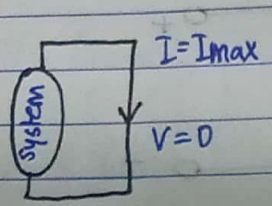
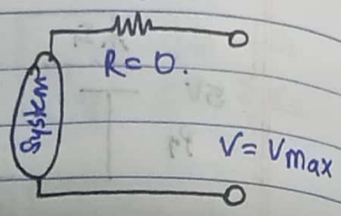
* Closed circuit



* Open circuit



In closed circuit, current is maximum and no voltage if unresistive.

In open circuit, current is zero and the voltage is maximum

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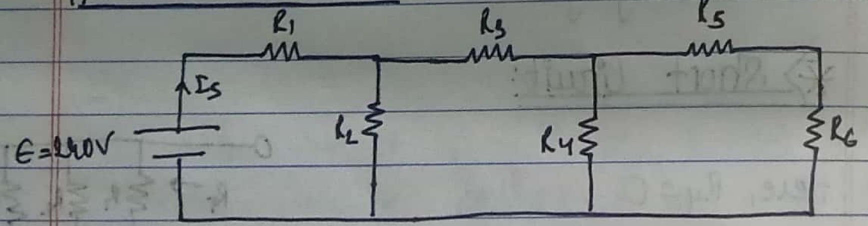
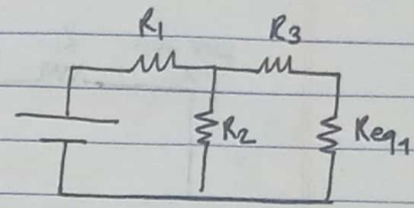
Ladder Network



For this ladder network, we use back to front to back approach.
Back to front to calculate total resistance then move front to back to find other unknown quantities.

Here, $R_1 = 5\Omega$ $R_2 = 6\Omega$ $R_3 = 4\Omega$
$R_4 = 6\Omega$ $R_5 = 1\Omega$ $R_6 = 2\Omega$

Step: 1: Redrawing the circuit,

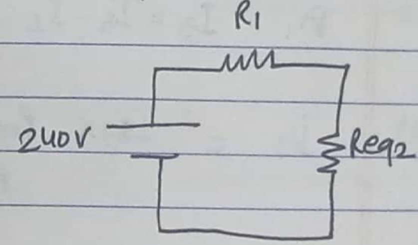


Here,

$$R_{eq_1} = (R_5 + R_6) \| R_4 = (1+2)\|6 = 3\|6 = \frac{6\times 3}{3+6} = 2\Omega$$

$\therefore R_{eq_1} = 2\Omega$

Step 2: Redrawing the circuit,



$$R_{eq_2} = (R_{eq_1} + R_3) \| R_2 = (2+4)\|6 = 6\|6$$

$\therefore R_{eq_2} = 3\Omega$

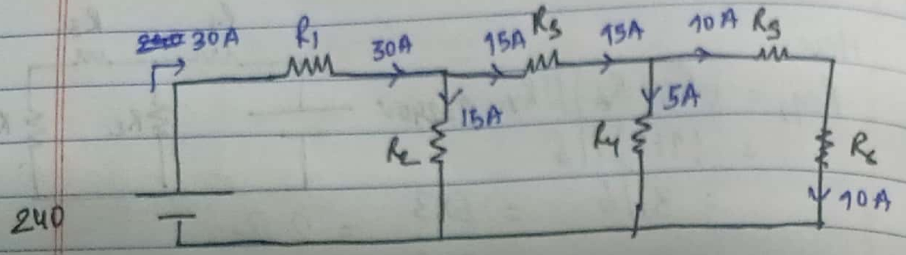
Then,

$$R_T = R_{eq_2} + R_1 = 3 + 5 = 8\Omega$$

So, $I_S = \frac{E}{R_T} = \frac{240}{8} = 30\,A$

Step: 3: Show current division in original circuit.

