Module 1

Elementary concepts & DC circuits.

Elementary concepts

Resistance (R):

- The opposition to the flow of current
- Measured in ohms (Ω).
- Symbol R
- Every materiel (metals, semiconders, insulators) has resistance.
- Resistance of metal is low while insulators have very high resistance.
- Metals - resistance small hence good conders of electricity.
- insulators - bad conders of electricity. e.g. plastic, wood, glass etc.

Mathematical expression for resistance -

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

ρ = resistivity of material & it is cont.
l = length of conder.
a = cross sectional area.

factors affecting the resistance value -

- R depends on ρ, l and a.
- Also depends on temperature.
  As temp. ↑, resistance ↑. because length of a conder will change which will change the value of R.

Resistivity or specific resistance (ρ) -

$$\rho = \frac{R \times a}{l}.$$

$$\rho = \frac{\Omega \times m^2}{m} = \Omega - m. \rightarrow \text{unit}$$

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Def^n of ρ -

Resistivity is defined as the resistance of the piece of material which is 1 meter long & of unit cross sectional area.

i.e. $\rho = R$ if $l = 1m$ & $a = 1m^2$

Best conductor has the lowest value of specific resistance.

- Conductance (G)

It is defined as the reciprocal of resistance.

$$G = \frac{1}{R}$$

$\therefore$ Unit of G is $\frac{1}{\Omega} = \Omega^{-1}$ or Siemens.

Conductivity (σ) -

- It is defined as reciprocal of the resistivity.

Its unit is $(\Omega m)^{-1}$ or siemens/meter.

e.g. - The resistivity of copper is 1.724 micro-ohm-cm. Find the resistance of a copper rod having dia. of 1mm & length of 1m.

$\rightarrow$

$$R = \rho \frac{l}{a}$$

$$= 1.724 \times 10^{-6} \times \frac{100}{\frac{\pi}{4}(0.1)^2}$$

$$= 0.02195 \Omega$$

Here resistivity is given in cm units.

e.g. - Find res. of follo. copper wires.

1) ~~cm~~ 1 mm^2 cross-section, 100 m long.

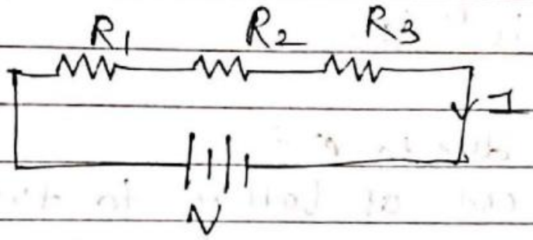
Given that $\rho = 1.73\ \mu\text{-}\Omega\text{-cm}$.

→ 1) $R = \rho \frac{l}{a} = 1.73 \times 10^{-6} \times \frac{100 \times 10^{2}}{1 \times 10^{-2}} = 1.73\ \Omega$

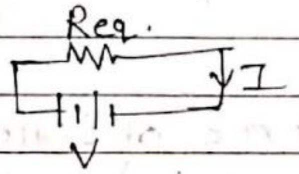
2) $R = 1.73 \times 10^{-6} \times \frac{200 \times 10^{2}}{25} = 0.001384\ \Omega$

– Resistance –

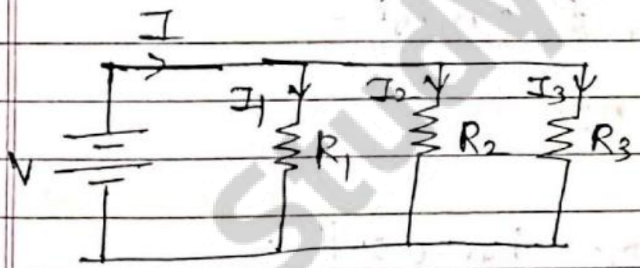
Resistors in series –

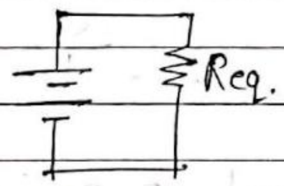


$R_{eq} = R_1 + R_2 + R_3$



Resistances in parallel –

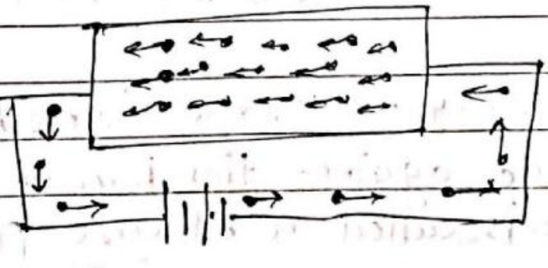




$R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

– Concept of EMF –

EMF – Electromotive Force.



Electrical force or pressure that causes the e^{-}s to move in a particular dir^{n} is called as EMF.

Unit of EMF is Volts 'V'.
Also called as voltg. or pote. diff.
Sometimes denoted by E.

- Current -
Defined as the movement of e⁻s or flow of e⁻s inside a conducting material.
Denoted by I & unit is (A)

- Electron c/t flows due to e⁻s.
- It flows from -ve end of battery to +ve end.

- Conventional current -
It is said to flow from +ve end of battery to the -ve. [higher to lower potential)

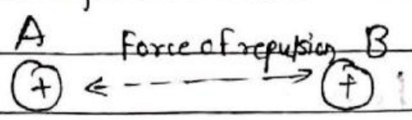
- Relation betn charge & current -

$I = \frac{Q}{t}$ Amperes.

Each e⁻ carries some charge on it.

c/t is rate of change of charge w.r.t. time.

- Concept of Electric potential & P.D.



← charge B is moved to charge A.

If charge B is brought closer to charge A then work has to be done against this force of repulsion.
- This work done is called as electric potential (V)

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Potential difference (PD):

$$A \odot \longleftrightarrow \odot B$$

$$V_{AB} = (V_A - V_B)\,V.$$

~~The electric~~

The difference betn the electric potentials at any two points is called as P.D.

~~It~~ can be +ve $(V_A > V_B)$

or −ve. $(V_A < V_B)$

Ohm's law –

The ohm's law state that the ratio of potential diff. (V) betn any two points and the ckt flowing betn them is cont. if temp. is cont.

