac{V}{R}$ at volt Not R give it is not taken

$$0 = \frac{V_A - V_C}{5} + \frac{V_A - V_B}{4} \quad \text{---} (1)$$

at B

$$2 = \frac{V_B - V_A}{4} + \frac{V_B - V_C}{3} \quad \text{---} (2)$$

at C

$$0 = \frac{V_C - V_B}{3} + \frac{V_C}{15} + \frac{V_C - V_A}{5}$$

Date : / /
Page No.

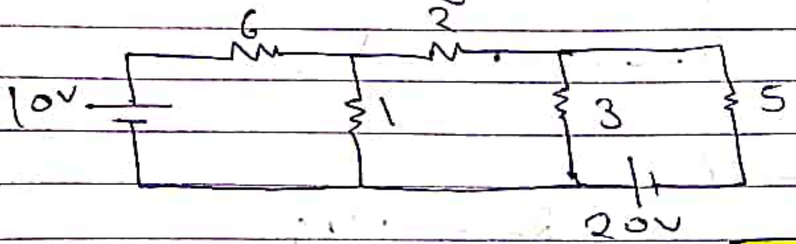
Thevenin's theorem

$V = IR$

Thevenin circuit = $I_L = \dfrac{V_{Th}}{R_{Th} + R_L}$

load current

Q) Determine the current through $\boxed{5\Omega \text{ resistor}}$ in the network by Thevenin's Theorem.



Sol)

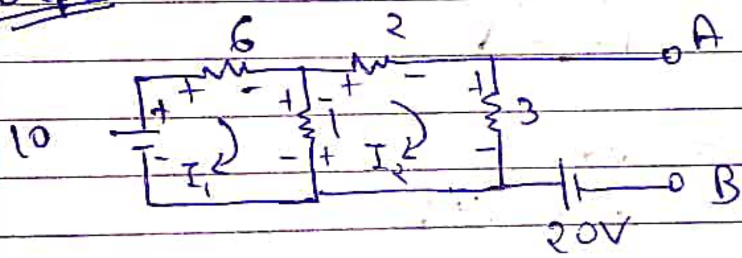
for V_{TH} finding R_L को open करो

Here $R_L = 5$

① calculation of V_{Th}

Step1

~~Short the load Resistance~~



loop ①

$$10 - 6I_1 - 1(I_1 - I_2) = 0 \quad - ①$$

loop②

$$-1(I_1 - I_2) + 2I_2 - 3I_2 = 0 \quad - ②$$

$$\boxed{I_2 = 0.244 \text{ A}}$$ download

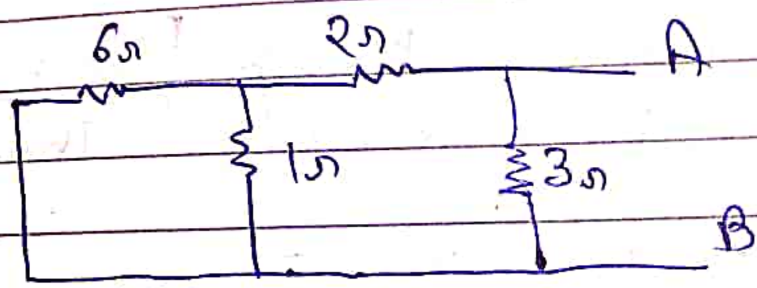
Now $I_{3\Omega} = 0.244$ A

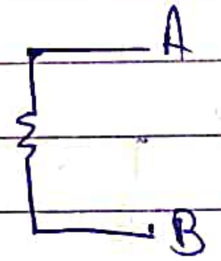
$$V_{TH} = V_{AB}$$
$$= 20 + 3I_2$$
$$\boxed{V_{TH} = 20.732 \text{ V}}$$

Date : / /
Page No.

(2) Calculation for R_{Th}

$$\boxed{\begin{array}{l}\text{Voltage} \rightarrow \text{Short Circuit} \\ \text{Current} \rightarrow \text{Open Circuit}\end{array}}$$





$R_{Th} = 1.46$

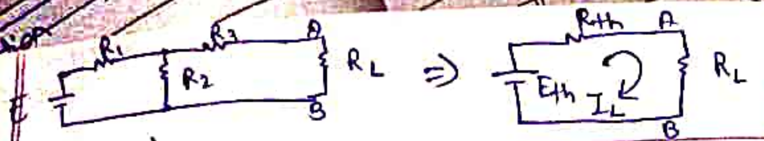
(3)

$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

$$= \frac{20.732}{5 + 1.46}$$

$= 3.21\,\Omega$ downward

Q) Determine the current through 1.5Ω resistor in network by

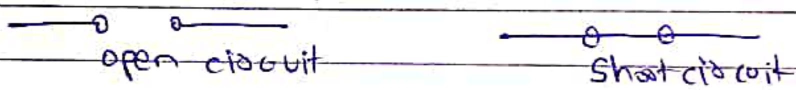


Thevenin Statement A linear network consisting of a no. of voltage sources & resistances can be replaced by an equivalent network having a single voltage source called Thevenin voltage (V_{Th}) & a single resistance called Thevenin's resistance (R_{th}) & load Resistance (R_L).

