Model Question and Answer
Basic Electrical Engineering (2019 course)

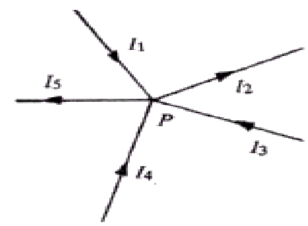
Unit 02: D. C. Circuit

Q1: State and explain Kirchhoff's law. **(6)**

Ans

Kirchhoff's stated two simple laws-one for current meeting at any point and other for voltage around closed loop.

1. Kirchhoff's Current Law or Point Law :



"In any Point or junction, the sum of current flowing towards junction is equal to the sum of current flowing away from a junction."

"The algebraic sum of all the currents meeting at a junction is zero.".

In fig., shows at point P, current flowing towards junctions are I_1, I_3 and I_4 while current flowing away from it are I_2 and I_5.

As per KCL statement current entering the junction = Current going away from junction.

$$I_1 + I_3 + I_4 = I_2 + I_5$$

or $\quad I_1 + I_3 + I_4 - I_2 - I_5 = 0$

i.e. $\quad \sum$ I at a junction $= 0$

2. Kirchooff's Voltage Law :

Statement, "In a closed loop (mesh) the algebraic sum of voltage drops are equal to the algebraic sum of voltage rise".

Or

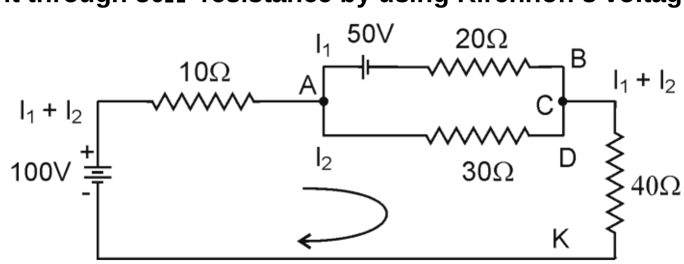
"In a closed loop, the algebraic sum of all voltages are equal to zero".

Or

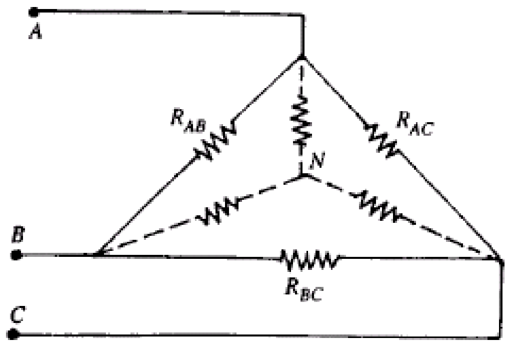
$\sum$ EMF + $\sum$ I.R = 0

or $\quad \sum$ V in a closed path = 0

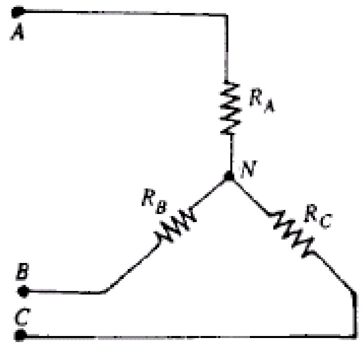
Q2: **Find current through 30Ω resistance by using Kirchhoff's voltage law.** **(6)**