Then,



$$I_{2} = I_s \times \frac{R_{eq_2}}{(R_{eq_1} + R_3)} = 30 \times \frac{\cancel{8}\ 3}{6}$$

$$\therefore I_2 = 15\,A$$

So, $I_3 = I_s - I_2 = 30 - 15 = 15\,A$

$$I_4 = I_{3} \times \frac{R_{eqn}}{R_4} = \cancel{30}\,15 \times \frac{2}{6}$$

$$= 5\,A$$

~~$I_5 = I_3 \times R$~~

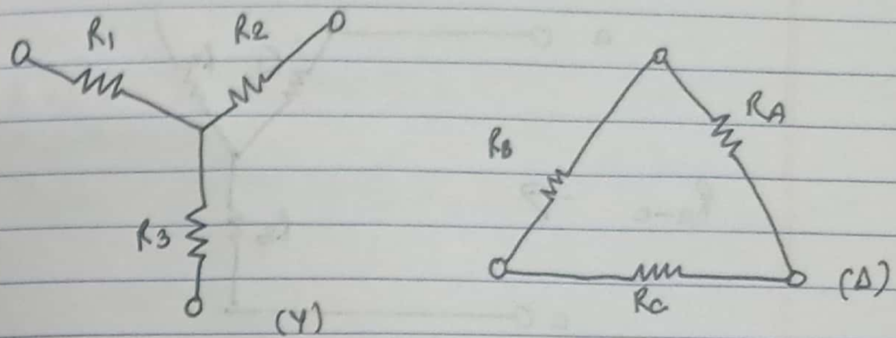
$$I_5 = I_3 - I_4$$

$$\therefore I_5 = 10\,A$$

$$V_6 = \frac{I_5 \times R_6}{\cancel{R_6}\,1} = \frac{10}{\cancel{2}} \times 2 = 20\,V$$

<u>Note:</u> Circuit must be redrawed as we create equivalence of combination.

<u>STAR-DELTA conversion:</u>



or,   or,

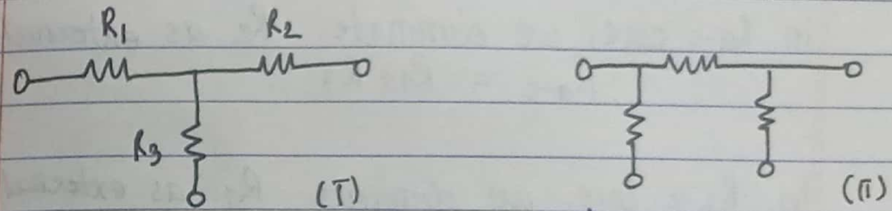
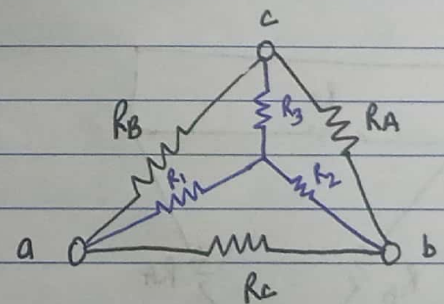
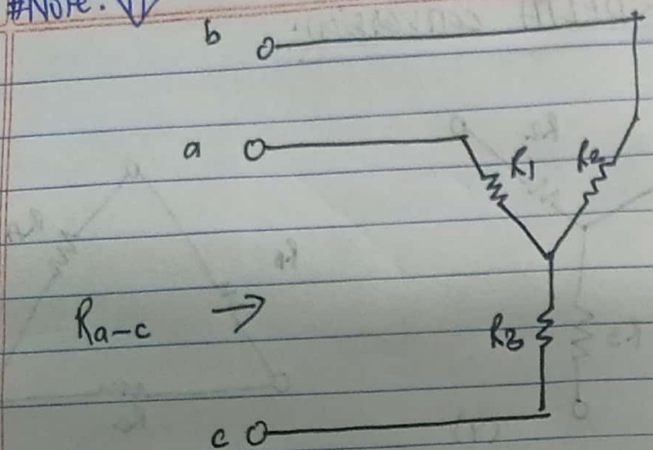


Fig: Y(T) or Δ(Π) configuration.

To solve this kind of question, we convert Y to Δ or vice versa.