This ratio is termed as resistance R

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

Elementary Power System –

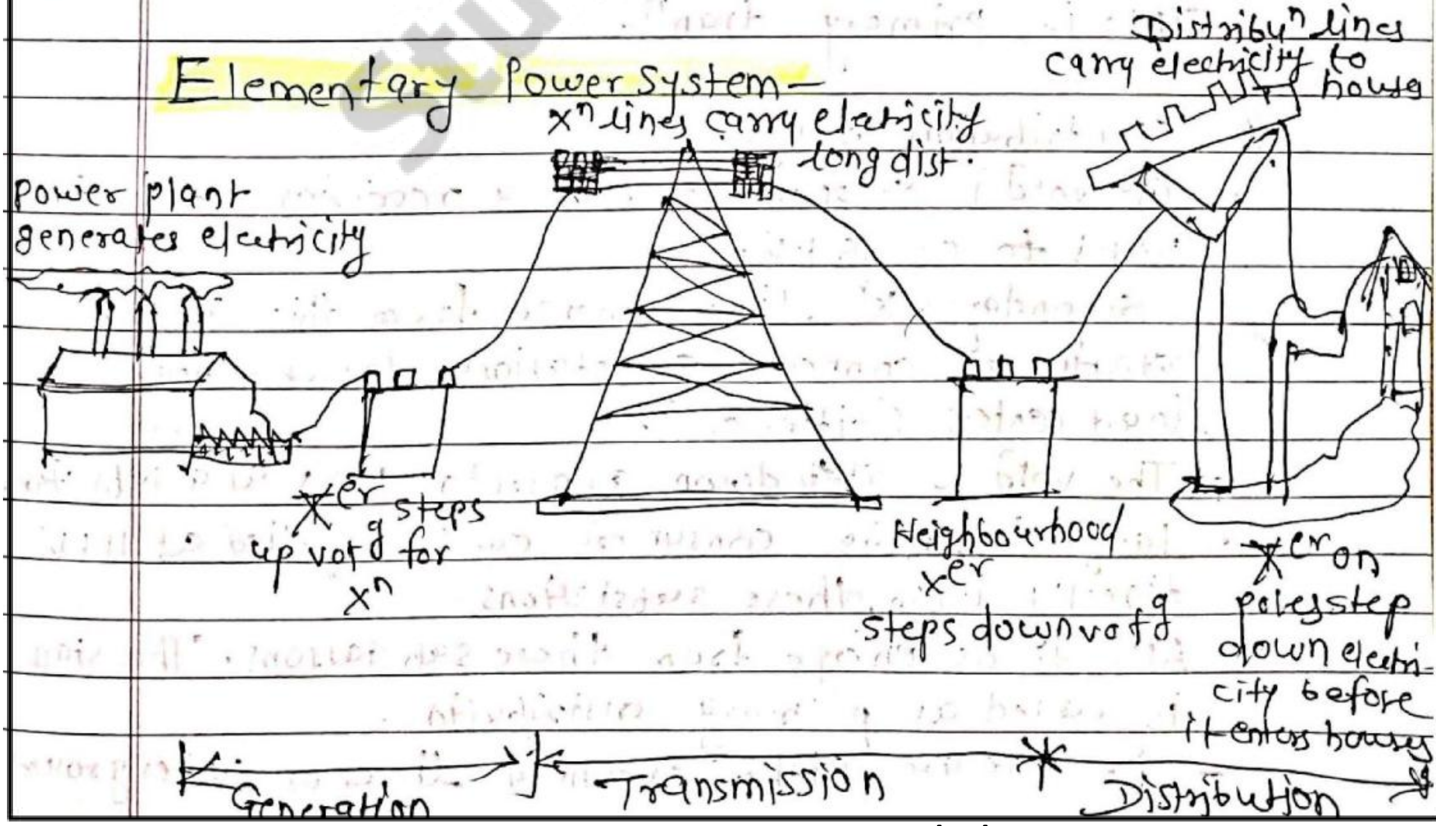

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Fig. shows typical tran line that is interconnected with one another. This is known as grid.
- There are 3 stages.
① generation ② transmission ③ distribution

① Generation stage -
Power is generated at 11 KV in generating stations in India & Europe. In some cases it can be higher or lower.

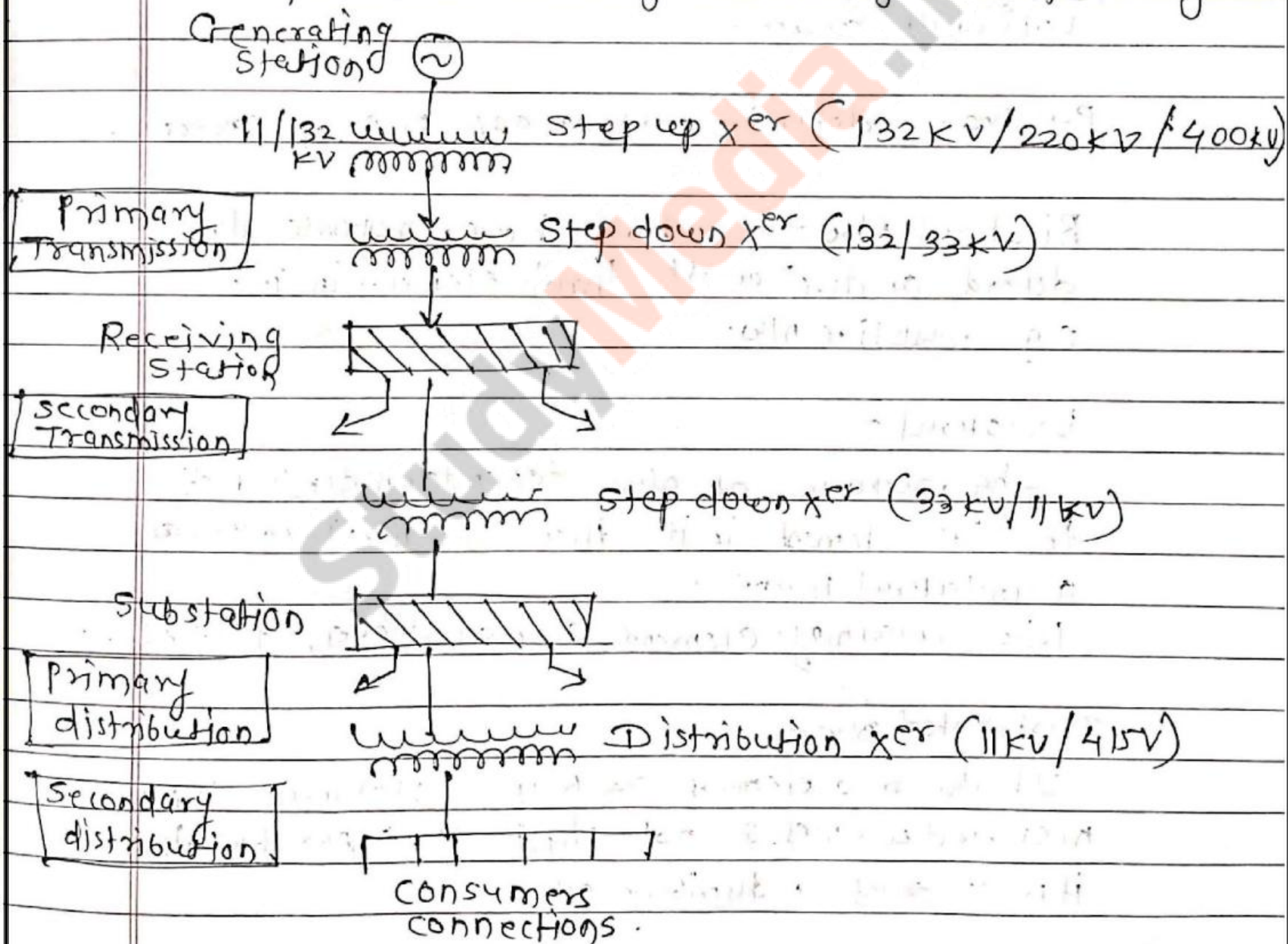
② Transmission stage -
- The generating volt is stepped up to 132 kV, 220 kV, 400 kV or 765 kV etc.
- stepping up volt depends upon the dist. at which power is to be transmitted.
- stepping up volt reduces I^2R losses.
(when V is stepped up, I reduces by relative amt so that power remains const. & hence I^2R loss also reduces.
- This is primary $tran^n$.

③ Distribution stage -
- The volt is stepped down at a receiving station to 33 kV ~~to~~ or 66 kV.
- Secondary x^n lines emerge from this receiving station to connect substations located near load centers (cities etc).
- The volt is step down again to 11 KV at a substation.
- large industrial consumers can be supplied at 11 kV directly from these substations.
- Also feeds emerge from these substations. This stage is called as primary distribution.
- Feeders are either overhead lines or underground

cables which carry power close to the load points (end consumers) up to a couple of km.