Ans	**Solution :** For solving this problem, first remark actual current in each branch means I_1, I_2 etc. Then take assumed direction for each loop separately. **Equation for loop ABCDA :** **50V :** For this source, consider only assumed direction. It is going from –ve to +ve terminal. Hence it is voltage rise. **$20I_1$:** For this resistance, consider both actual and assumed direction of current. Since both are in the same way, it will be voltage drop. **$30I_2$:** In the 30Ω resistance, consider both actual direction and assumed direction of current. Since both are in opposite way so it will be voltage rise. Hence equation for loop ABCDE : $-20 I_1 + 30 I_2 + 50 = 0$ or $2 I_1 - 3 I_2 = 5$ .... (1) Equation for loop ADCKA : $100 - 10 (I_1 + I_2) - 30 I_2 - 40 (I_1 + I_2) = 0$ or $5 I_1 + 8 I_2 = 10$ .... (2) Solve equation (1) and (2) $5 \times [2 I_1 - 3 I_2] = 5$ .... (1) $2 \times [5 I_1 + 8 I_2] = 10$ .... (2) On subtraction $-31 I_2 = 5$ $\therefore \quad I_2 = \frac{-5}{31} = -0.1612$ Amp. Hence current through 30Ω resistance is 0.1612 Amp from D to A.	
Q3:	Derive the formula for Delta to star transformation	
Ans	Consider three resistances R_{AB}, R_{BC}, R_{AC} are forming a delta. Let R_A, R_B, R_C be their star equivalent which are connected at points A, B and C. Both these delta and star are equivalent to each other means total resistance between A and B in delta is equal to total resistance between A and B in star. Equivalent resistance between A and B in delta $= \frac{R_{AB} (R_{BC} + R_{AC})}{R_{AB} + R_{BC} + R_{AC}}$	



(a) Delta Connection



(b) Star connection

Since C point is not connected anywhere so R_{AC} and R_{BC} are in series which is in parallel with R_{AB}.

The equivalent resistance between A and B in star.

$$= \quad R_A + R_g.$$

Since both delta and star are equivalent to each other.

Hence,

$$R_A + R_B = \frac{R_{AB}\,(R_{BC} + R_{AC})}{R_{AB} + R_{BC} + R_{AC}} \qquad (1)$$

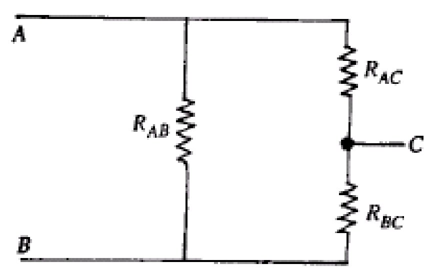
Similarly,

$$R_B + R_C = \frac{R_{BC}\,(R_{AB} + R_{AC})}{R_{AB} + R_{BC} + R_{AC}} \qquad (2)$$

$$R_A + R_C = \frac{R_{AC}\,(R_{AB} + R_{BC})}{R_{AB} + R_{BC} + R_{AC}} \qquad (3)$$

Equation (3) and Equation (2),

$$R_A - R_B = \frac{R_{AB}\,(R_{AC} - R_{BC})}{R_{AB} + R_{BC} + R_{AC}} \qquad (4)$$



(c) Star connection

Now add Equations (1) and (4),

$$2R_A = \frac{2R_{AB}.R_{AC}}{R_{AB} + R_{BC} + R_{AC}} \qquad \therefore \qquad \boxed{\mathbf{R_A = \frac{R_{AB}.R_{AC}}{R_{AB} + R_{BC} + R_{AC}}}}$$

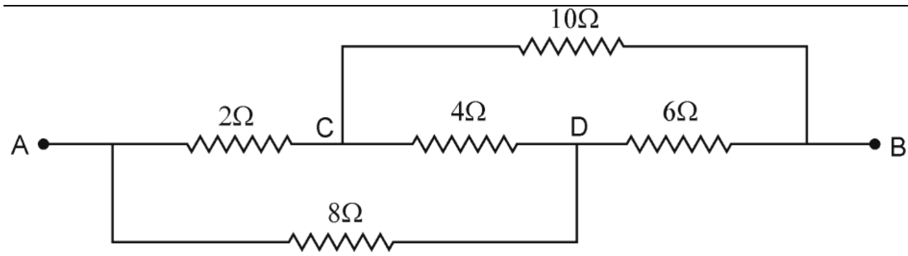
Similarly subtract equations (3) from (2) and add equation (1)

$$\boxed{\mathbf{R_B = \frac{R_{BC}.R_{BC}}{R_{AB} + R_{BC} + R_{AC}}}}$$

Similarly subtract equations (1) from (3) and add equation (2),

$$\boxed{\mathbf{R_C = \frac{R_{AC}.R_{BC}}{R_{AB} + R_{BC} + R_{AC}}}}$$

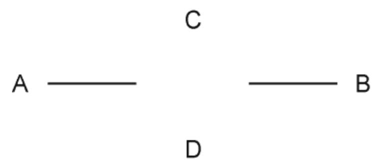
Qu 4:

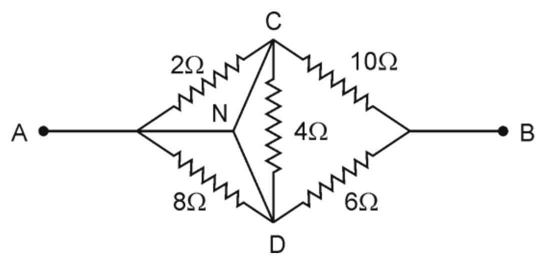


Find equivalent resistance between A and B in the network shown in fig.

Ans.

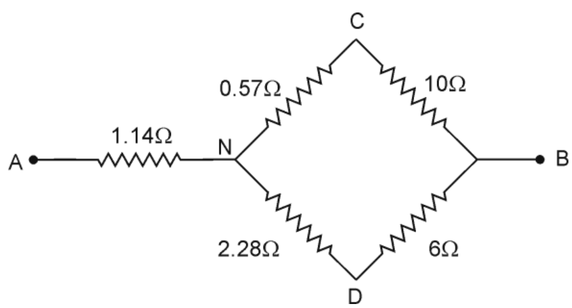
Solution : The given network can be simplified. First remark the names to each junction (say A, B, C etc.) and try to convert the network into delta fashion.

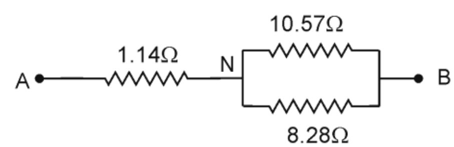


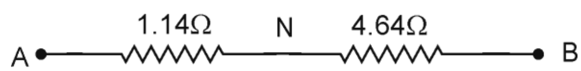


Join all points by resistance of given value.

In fig. (c), branches ACD are forming delta. Convert this delta into equivalent star.







Here,

$$R_A = \frac{2 \times 8}{2 + 8 + 4} = 1.14\Omega$$

$$R_C = \frac{2 \times 4}{14} = 0.57\Omega$$

$$R_D = \frac{8 \times 4}{14} = 2.28\Omega$$

In fig. (e), 10.57 and 8.28 are in parallel = $\frac{10.57 \times 8.28}{10.57 + 8.28} = 4.64\ \Omega$

Req. = 1.14 + 4.64 = 5.78Ω

Qu 5: Derive the formula for star to Delta transformation

Ans.

Star to Delta Transformation. The basic equation guiding this conversion remain the same.

$$R_A = \frac{R_{AB}.R_{AC}}{R_{AB} + R_{BC} + R_{AC}} \quad \dots (A)$$

$$R_B = \frac{R_{BC}.R_{BC}}{R_{AB} + R_{BC} + R_{AC}} \quad \dots (B)$$

$$R_C = \frac{R_{AC}.R_{BC}}{R_{AB} + R_{BC} + R_{AC}} \quad \dots (C)$$

Now,

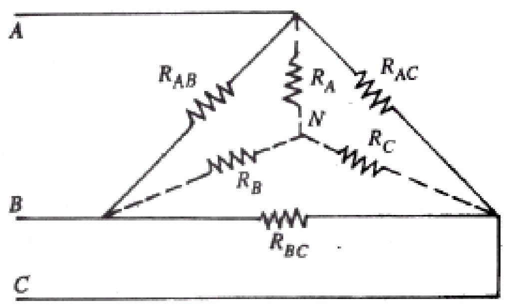
Eqn. (A) x Eqn. (B) + Eqn. (B) x Eqn. (C) + Eqn. (C) x Eqn. (A),