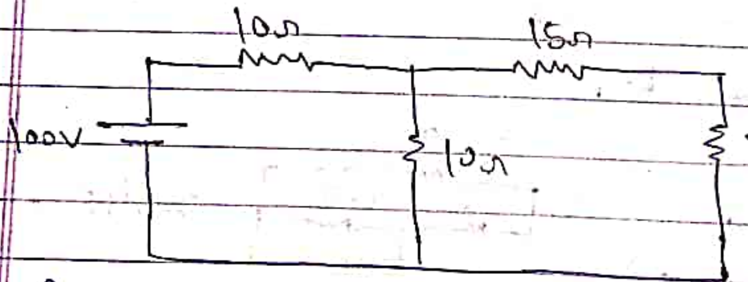
Norton's theorem

$$\boxed{I_L = \frac{I_N R_N}{R_N + R_L}} \qquad \boxed{R_N = R_{Th}}$$

Concept for $I_N \Rightarrow R_L$ Short circuit

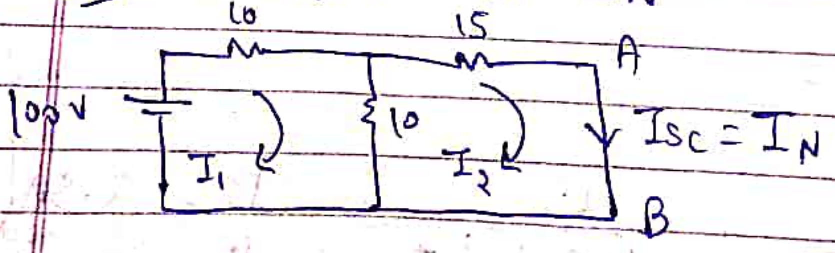


Q) By Norton's theorem find current in 20Ω in the Network



Sol) $R_L = 20\Omega$

Step 1 Calculation of I_N



Date : / /
Page No.

Apply KVL in Mesh 1

$100 - 10I_1 - 10(I_1 - I_2) = 0$ — (1)

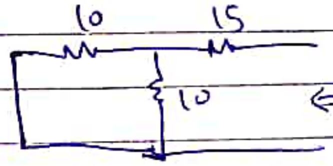
KVL in 2

$-10(I_2 - I_1) - 15 I_2 = 0$ — (2)

$\boxed{I_2 = 2.5A}$

$\boxed{I_N = I_{SC} = I_2 = 2.5A}$

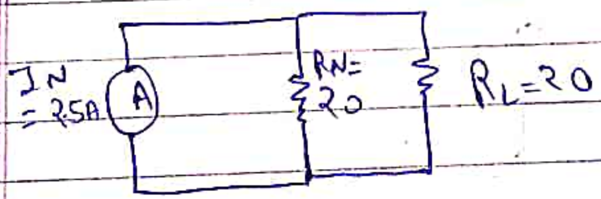
Step2 Calculation of R_N



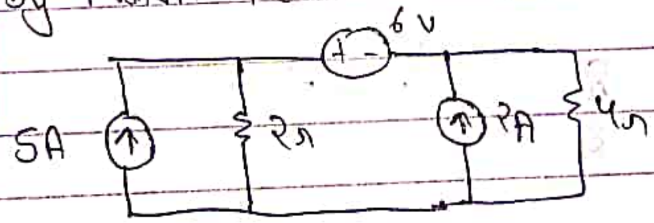
$R_{Th} = 20\Omega$

Step3 $I_L = \dfrac{I_N R_N}{R_N + R_L}$

$I_L = \dfrac{2.5 \times 20}{20 + 20} = 1.25A$



Q) By Norton theorem find current in 4Ω ~~de~~ network



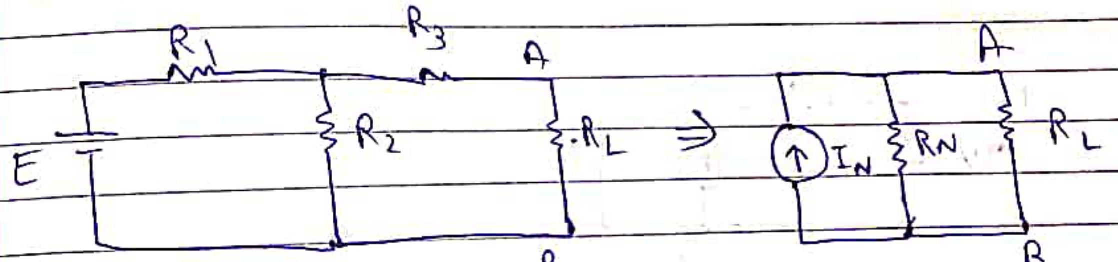
Date: / /
Page No.