- Finally volt^g is stepped down to 415 V by a pole-mounted distribu^n x^{er} & delivered to the distributors.
- End consumers are supplied thro' a service mains line from distributors.
- Secondary distr^n system consists of feeders, distributors & service mains.

Simplified block diagram of High volt^g AC X^n sy-



Basic HVAC system

DC circuits:

Network -
A n/w or ckt is an electrical confⁿ which electrically connects various components such as resistors, capacitors, inductors etc & vol^{g} or c/t sources to each other.

Classⁿ of electric N/w:-

Active - consists of energy source. It can be vol^{g} or c/t source.

passive - doesn't contain any energy source.

Bilateral n/w - whose cha. or response doesn't depend on direⁿ of c/t thro' elements in it.
e.g. resistive n/w.

Unilateral -
cha., response of n/w depends on direⁿ of c/t thro' its elements in it then the n/w is called as a unilateral n/w.
N/w containing elements such as diodes, T^{rs} etc.

Distributed n/w -
If the n/w elements such as resistances, capacitances, inductances are not physically separable then it is called as a distributed n/w.

Lumped n/w - If n/w elements can be separated physically from each other, then they are called as lumped n/w.

Linear n/w —

If characteristics, parameters such as R, L, C etc. remains constant irrespective of changes in c/t, volt etc then the ckt or n/w is called as linear n/w.

- **Non-linear n/w. —**

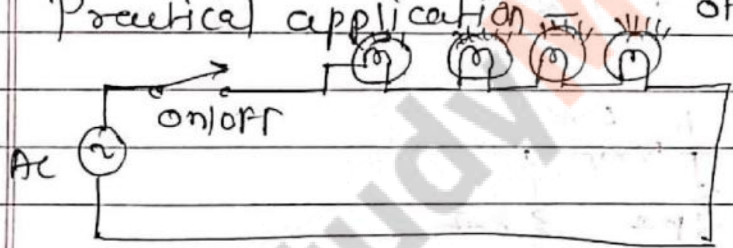
Parameters change their values with change in volt, c/t etc.

Circuit simplification techniques —

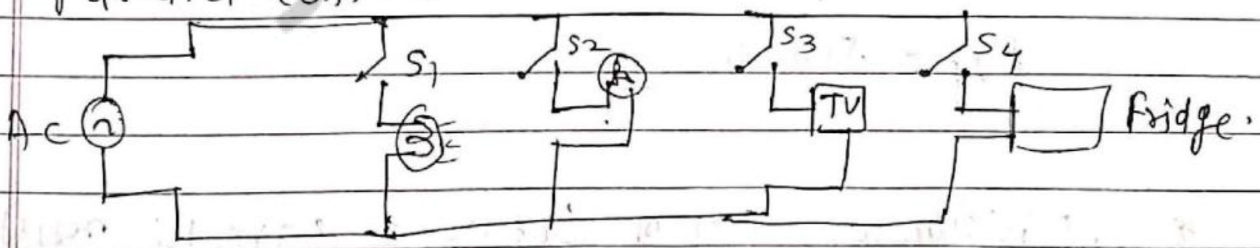
1) Series-parallel combinaⁿ
2) Use redundunt branch removal
3) Star delta.

Series - parallel —

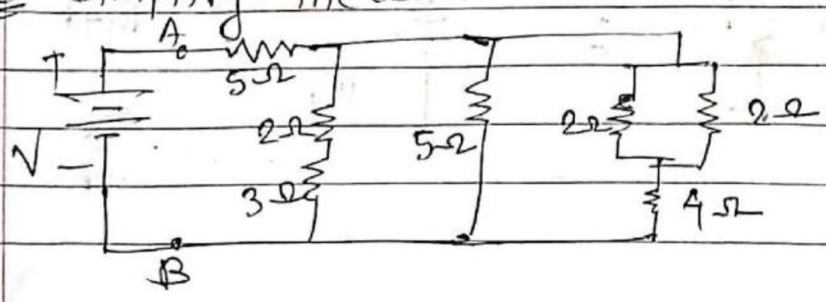
Practical application of series connⁿ —



Parallel connⁿ —



Ex: Simplify the ckt.

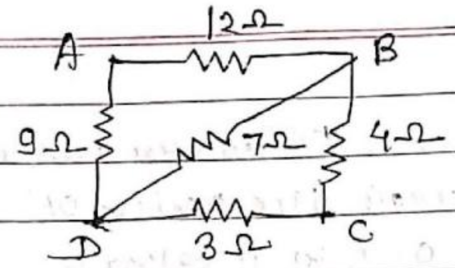


$Req = [[(2||2)+4]||5] \cancel{||(2+3)}$

$Req = 5 + [5||5||5]$

$= 6.66\ \Omega$

Ex Find R_{BC} -



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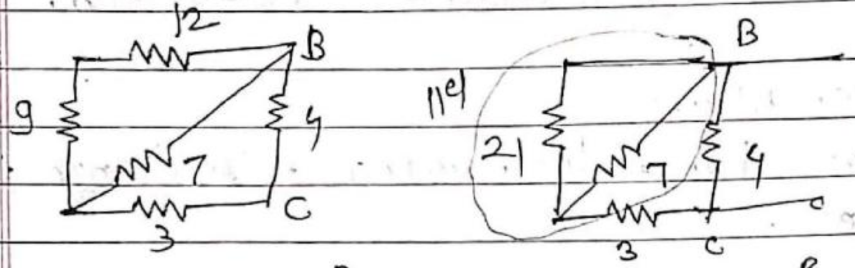
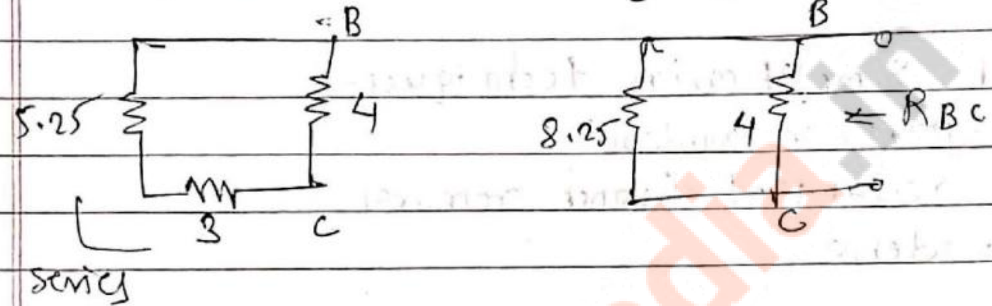
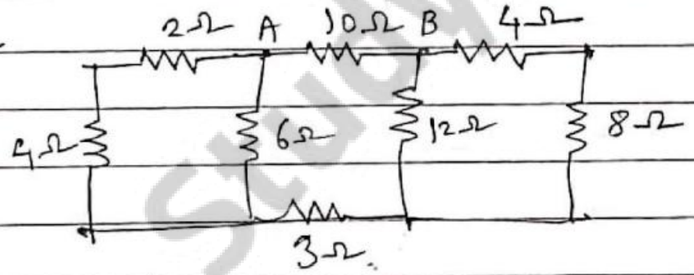




$\therefore R_{BC} = 8.25 \parallel 4$

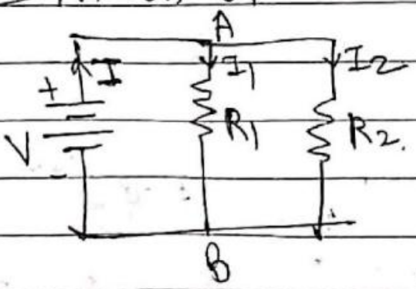
$\therefore R_{BC} = 2.7\ \Omega$

H.W.