$$R_AR_B + R_BR_C + R_AR_C = \frac{R^2_{AB}.R_{BC}.R_{AC} + R_{AB}.R^2_{BC}.R_{AC} + R_{AB}.R_{BC}.R^2_{AC}}{(R_{AB} + R_{BC} + R_{AC})^2} \quad (D)$$

$$= \frac{R_{AB}.R_{BC}.R_{AC}\,(R_{AB} + R_{BC} + R_{AC})}{(R_{AB} + R_{BC} + R_{AC})^2} = \frac{R_{AB}.R_{BC}.R_{AC}}{(R_{AB} + R_{BC} + R_{AC})}$$

Divide equation (D) by equation (C),

$$\frac{R_AR_B}{R_C} + R_A + R_B = R_{AB}$$



Hence, $\boxed{\mathbf{R_{AB} = R_A + R_B + \frac{R_AR_B}{R_C}}}$ ... (E)

Similarly from Fig.

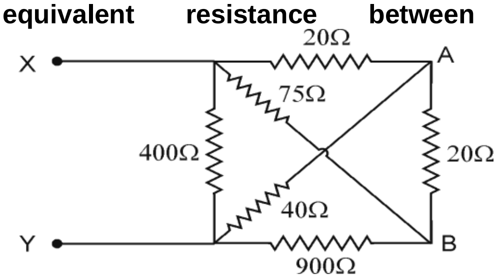
$\boxed{\mathbf{R_{BC} = R_B + R_C + \frac{R_BR_C}{R_A}}}$ ... (F)

$\boxed{\mathbf{R_{AC} = R_A + R_C + \frac{R_AR_C}{R_B}}}$ ... (G)

Relationships expressed from equations (E) to (G) are used to convert a star connected network into its equivalent delta.

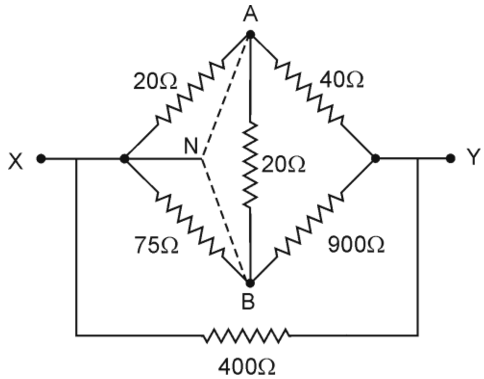
Qu 6:

Find equivalent resistance between X and Y as shown in fig.



Ans.

Solution : Simplify the circuit.



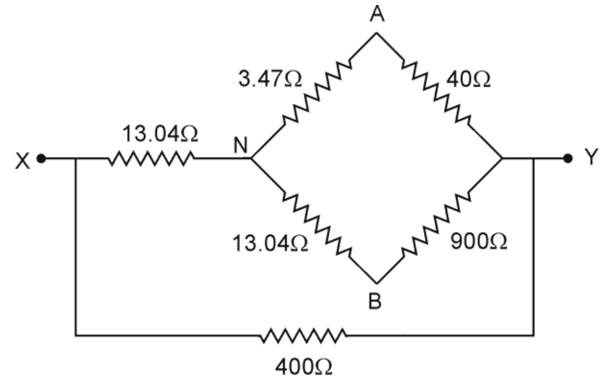


Fig. : (b) **Fig. : (c)**

In fig. (b), branches XAB are forming delta, convert this delta into equivalent star.