#Note:



In R_{a-c} case, we eliminate R_2 as external path

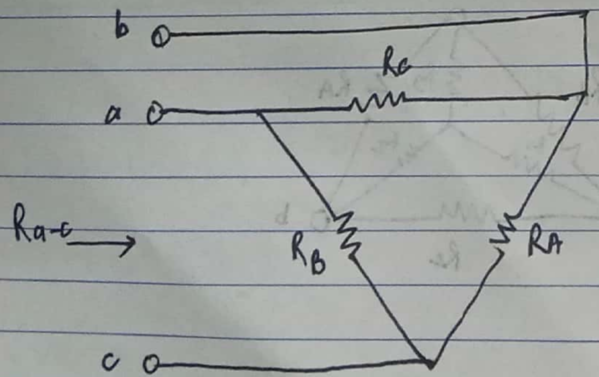
$\therefore R_{a-c} = R_1 + R_3$

In R_{b-c} case, we eliminate R_1 as external path

$\therefore R_{b-c} = R_2 + R_3$

In R_{a-b} case, we eliminate R_3 as external path

$\therefore R_{a-b} = R_1 + R_2$



Here,

$R_{AC} = R_B \parallel (R_A + R_C)$

$R_{BC} = R_A \parallel (R_B + R_C)$

$R_{AB} = R_C \parallel (R_A + R_B)$

And,

$R_{AC}(Y) = R_{AC}(\Delta)$

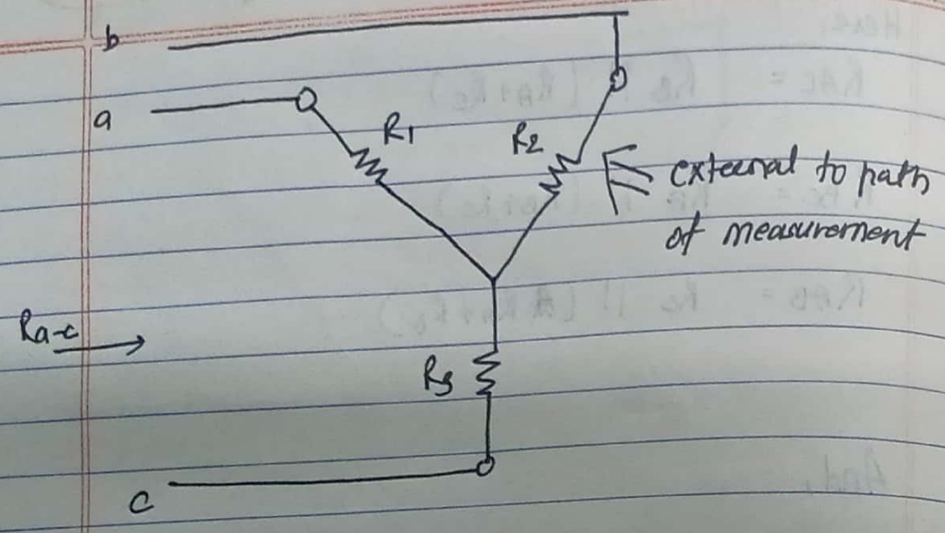
$R_{BC}(Y) = R_{BC}(\Delta)$

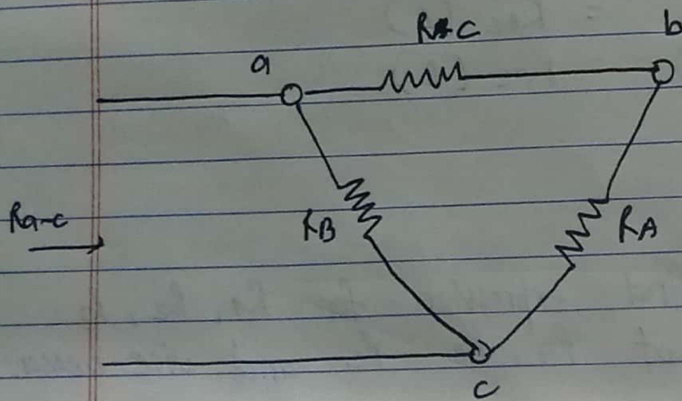
$R_{AC}(Y) = R_{AC}(\Delta)$

Derivation:

To find expression for R_1, R_2, R_3 in terms of R_A, R_B, R_C and vice-versa.

The resistance between any two terminals of the Y- configuration will be the same with Δ- configuation inserted in place of the Y-configuration.