$R_{AB} = 5.45\ \Omega$

* Division of current between parallel resistors -

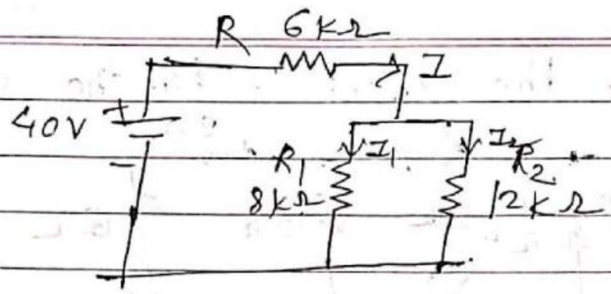


$$I_1 = \frac{R_2}{R_1 + R_2} \times I$$

IIIy

$$I_2 = \frac{R_1}{R_1 + R_2} \times I$$

e.g.-



$$\rightarrow I_1 = \frac{12k}{8k+12k} \times I. \qquad I = \frac{V}{R_{eq}} = \frac{V}{(R_1 \| R_2) + R}$$

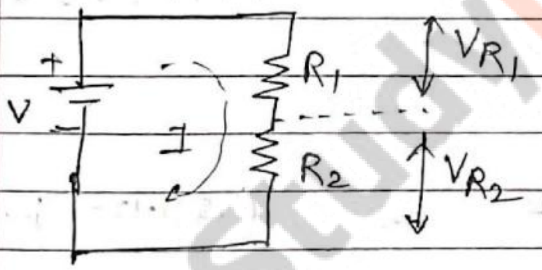
$$= \frac{12k}{8k+12k} \times 3.7\,mA. \qquad = \frac{40\,V}{10.8\,k\Omega} = 3.7\,mA.$$

$$= 2.22\,mA.$$

$$I_2 = I - I_1$$

$$\boxed{I_2 = 3.7 - 2.22 = 1.48\,mA}$$

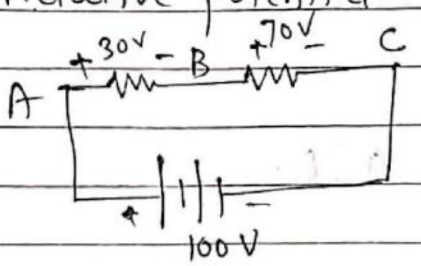
* Division of voltage in the series resistors—

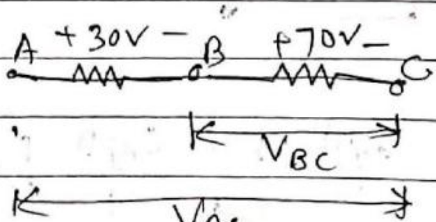


$$V_{R_1} = \frac{V}{R_1+R_2} R_1$$

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

* Relative potential—





$V_{AC} = 30+70 = 10$

$V_{BC} = 70V$

$V_{CC} = 0\,V.$

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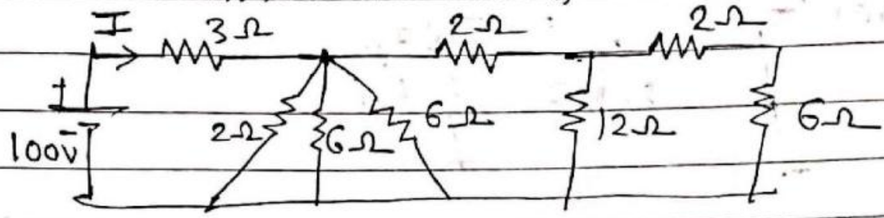
Ex Determine the current I for the circuit.



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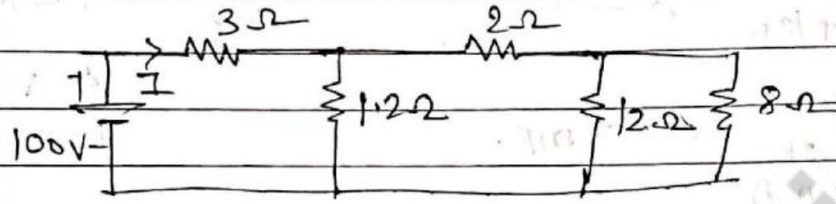
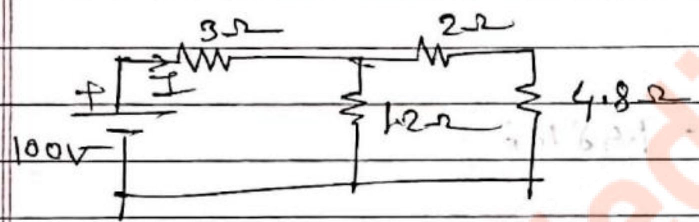
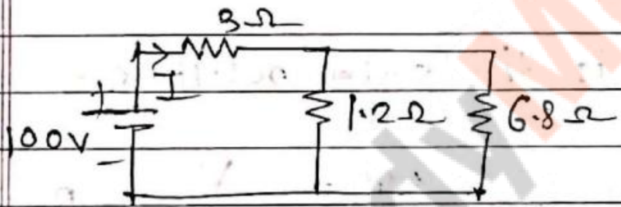


$6+2=8\Omega$

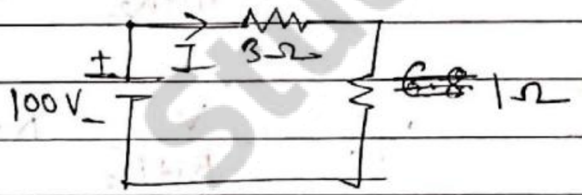
$2||6||6 = 1.2\Omega$



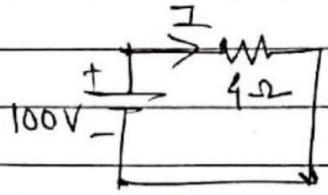
$12||8 = 4.8\Omega$



$2+4.8 = 6.8\Omega$

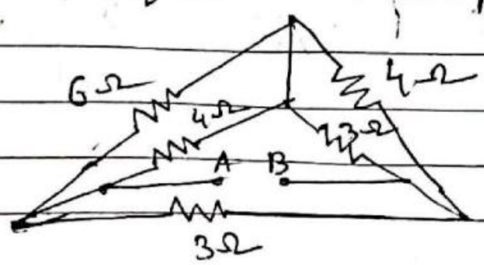


$6.8||1.2 = 1\Omega$

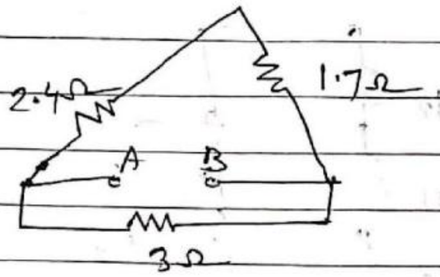


$\therefore I = \frac{100}{4} = 25\ A.$

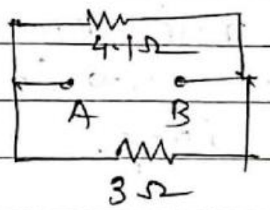
Ex Find eq^{nt} resi. bet^{n} points A & B.