Norton's theorem

Any linear, active, bilateral complicated Network across its load terminals can be replaced by single current Source & one parallel resistance.

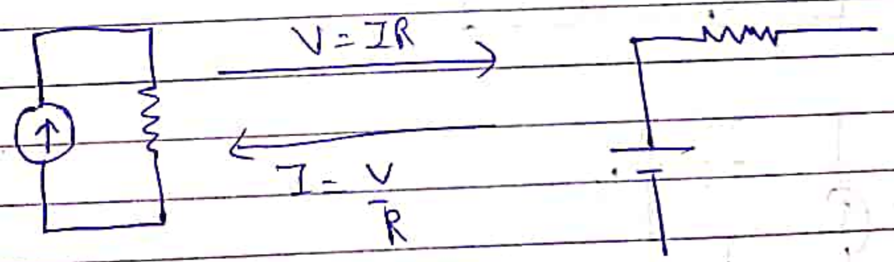
or

A linear network consisting of a no. of voltage Source & resistance can be replaced by an equivalent network having a single current source (I_N) & a single resistance (R_N).

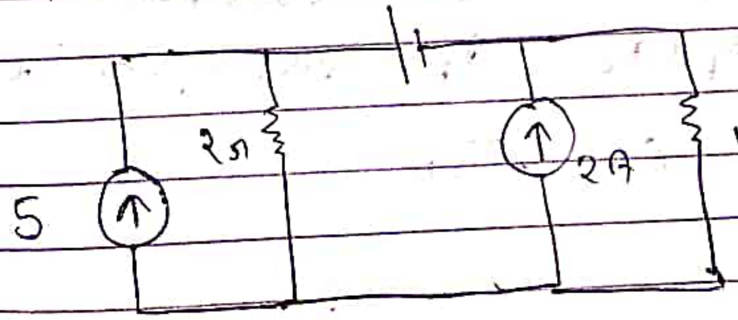


Norton's equivalent circuit

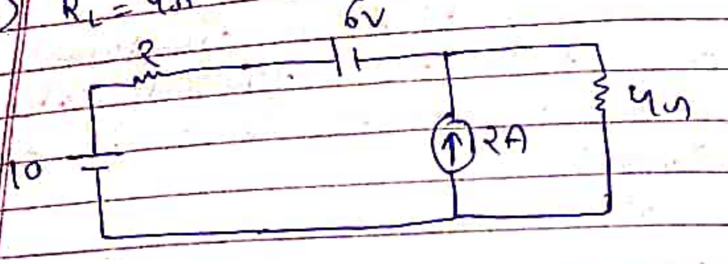
Source transformation

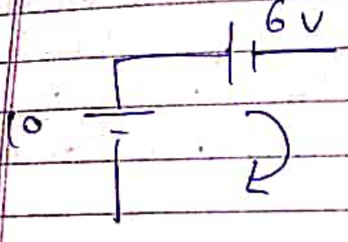


Q) By Source transformation find the current in 4Ω resistor

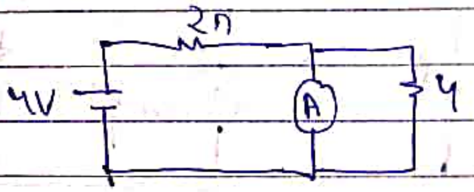


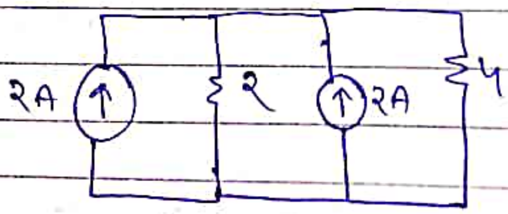
Sol) S1) $R_L = 4\Omega$

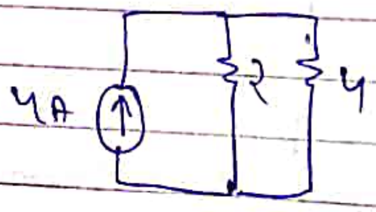




$, 10 - 6 = 4V$







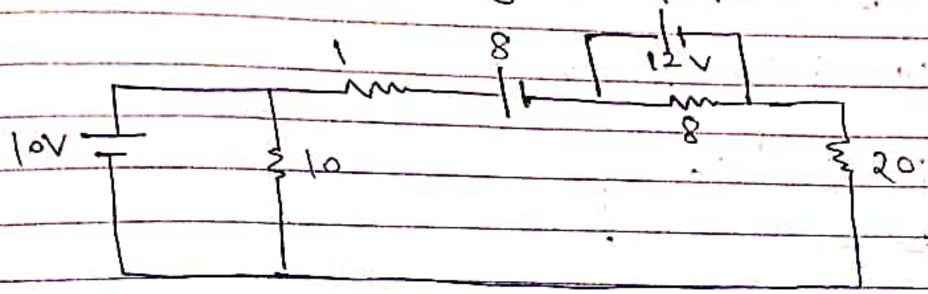
$I_L = R_L \times \frac{R_P}{R_P + R_L}$ R_L = Load Resist
R_P = Resist parallel to load