$R_X = \frac{20 \times 75}{20 + 20 + 75} = 13.04\Omega$ $R_A = \frac{20 \times 20}{115} = 3.47\Omega$

$R_B = \frac{20 \times 75}{115} = 13.04\Omega$

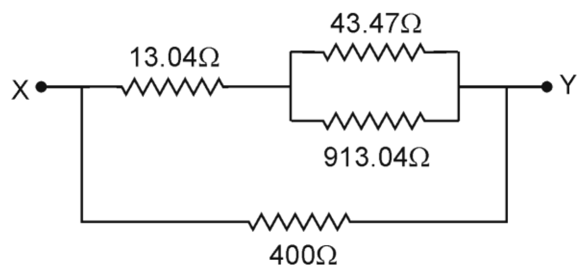


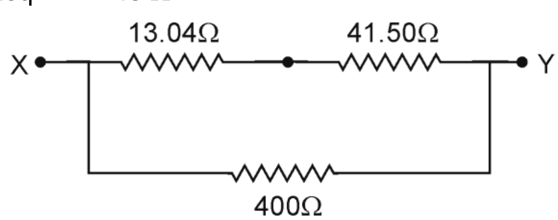
Fig. : (d)

In fig. (d), 43.47 Ω and 913.04Ω are in parallel = $\frac{43.47 \times 913.04}{956.51} = 41.50\Omega$

In fig. (e), 13.04 and 41.5 are in series = 54.54Ω which is in parallel with 400Ω.

$$\text{Req.} = \frac{400 \times 54.54}{454.54} = 48\ \Omega$$

$$\text{Req.} = 48\ \Omega$$



Qu.7: State and explain Superposition Theorem.

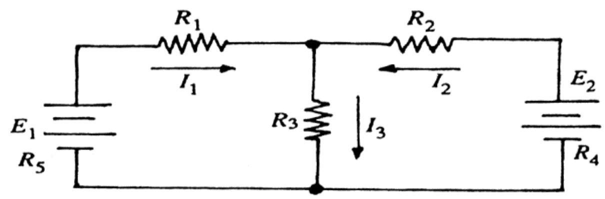
Ans.

Statement :

Superposition theorem states that, in a linear network consisting of more than one source of energy,, the current flowing through any resistance is the sum of all the current flowing through that resistance, produced by each energy source acting alone, all other sources of energy being replaced by their respective internal resistances.

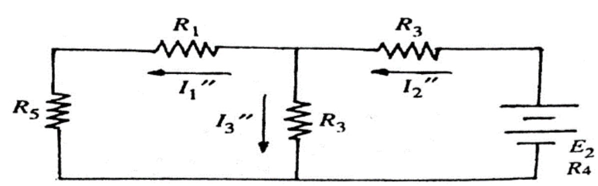
The Superposition theorem can also be used to determine voltage across any component of a multisource electric circuit.

Explanation : In Fig. (a), I_1, I_2 and I_3 are actual currents when both batteries are present in the circuit.



(a)

In Fig. (b), I_1', I_2', and I_3', are actual currents due to E_1 battery is acting in circuit and E_2 is replaced by its internal resistance R_4.



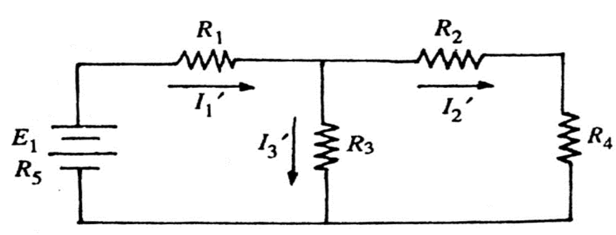
(c)

In Fig. (c), I_1'', I_2'' and I_3'' are actual currents due to E_2 battery is in the circuit and remove E_1 by their internal resistance R_5.

So, actual currents,

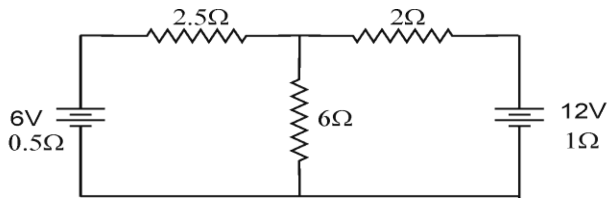
$I_1 = I_1' + (-I_1'') = I_1' - I_1$ $\quad$ $I_2 = I_2'' + (-I_2') = I_2'' - I_2'$

$I_3 = I_3' + I_3''$.