→ $6\Omega \parallel 4\Omega = 2.4\Omega$ & $4 \parallel 3 = 1.7\Omega$



$2.4 + 1.7 = 4.1\Omega$

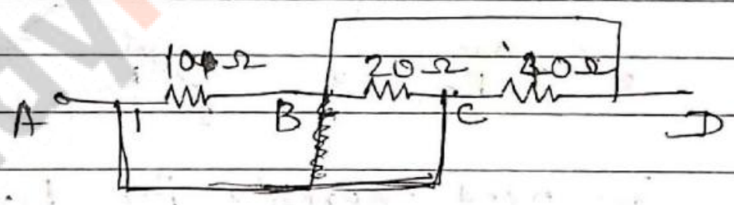


$4.1 \parallel 3\Omega = R_{A-B}$

$\therefore R_{AB} = 1.732\Omega$

* ~~Star~~

HW. Find R_{AD}



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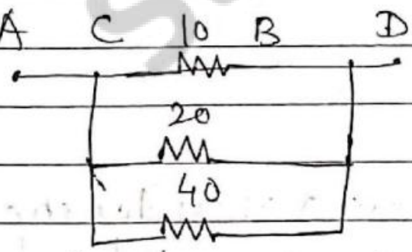
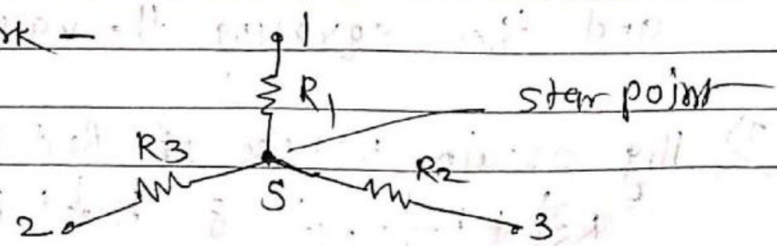


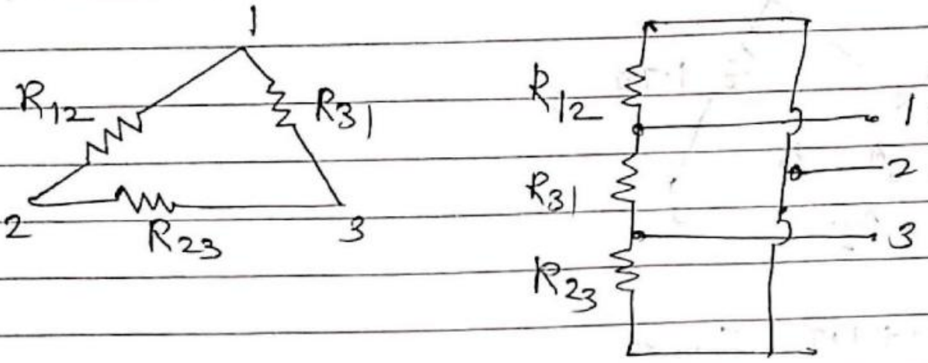
$R_{AD} = 5.71\Omega$

* Star-Delta & Delta-star Transformation –

The star network –

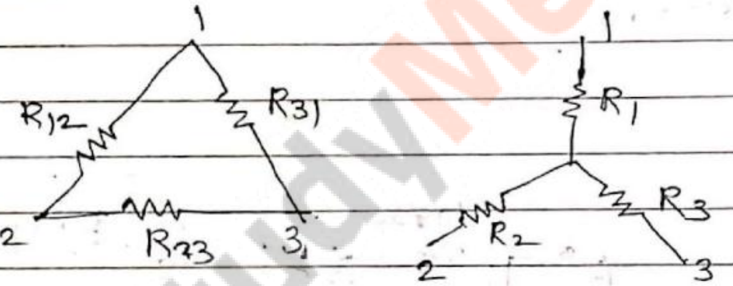


The Delta network –



– Delta network also known as mesh connection.
– It resembles with greek letter delta (Δ)
– Three resistors form a closed loop.

* Delta to star conversion –



We need expression for R_1, R_2, R_3 in terms of R_{12}, R_{23}, R_{31}.

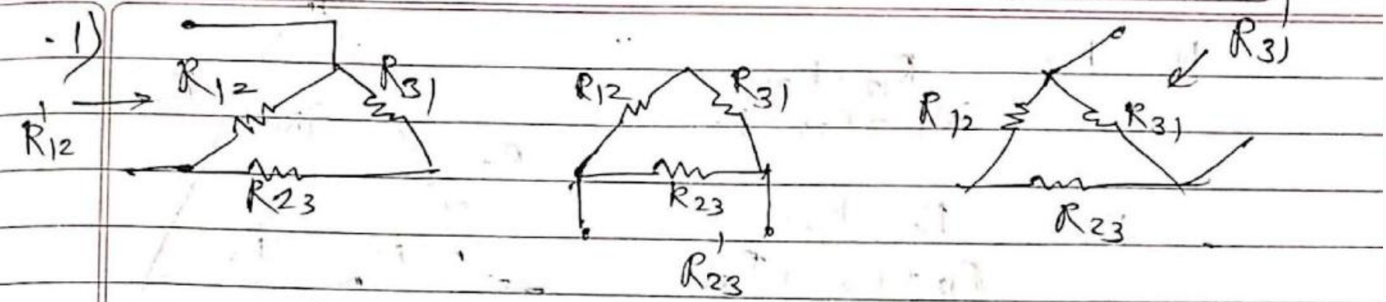
Steps –

1) Write down the resistance values for the delta and star networks. e.g. – $R_{12}', R_{23}', R_{31}'$

2) Obtain the value of R_1 by solving the expression $R_{12}' + R_{31}' - R_{23}'$ for star and delta networks and then equating the values for both the n/ws

3) |||ly, obtain values of R_2 & R_3 by solving eq^{ns} $R_{31}' + R_{23}' - R_{12}'$ & $R_{12}' + R_{23}' - R_{31}'$

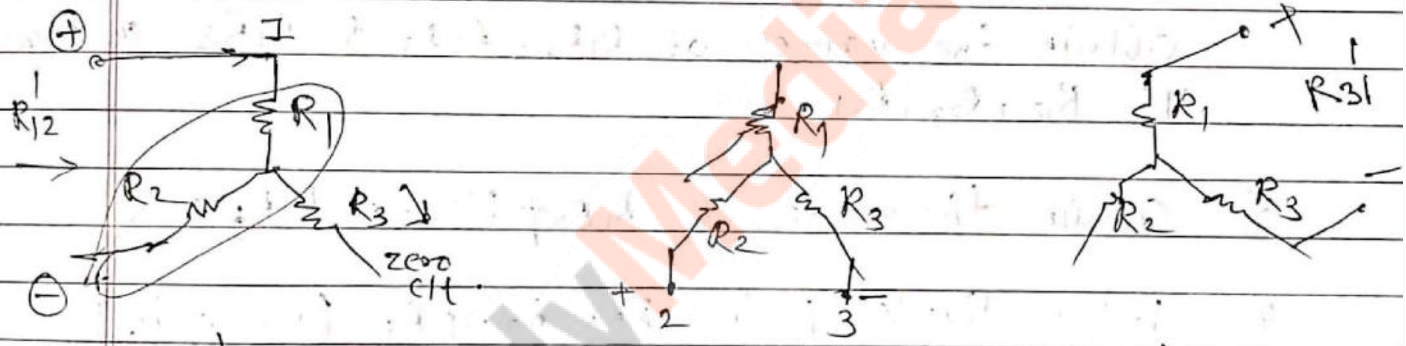
1)



$$\therefore R'_{12} = R_{12} \parallel (R_{31} + R_{23})$$

$$R'_{12} = \frac{R_{12}\,[R_{31}+R_{23}]}{R_{12}+R_{23}+R_{31}} \qquad R'_{23} = \frac{R_{23}(R_{12}+R_{31})}{R_{12}+R_{23}+R_{31}} \qquad R'_{31} = \frac{R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}}$$