$I_L = 4 \times \frac{2}{2+4} = \frac{8}{6} = 1.33A$

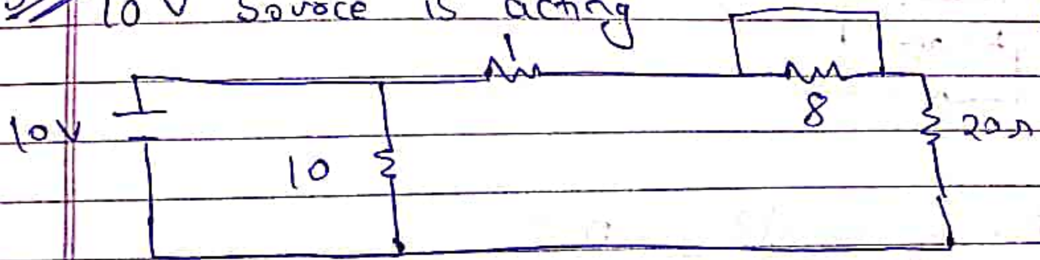
Date : / /
Page No.

Superposition Theorem

1) Determine the current in 20 Ω resistor in the network by superposition Theorem.



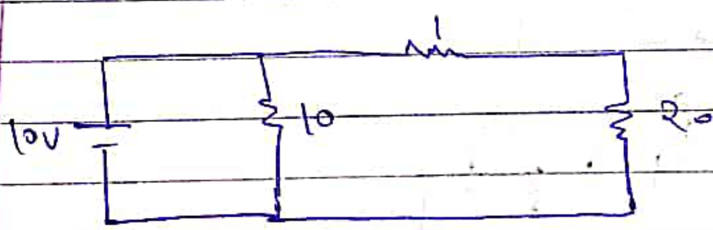
Sol) Step 1) 10 V Source is acting

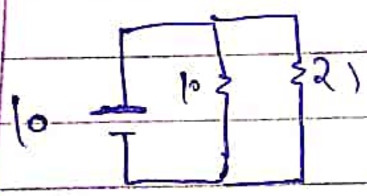


WC

अगर resistence के साथ दूसरी branch में short circuit है तो वो Resistance को हटा देना चाहिए

8 Ω resistor becomes redundant

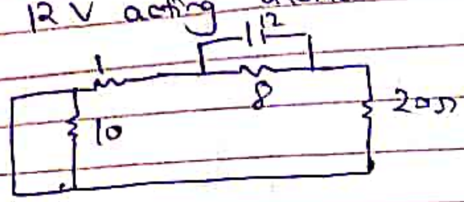




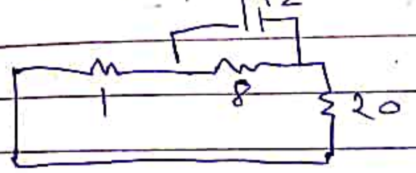
$I_{10\Omega} = \frac{10}{21} = 0.476\,A$

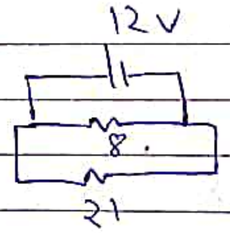
$I_{10\Omega} = -0.476$

<u>Step 2</u> 12 V acting alone



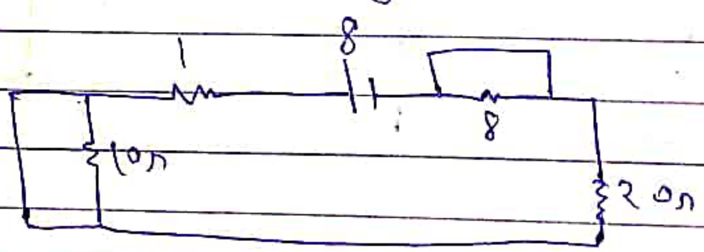
10Ω becomes redundant



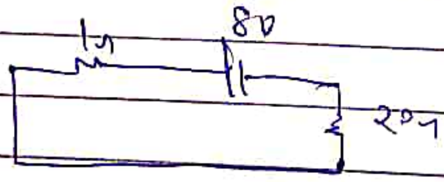


$$I = \frac{V}{R} = \frac{12}{21} = 0.5$$

<u>Step 3</u> 8V is acting alone



10 & 8 are redundant



$$I = \frac{V}{R} = \frac{8}{20+1} = 0.381\ A$$

$$I_{Total} = I_1 + I_2 + I_3$$

$$= -0.476 + 0.571 + 0.381$$

$$= 0.476 \text{ A}$$

Statement

If no of voltage sources or current Source acting in a linear network then the resulting current in any branch is the algebraic sum of all the current that would be produced in it when each source act alone ~~when~~ while all the other independent source are replaced by their internal resistances.