Let us convert the $\Delta(R_A, R_B, R_C)$ to $Y(R_1, R_2, R_3)$

We know,

$$R_{a-c}(Y) = R_{a-c}(\Delta)$$

so that,

$$R_1 + R_3 = \frac{R_B(R_A + R_C)}{R_B + (R_A + R_C)} \quad \text{—(i)}$$

Using the same approach for a-b & b-c,

$$R_{a-b}(Y) = R_{a-b}(\Delta)$$

so that,

$$R_1 + R_2 = \frac{R_C(R_A + R_B)}{R_C + (R_A + R_B)} \quad \text{—(ii)}$$

$$R_{b-c}(Y) = R_{b-c}(\Delta)$$

so that,

$$R_3 + R_2 = \frac{R_A(R_B + R_C)}{R_A + (R_B + R_C)} \quad \text{—(iii)}$$

Subtracting eq^n (i) ~~or~~ from (ii), we get

$$(R_1 + R_2) - (R_1 + R_3) = \left(\frac{R_C R_B + R_C R_A}{R_A + R_B + R_C}\right) - \left(\frac{R_B R_A + R_B R_C}{R_A + R_B + R_C}\right)$$

or, $$R_2 - R_3 = \frac{R_A R_C - R_B R_A}{R_A + R_B + R_C} \quad \text{—(iv)}$$

Subtracting (iv) from (iii), we get.

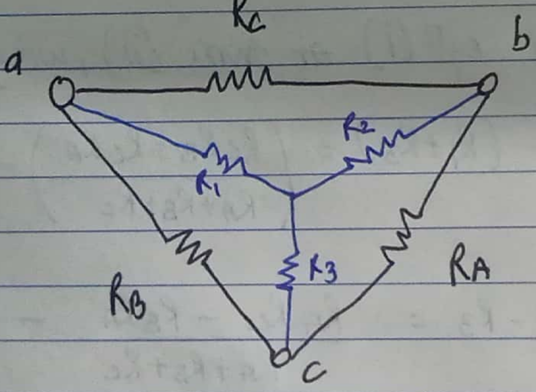
$$(R_2+R_3)-(R_2-R_3) = \left(\frac{R_A R_B + R_A R_C}{R_A+R_B+R_C}\right) - \left(\frac{R_A R_C - R_B R_A}{R_A+R_B+R_C}\right)$$

or, $$2R_3 = \frac{2R_A R_B}{R_A+R_B+R_C}$$

$$\therefore R_3 = \frac{R_A R_B}{R_A+R_B+A_C.} \quad \text{—(v)}$$

Similarly,

$$R_1 = \frac{R_B R_C}{R_A+R_B+R_C} \quad \text{—(vi)} \qquad R_2 = \frac{R_A R_C}{R_A+R_B+R_C.} \quad \text{—(vii)}$$



Note: Each resistor of the Y is equal to the product of the resistors in the two closest branches of Δ divided by the sum of total resistor in Δ.

For Y to Δ.

Dividing eq^n(v) by eq^n(vi).

$$\frac{R_3}{R_1} = \frac{(R_A R_B)}{(R_A+R_B+\cancel{B_C}R_C)} \times \frac{(R_A+R_B+R_C)}{(R_B R_C)}$$

$$\therefore R_A = \frac{R_3 R_C}{R_1} \quad \text{—(viii)}$$

Then,

Dividing eq^n(v) by eq^n(vii),

$$\frac{R_3}{R_2} = \frac{(R_A R_B)}{(R_A+R_B+R_C)} \times \frac{(R_A+R_B+R_C)}{(R_A R_C)}$$

$$\therefore R_B = \frac{R_3 R_C}{R_2} \quad \text{—(ix)}$$

Substituting for R_A and R_B in eq^n(vii),

$$R_2 = \frac{\left(\frac{R_3 R_C}{R_1}\right) R_C}{\left(\frac{R_3 R_C}{R_2}\right) + \left(\frac{R_C R_3}{R_1}\right) + R_C}$$

$$= \frac{(R_3 R_C)/R_1}{(R_1R_2 + R_1R_3 + R_3R_2)/R_1R_2}$$

$$\text{or, } R_2 = \frac{R_C R_2 R_3}{R_1R_2 + R_1R_3 + R_2R_3}$$

$$\therefore R_C = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_3} \quad \text{——} (x)$$

Similarly,

$$R_A = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1} \qquad R_B = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2}$$

Note: The value of each resistor of the Δ is equal to the sum of the possible product combinations of the resistance of the Y divided by the resistance of the Y farthest from the resistor to be determined.

Special Case:

If $R_1 = R_2 = R_3 = R$ or $R_A = R_B = R_C = R$

then,

$$R_A = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1} = \frac{3R^2}{R} = 3R$$

$$\therefore R_A = 3R = R_B = R_C.$$

$$\text{So, } R_\Delta = 3R_Y$$

{Num. No. 30/31/32 ⇒ In numerical c/M}