Now, for star network –



$$\therefore R'_{12} = R_1 + R_2 \qquad R'_{23} = R_2 + R_3 \qquad R'_{31} = R_1 + R_3$$

To obtain the value of R_1 –
solve

$$R'_{12} + R'_{31} - R'_{23}$$

$$\therefore (R_1+R_2) + (R_3+R_1) - (R_2+R_3) = 2R_1 \quad \text{--- for star n/w.}$$

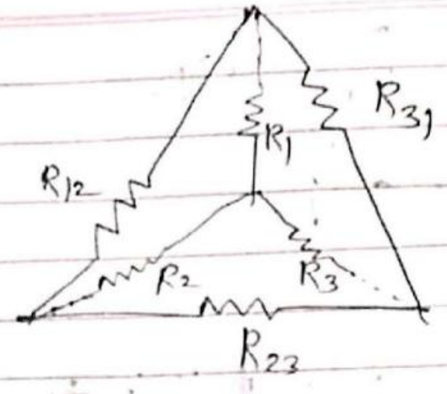
$$\therefore \frac{R_{12}(R_{31}+R_{23})}{R_{12}+R_{23}+R_{31}} + \frac{R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}} - \frac{R_{23}(R_{12}+R_{31})}{R_{12}+R_{23}+R_{31}}$$

$$= \frac{2R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} \quad \text{--- For Delta n/w}$$

$$\therefore 2R_1 = \frac{2R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} \qquad \therefore \boxed{R_1 = \frac{R_{12}\cdot R_{31}}{R_{12}+R_{23}+R_{31}}}$$

IIIly. $R_2 = \dfrac{R_{12} \cdot R_{23}}{R_{12}+R_{23}+R_{31}}$

$R_3 = \dfrac{R_{23} \cdot R_{31}}{R_{12}+R_{23}+R_{31}}$



* Star to Delta conversion -

1) consider the resistance values between different node for star and delta networks.

2) Obtain the values of R_1R_2, R_2R_3 & R_1R_3 in terms of R_{12}, R_{23}, R_{31}.

3) Obtain the values of $R_1R_2 + R_2R_3 + R_1R_3 = R$

4) Now divide R by R_1, R_2 & R_3 to obtain the expressions for R_{12}, R_{23} & R_{31}.

1) We know,

$R_1 = \dfrac{R_{12} \cdot R_{31}}{R_{12}+R_{23}+R_{31}}$

$R_2 = \dfrac{R_{23} R_{12}}{R_{12}+R_{23}+R_{31}}$

$R_3 = \dfrac{R_{31} R_{23}}{R_{12}+R_{23}+R_{31}}$

Now find

$R_1R_2 = \dfrac{R_{12}^2 R_{23} R_{31}}{(R_{12}+R_{23}+R_{31})^2}$

$$R_2R_3 = \frac{R_{23}^2 R_{12}R_{31}}{(R_{12}+R_{23}+R_{31})^2}$$

$$R_1R_3 = \frac{R_{31}^2 R_{12}R_{23}}{(R_{12}+R_{23}+R_{31})^2}$$

Adding above three eq^{ns}, & dividing it by R_1

$$\frac{R_1R_2+R_2R_3+R_1R_3}{R_1} = \frac{R_{12}R_{23}+R_{23}^2+R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}$$

$$= \frac{R_{23}(R_{12}+R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}}$$

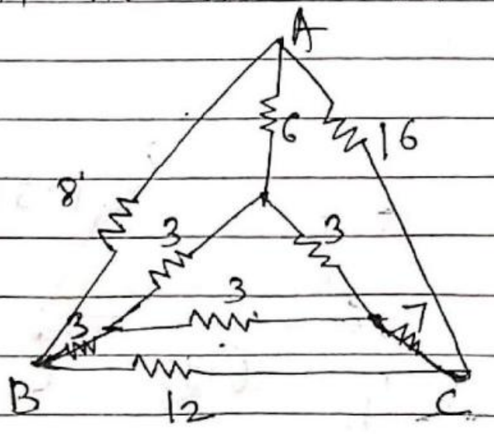
$$\therefore \boxed{\frac{R_1R_2+R_2R_3+R_1R_3}{R_1} = R_{23}}$$

||ly,

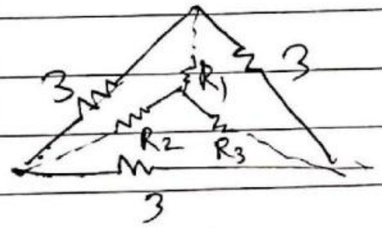
$$\frac{R_1R_2+R_2R_3+R_1R_3}{R_2} = R_{31}.$$

$$\frac{R_1R_2+R_2R_3+R_1R_3}{R_3} = R_{12}.$$

Ex Find the resistance bet^n B and C.



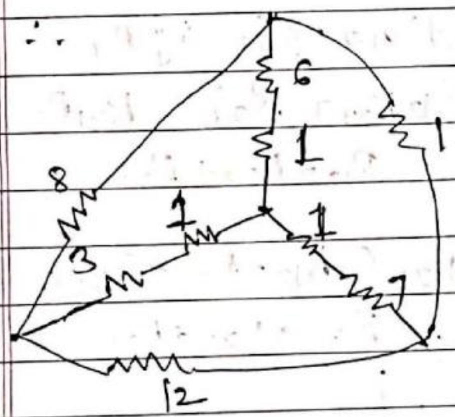
→ convert inner delta to star.



$\therefore R_1 = \dfrac{3 \times 3}{3+3+3} = 1\Omega$

$\text{|||ly } R_2 = R_3 = 1\Omega.$

$\therefore$



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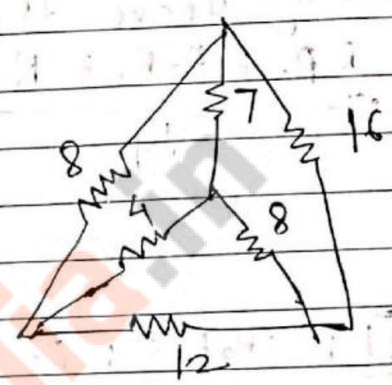
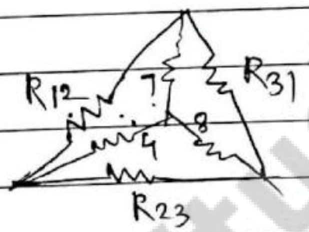


convert star to delta.