Maximum Power Transfer theorem

$$\text{Power} = VI = I^2R = \frac{V^2}{R}$$

$$\boxed{P_{max} = \frac{V_{Th}^2}{4R_{Th}}}$$

Step 1 calculation of R_{Th}

① voltage ⟶ Short circuit
Current ⟶ open circuit

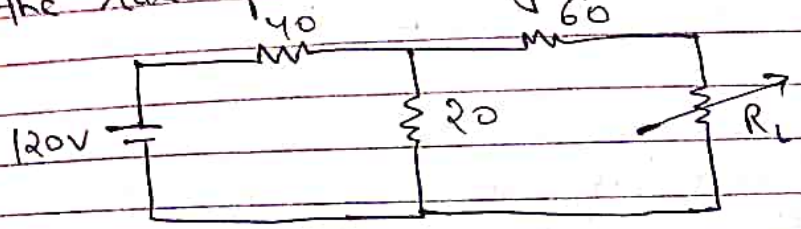
② R_L → open

Step 2 Calculation of V_{Th}

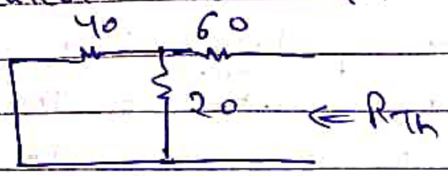
① R_L → open

② KVL | KCL | ohm's

Q) Calculate the value of R_L for it to be absorbed the Max power and find the Max power through it.

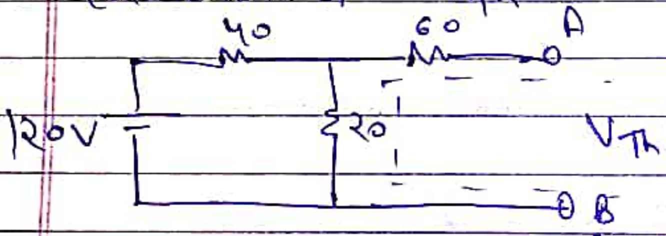


Sol) Calculation of R_{Th}



$\boxed{R_{Th} = 73.33\,\Omega}$

Calculation of V_{Th}



यहा पर 60Ω हटा दो क्योंकि open में है 60 पर current नहीं जायेगा

$I = \frac{V}{R} = \cancel{2A}\ \frac{120}{60} = 2A$

$V_{Th} = V_{AB}$

$= 2 \times 20 = 40V = \boxed{V_{Th} = 40V}$

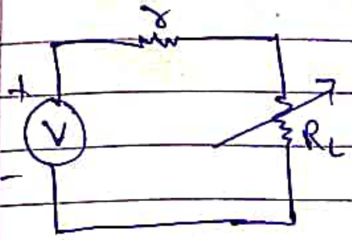
$P_{Max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{40 \times 40}{4 \times 73.33} = 5.45\,\omega$

$\boxed{P_{Max} = 5.45\,\omega}$

Date : / /
Page No.

statement (Max power transfer theorem)

It states that the DC voltage source will deliver Maximum power to the variable load resistance only when the load resistance is equal to the source resistance.



$\boxed{r = R_L}$

V = DC voltage Source

R_L = variable load Resistance

r = internal resistance of DC voltage source

I_L be the current flowing through Load Resistance R_L

$$I_L = \frac{V}{r + R_L} \quad \text{(ohm law)} \quad -(1)$$

Power transfered to the load resistance (R_L) is

(2)

$$P_L = I_L^2 R_L$$

$$P_L = \left(\frac{V}{r+R_L}\right)^2 R_L = \frac{V^2 R_L}{(r+R_L)^2} \quad -(2)$$

for P_L to be Maximum $\frac{dP_L}{dR_L} = 0$

$$\Rightarrow 0 = V^2 \left[\frac{(r+R_L)^2 \cdot 1 - R_L \cdot 2(r+R_L) \cdot 1}{(r+R_L)^4}\right]$$

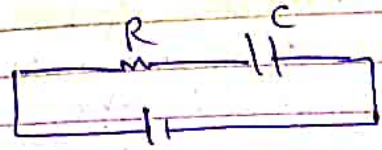
$$\boxed{r = R_L}$$ ~~Proved~~

$$P_L = \frac{V^2 R_L}{(r+R_L)^2}$$

$$(P_L)_{Max} = \frac{V^2 r}{(r+r)^2} = \frac{V^2 r}{4r^2} = \frac{V^2}{4r}$$ Proved

Time Domain Analysis of 1st order RC circuit (charging of capacitor)

RC circuit



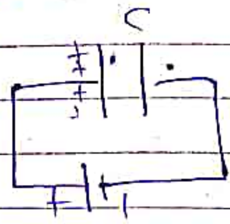
1st order circuit → ऐसा circuit जिसमें अन्दर एक ही energy को store करने वाला device रखा गया है