(b)

Qu. 8 **Find current in different branches by superposition theorem.**



Ans.

Step 1 : First of all remark the actual current in each branch.

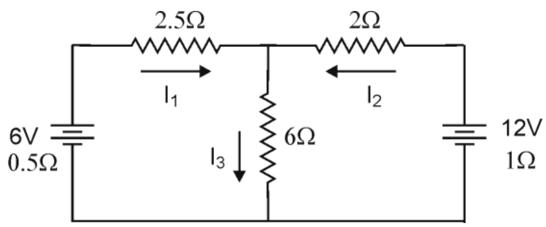


Fig. (b)

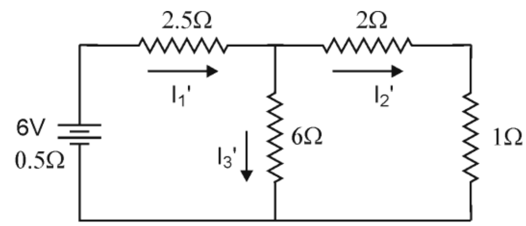


Fig. (c)

Step 2 : Remove12 volt battery by its internal resistance and remark the currents.

Now, 2 & 1 ohms are in series = 3Ω

Now, 6 & 3Ω are in parallel = 6 × 3 – 6 + 3 = 2Ω

Now, 2Ω, 2.5Ω and 0.5Ω are in series = 5Ω

So, I'_1 = 6 / 5 = 1.2 amp.

By applying current division theorem

I'_3 = 1.2 × 6/6 + 3 = 0.8 amp.

I' = 1.2 – 0.8 = 0.4 amp.

Step 3 : Remove 6V battery by its internal resistance and remark the actual current.

Here 0.5Ω & 2.5Ω are in series = 3Ω

3Ω and 6Ω are in parallel = 6 × 3 / 9 = 2Ω

Now, 2Ω, 2Ω and 1 Ω are in series = 5Ω

I''_2 = 12/5 = 2.4 ap.

I'' = 2.4 × 6 / 9 = 1.6 amp.

I''_3 = 2.4 – 1.6 = 0.8 amp.

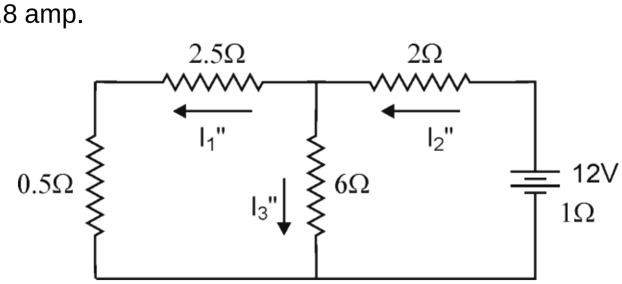


Fig. : (d)

Actual current

I_1 = $I'_1 + (-I''_1)$ = 1.2 – 1.6 = -0.4A

I_2 = $I'_2 + (-I''_2)$ = 2.4 – 0.8 = 1.6A

I_3 = $I'_3 + I''_3)$ = 0.4 + 0.8 = 1.2A

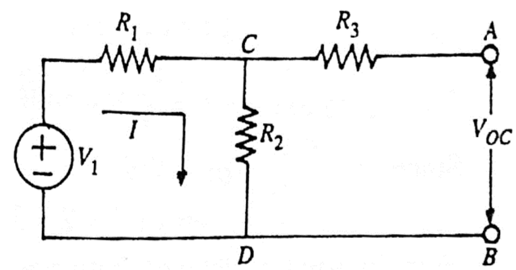
Qu. 9 State and explain Thevenin'**S** Theorem.

Ans.