$R_{12} = \dfrac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$

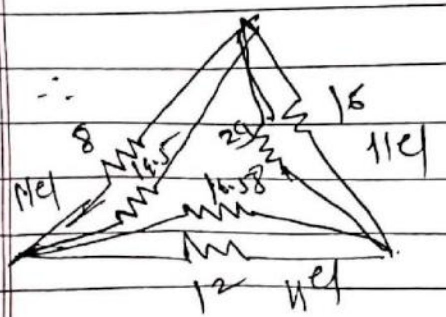
$= \dfrac{116}{8}$

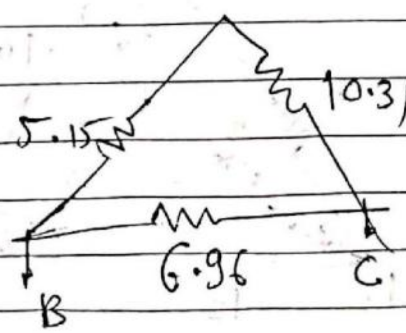
$= 14.5\Omega$

$R_{23} = \dfrac{116}{7} = 16.58$

$R_{31} = \dfrac{116}{4} = 29\Omega.$

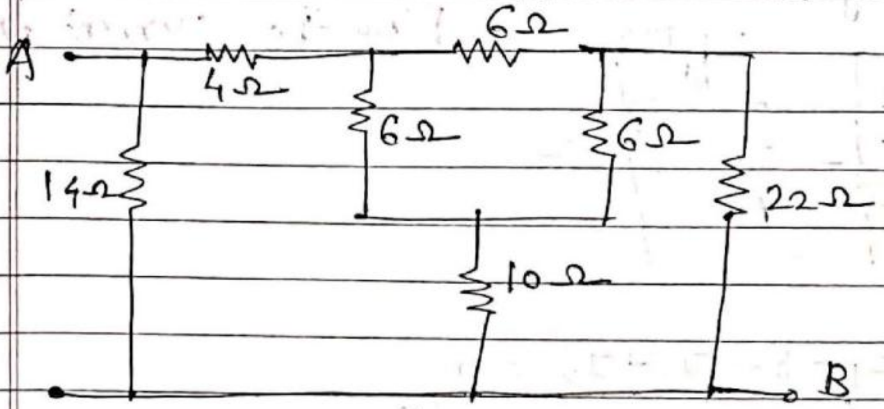
$\therefore$





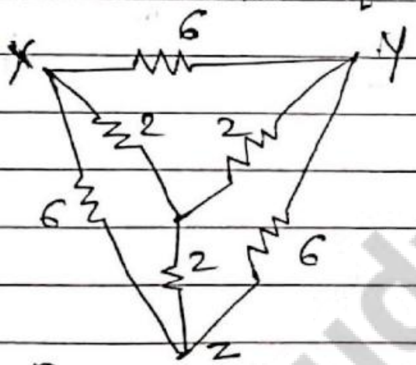
$\therefore R_{BC} = (5.15 + 10.31) \,||\, 6.96 = 4.8\Omega$

H.W Determine the effective resi. betn A & B.



Ans 7Ω.

H.W. Determine eqnt resi: betn XY.



$R_{xy} = 2\Omega$

* Kirchhoff's Laws —

1) Current law (KCL) —

The sum of c/ts directed into any node in a circuit is equal to the sum of the currents coming out of same node

2) Voltage law (KVL) —

The algebric sum of the volt^g around a closed loop in a circuit must be equal to zero.

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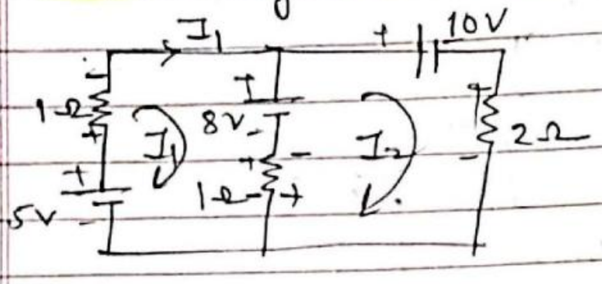
* Mesh analysis —



Find the current thro' 5V battery

Loop 1

$5 - 1\times I_1 - 8 - I_1 + I_2 = 0$

$\therefore -2I_1 + I_2 = 3$ — (1)

Loop 2

$-10 - 2I_2 - I_2 + I_1 + 8 = 0$

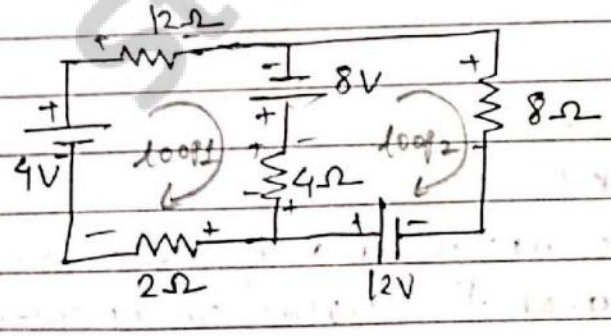
$\therefore -3I_2 + I_1 = 2$

$\therefore I_1 - 3I_2 = 2$ — (2)

$\therefore I_1 = \cancel{2.2A}\ 0.8A$

$I_2 = -1.4A$

Ex.
H.W.



Determine all loop currents.

→ Loop 1,

$4 - 12I_1 + 8 - 4I_1 - 2I_1 + 4I_2 = 0$

$\therefore 12 - 18I_1 + 4I_2 = 0$

$\therefore +18I_1 - 4I_2 = 12$ — (1)

Loop 2,

$-8I_2 + 12 - 4I_2 + 4I_1 - 8 = 0$

$\therefore 4 + 4I_1 - 12I_2 = 0$

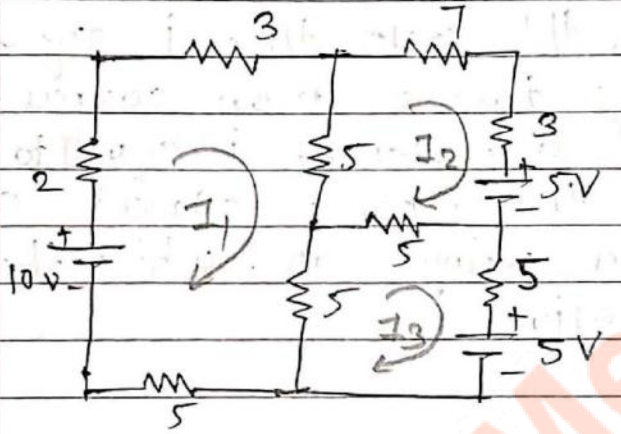
$\therefore -4I_1 + 12I_2 = 4 \quad \text{--- (2)}$

Solving (1) & (2),

$I_1 = 0.8A$

$I_2 = 0.2A$.

Ex



Determine all loop currents.

→ loop 1,

$10 - 2I_1 - 3I_1 - 5I_1 + 5I_2 - 5I_1 + 5I_3 - 5I_1 = 0$

$-20I_1 + 5I_2 + 5I_3 = -10$

$\therefore 20I_1 - 5I_2 - 5I_3 = 10 \quad \text{--- (1)}$

loop 2,

$-7I_2 - 3I_2 - 5 - 5I_2 + 5I_3 - 5I_2 + 5I_1 = 0$

$5I_1 - 20I_2 + 5I_3 = 5 \quad \text{--- (2)}$

loop 3,

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

$5I_1 + 5I_2 - 15I_3 = 5 \quad \text{--- (3)}$

Solving (1), (2), (3),

$I_1 = 0.3714\,A$, $I_2 = -0.2285\,A$, $I_3 = -0.2857$

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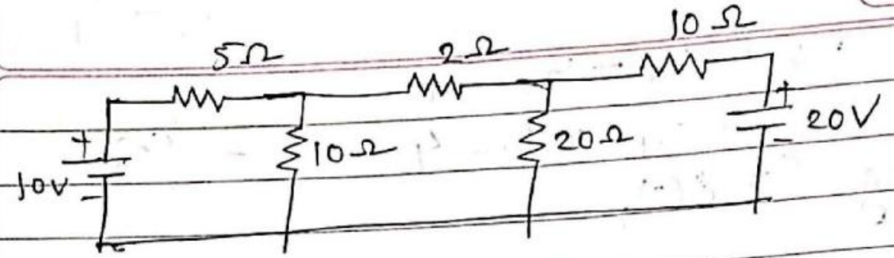
HW



Find c/t thro' 2Ω resi.