$t=0$ $q=0$

$Q=CV$

$\boxed{V=0}$

Now

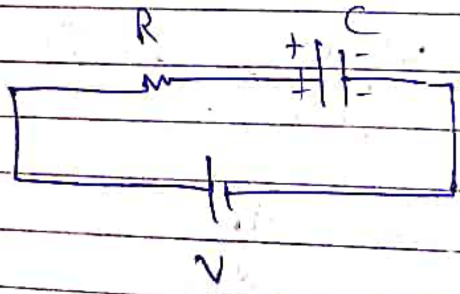


$t=t$ $q=q$

$Q=CV$

$V=\frac{Q}{C}=\boxed{\frac{q}{C}=V}$

with respect to time the study of charge, current, voltage is known as Time Domain analysis.



$\Delta V = iR$

$i = \frac{\Delta V}{R}$

$i = \frac{V - \frac{q}{C}}{R}$

$i = \frac{CV - q}{RC}$

$\frac{dq}{dt} = \frac{CV - q}{RC}$

Date : / /
Page No.

$$\frac{dq}{CV-q} = \frac{dt}{RC}$$

$$\Rightarrow \int_0^q \frac{dq}{CV-q} = \int_0^t \frac{dt}{RC}$$

$$\Rightarrow \left[\frac{\ln(CV-q)}{-1}\right]_0^q = \frac{1}{RC}[t]_0^t$$

$$\ln(CV-q) - \ln(CV) = -\frac{t}{RC}$$

$$\ln\left(\frac{CV-q}{CV}\right) = -\frac{t}{RC}$$

$$1-\frac{q}{CV} = e^{-t/RC}$$

$$\frac{q}{CV} = 1-e^{-t/RC}$$

$$\boxed{q = q_0\left(1-e^{-t/RC}\right)}$$

q_0 — max charge

$$\boxed{q = q_0\left(1-e^{-t/\tau}\right)}$$

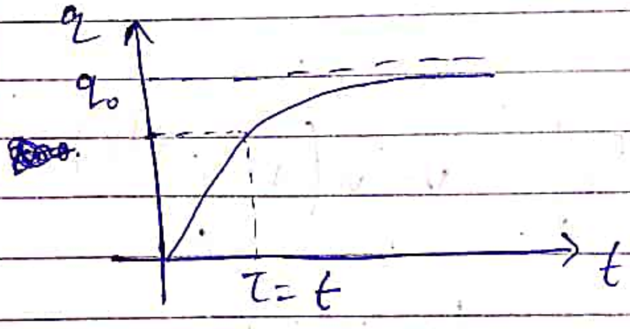
$t = \tau$

$$q = q_0\left[1-e^{-1}\right]$$

$$q = q_0(1-0.37)$$

$$q = 0.639\,q_0$$

$$\boxed{q = q_0\, 0.639}$$



Date : / /
Page No.