$I_2 = 0.56\,A = -0.56\,A$

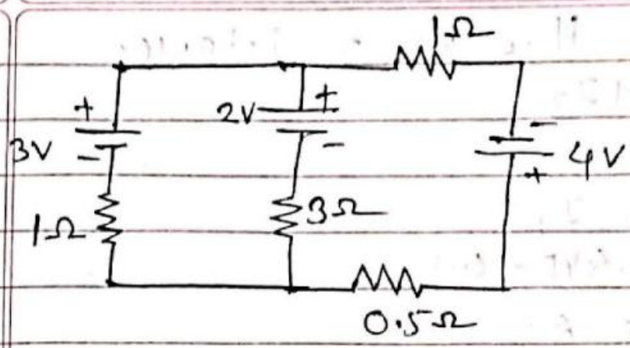
* Superposition Theorem–

The super position thm states that in any linear network containing two or more sources, the response (current) in any element is equal to the algebric sum of the response (current) caused by individual sources acting alone, while the other sources are inoperative.

Steps–

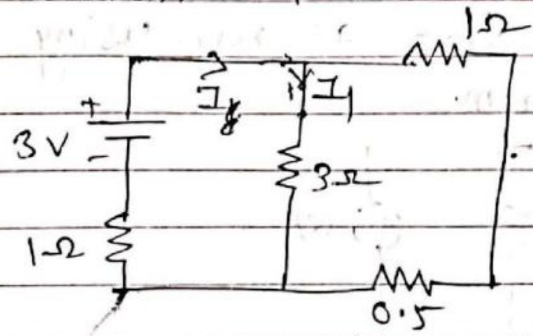
1) Select any one energy source.
2) Replace all the other energy sources by:
   - Their internal series resistances for voltage sources.
   - Their internal shunt resistaces for current sources.
3) With only one energy source calculate the volg drops or branch currents paying attention to the voltage polarities and current directions.
4) Repeat steps 1, 2 and 3 for each source individually.
5) Add algebrically the volg drops or branch currents obtained due to the individual source to obtain the combined effect of all the sources.

Ex Apply superposition thm to calculate current flowing in 3Ω resistance for the n/w.



→ Step 1.

Current I_1 due to 3V source.



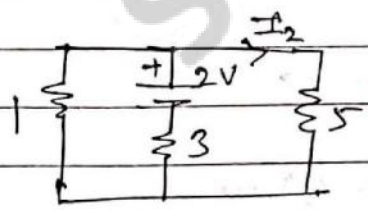
$(1+0.5) \| 3 = 1\Omega$.

$\therefore I = \frac{3}{2} = 1.5\,A$.

$\therefore I_1 = I \times \frac{1.5}{4.5} = 1.5 \times \frac{1.5}{4.5} = 0.5\,A \downarrow$

Step 2.

Current I_2 due to 2V source.

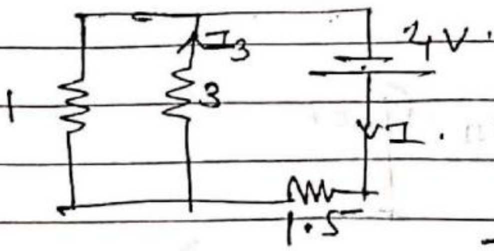


$(1 \| 5) + 3 = 3.6\Omega$.

$\therefore I_2 = \frac{2}{3.6} = 0.56\,A \uparrow$

Step 3.

Current I_3 due to only 4V source.



$(3 \| 1) + 1.5 = 2.25\Omega$

$\therefore I = \frac{4}{2.25} = 1.78$.

$I_3 = I \times \frac{1}{1+3} = 1.78 \times \frac{1}{4} = 0.445\,A \uparrow$

∴ Total current thro' 3Ω resistance:

$I_T = I_1 + I_2 + I_3$

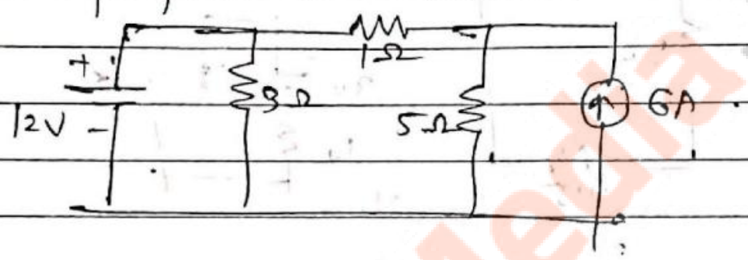
$= \cancel{0.56}$

$= I_2 + I_3 - I_1$

$= 0.56 + 0.445 - 0.5$

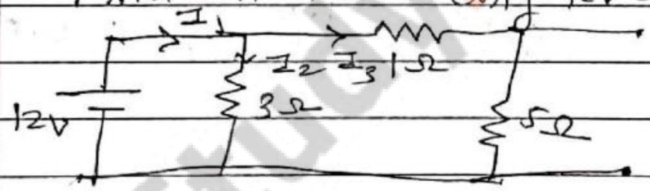
$I_T = 0.505\ A$

Ex calculate the c/t thro' all resi. using superposition theorem.



→ Step 1:

Find c/t due to only 12V source.



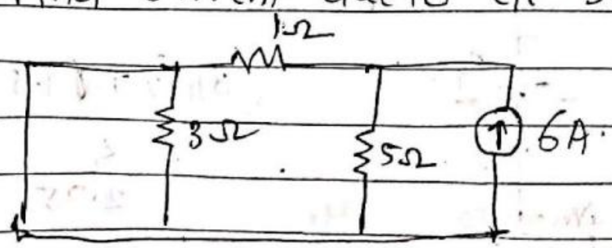
$I_2 = \frac{12}{3} = 4A \downarrow$

$I_3 = \frac{12}{5+1} = \frac{12}{6} = 2A \rightarrow$

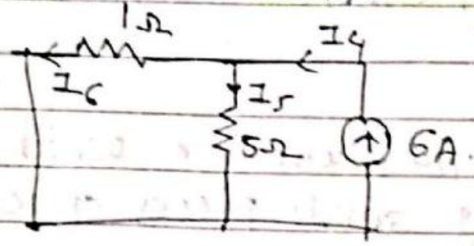
$I_1 = I_2 + I_3 = 4 + 2 = 6A \rightarrow$

Step 2:

Find current due to c/t source.



3Ω is redundant.



$I_4 = 6A \uparrow$

$I_5 = \frac{1}{1+5} I_4 = \frac{1}{6} \times 6 = 1A \downarrow$

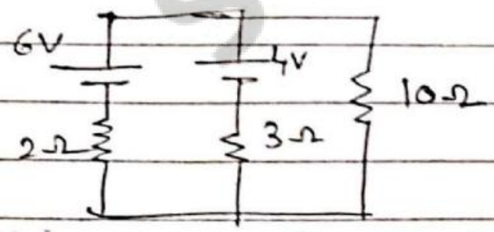
$I_6 = \frac{5}{1+5} \times 6 = 5A \leftarrow$

Step 3

C/t thro' all branches –

1) c/t thro' 12V source = $I_1 - I_6 = 6 - 5 = 1A \rightarrow$
2) c/t thro' 3Ω = $I_2 = 4A \downarrow$
3) c/t thro' 1Ω = $I_3 - I_6 = 2 - 5 = -3A \rightarrow\ = 3A \leftarrow$
4) c/t thro' 5Ω = $I_3 + I_5 = 2 + 1 = 3A \downarrow$
5) c/t thro' 6A source = $I_4 = 6A \leftarrow$

Ex Apply superposition th^m to calculate c/t flowing in 10Ω resistance for the ckt.



$I_L = 0.4637A$