$i = \frac{dq}{dt}$

$i = \frac{d}{dt}\left[q_0\left(1 - e^{-t/RC}\right)\right]$

$i = \frac{q_0 e^{-t/RC}}{RC}$

$i = \frac{CV}{RC} e^{-t/RC}$ $\boxed{q = CV}$

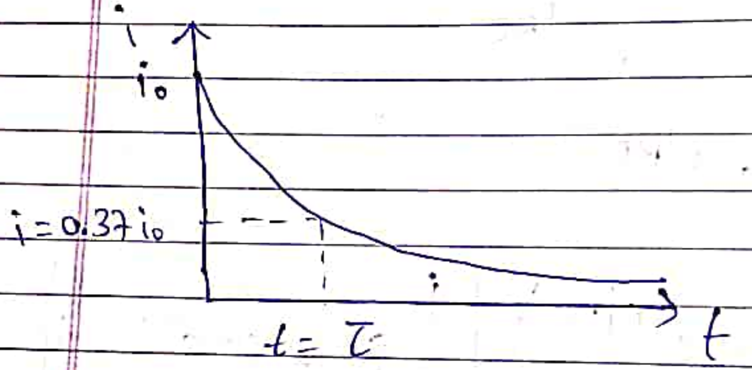
$i = \frac{V}{R} e^{-t/RC}$

$\boxed{i = i_0 e^{-t/RC}}$ $i = i_0 \cdot e^{-t/\tau}$

$t = \tau$

$i = i_0 e^{-1}$

$\boxed{i = 0.37 i_0}$



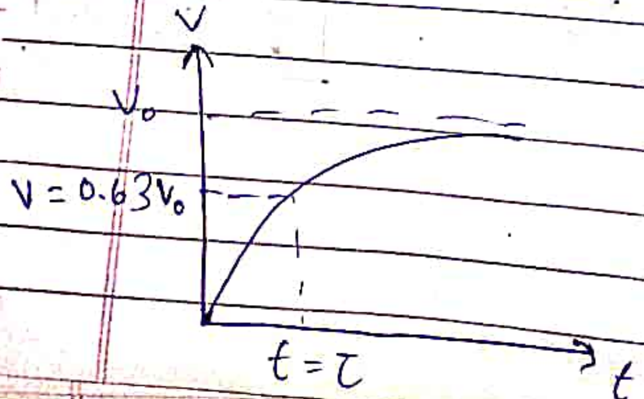
$V = \frac{q}{C}$

$V = \frac{q_0\left(1 - e^{-t/RC}\right)}{C}$

$\boxed{V = V_0\left(1 - e^{-t/RC}\right)}$ $V = V_0\left(1 - e^{-t/\tau}\right)$

$t = \tau$

$\boxed{V = V_0\, 0.63}$



Date : / /
Page No.

Discharging of Capacitor

$t=0 \quad q=0$
$t=t \quad q=q$
$t=\infty \quad q=q_{max}$

Here
$t=0 \quad q=q_{max}$
$t=t \quad q=q$
$t=\infty \quad q=0$

$V = iR$

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

$i = \frac{q/C}{R} = \frac{q}{RC}$

$-\frac{dq}{dt} = \frac{q}{RC}$

$-\int_{q_m}^{q=q} \frac{dq}{q} = \int_{t=0}^{t=t} \frac{1}{RC}\, dt$

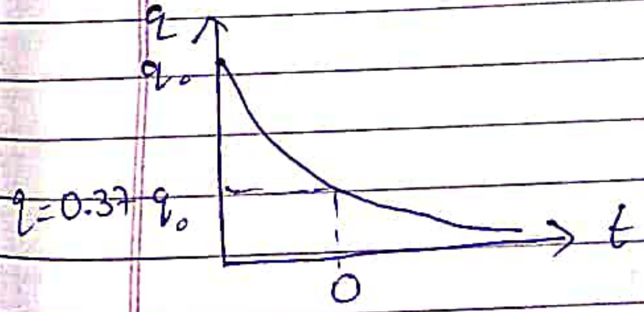
$\boxed{q = q_0 e^{-t/RC}}$

$q = q_0 e^{-t/\tau}$

$t = \tau$

$q = q_0 e^{-1}$

$\boxed{q = 0.37 q_0}$



$i = -\frac{dq}{dt}$

$e^{-1} = 0.37$

$i = -\frac{d}{dt}\left(q_0 e^{-t/RC}\right)$

$i = -q_0 e^{-t/RC} \times \frac{-1}{RC}$

$i = \frac{q_0}{RC} e^{-t/RC}$

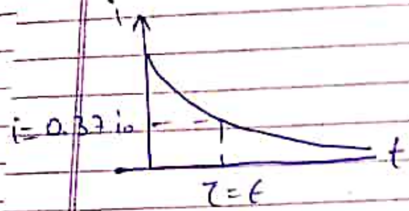
$\boxed{i = i_0 e^{-t/RC}}$

$i = i_0 e^{-t/\tau}$

$t = \tau$

$i = i_0 e^{-1}$

$\boxed{i = 0.37\, i_0}$



$v = iR$

$V = i_0 e^{-t/RC} \times R$

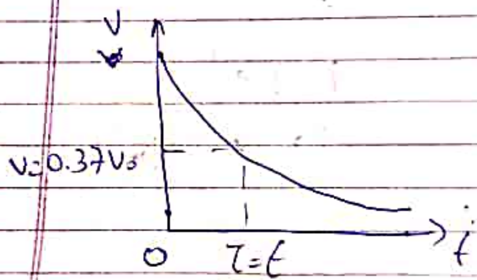
$V = \frac{V_0}{R} e^{-t/RC} \times R$

$\boxed{V = V_0 e^{-t/RC}}$

$V = V_0 e^{-t/\tau}$

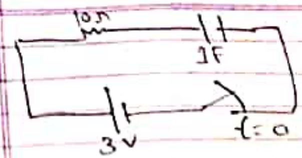
$t = \tau$

$V = 0.37\, V_0$



Nos Numericals: charging → Battery $\mathcal{E}$; discharging → No Battery

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

Q) 

at time t=0 switch is closed find the time in which capacitor is 10% charged

Sol) $q = q_0\left(1 - e^{-t/RC}\right)$

given $q = q_0 \times 10\% = \frac{q_0}{10}$

$\frac{q_0}{10} = q_0\left(1 - e^{-t/RC}\right)$

$\frac{1}{10} = 1 - e^{-t/RC}$

$e^{-t/RC} = 1 - \frac{1}{10} = \frac{9}{10}$

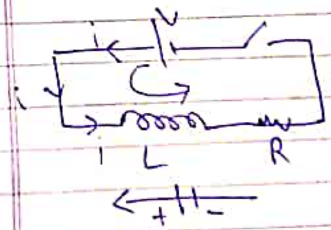
$\ln e^{-t/RC} = \ln \frac{9}{10}$

$-\frac{t}{RC} = \ln 9 - \ln 10$

$-\frac{t}{RC} = 2.303\left[\log_{10} 9 - \log_{10} 10\right]$

find t

Time domain analysis of 1st order LR circuit (growth of current in inductor)



inductor की change current passage होगा तो induced current आएगा so we ~~used~~ in the direction opposite to current.

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

$t=0 \quad i=0$
$t=t \quad i=i$

$+V - L\frac{di}{dt} - iR = 0$

$\int_0^t \frac{dt}{L} = \int_0^i \frac{di}{V-iR}$

$\frac{1}{L}\int_0^t 1\,dt = \left[\frac{\ln(V-iR)}{-R}\right]_0^i$

$i = \frac{V}{R}\left(1-e^{-\frac{R}{L}t}\right)$

$\boxed{i = i_m\left(1-e^{-\frac{R}{L}t}\right)}$

$i = i_m\left(1-e^{-\frac{1}{\tau}t}\right)$

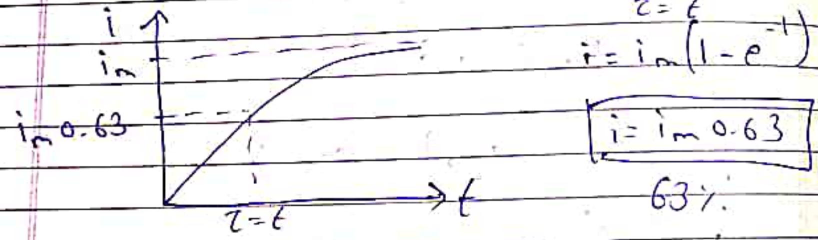
$\boxed{\frac{1}{\tau} = \frac{R}{L}}$

$\tau = t$

$i = i_m\left(1-e^{-1}\right)$

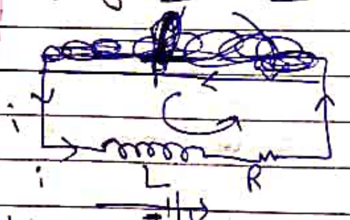
$\boxed{i = i_m\, 0.63}$

63%

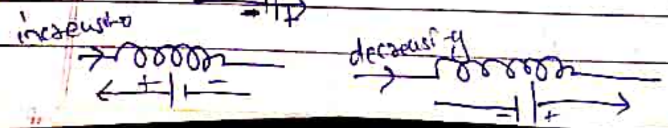


τ is a time when the current grows in inductor it's value is equal to 63% of its Max value

Decay of current



$t=0 \quad i=i_m$
$t=t \quad i=i$



$+L\frac{di}{dt} - iR = 0$ ✗

$-L\frac{di}{dt} - iR = 0$ current is decreasing

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

$-\frac{R}{L}dt = \frac{di}{i}$

$\Rightarrow \int_0^t -\frac{R}{L}dt = \int_{i_m}^i \frac{di}{i}$

$-\frac{R}{L}\int_0^t 1\,dt = [\ln i]_{i_m}^i$

$\boxed{i = i_m e^{-\frac{R}{L}t}}$

$\tau = \frac{L}{R}$

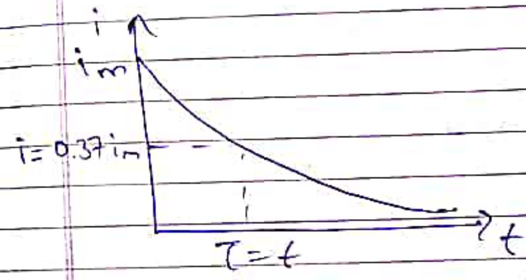
$\frac{R}{L} = \tau$

$i = i_m e^{-\frac{1}{\tau}t}$

$t = \tau$

$i = i_m e^{-1}$

$\boxed{i = 0.37\, i_m}$



Q) A coil having a resistance of 20Ω and inductance of 1H is connected to a constant supply voltage source of 100V find

i) Rate of change in current at the instant of closing the switch
ii) Final steady value of current
iii) Time constant
iv) Time taken for current to reach a value of 4A

Date : / /
Page No.

6d) $R = 20\Omega$
$L = 12 H$
$V = 100V$
charging case है because battery है

$i = i_m(1 - e^{-t/\tau})$

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

$\frac{di}{dt} = \frac{V}{L} = \frac{100}{12} = 8.33$ A/sec

ii) $V = iR$
$i_m = \frac{V_m}{R}$

$i_m = \frac{V}{R} = \frac{100}{20} = 5$ Ampere

iii) $\tau = \frac{L}{R}$

$\tau = \frac{12}{20} = 0.6$

iv)
$i_m = 5$
$i = 4$
$4 = 5(1 - e^{-t/\tau})$
$4 = 5(1 - e^{-t/0.6})$

An