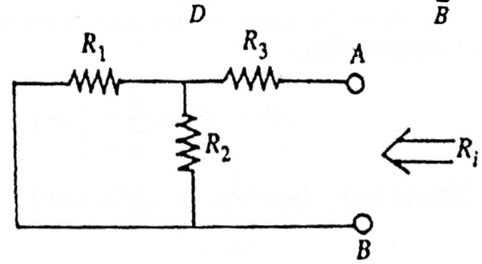
THEVENIN'S THEOREM :

This theorem states that the current through any load resistance, connected across any two points A and B of any linear network, can be obtained by dividing the potential difference these two points A and B with the load resistance, disconnected (called Thevenin's equivalent voltage), by the sum of load resistance and the internal resistance of network measured between these two points A and B with load resistance of disconnected and energy sources are replaced by their internal resistance if any,

i. e., $I_L = \dfrac{V_{OC}}{R_i + R_L}$

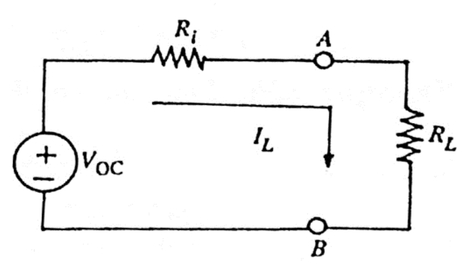


Here V_{OC} is the open circuit voltage developed between two points A and B when load resistance is removed. R_i is the internal resistance between points. A and B when all sources of energy are replaced by their internal resistance if any and R_L is theload resistance whose current is to be determined.



Explanation : If the current is to be determined through points AB, so resistance connected between A and B is called load resistance (R_L).

Step 1 : The first step is to remove load resistance so points A and B will become open. Hence, some potential difference will exist between A and B called as Open circuit voltage or Thevenin's equivalent voltage,



V_{OC} or V_{th}

$V_{OC} = V_{CD} = IR_2$

$V_{OC} = \dfrac{V_1}{R_1 + R_2} \times R_2$.

Step 2 : The second step is to find internal resistance (R_i) of a given network between points A and B. This can be obtained by removing all sources of energy by their internal resistances if any,

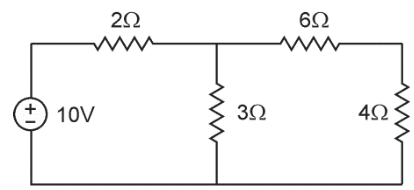
$Ri = \dfrac{R_1 \times R_2}{R_1 + R_2} + R_3$.

If the ideal voltage source is given, so it will be replaced by short circuit and ideal current source is replacing it by open circuit.

Now, Thevenin's equivalent circuit is

$$\therefore \quad I_L = \frac{\mathbf{V_{OC}}}{\mathbf{R_i + R_L}} \qquad \text{.... (1)}$$

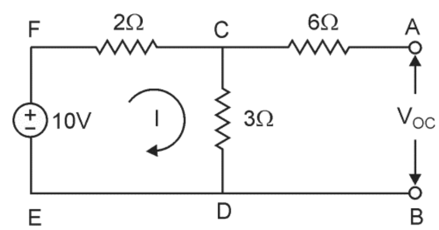
Qu. 10 Find current through 4 Ω by using thevenin's theorem.



(a)

Ans.

Solution : Remove 4Ω resistance from points A and B, calculate open circuit voltage between points AB (V_{OC}).



(b)

Apply KVL in loop FECDE and find current through CD branch,

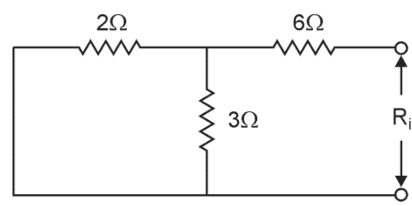
$$10 = (2 + 3)\, I$$

$$\therefore \quad I = \frac{10}{5} = 2 \text{ Amp.}$$

Since, $\quad V_{OC} = V_{CD}$

$$I \times 3 = 2 \times 3 = 6\text{V}.$$

Find internal resistance between A and B when all sources of energy are replaced by their internal resistances.

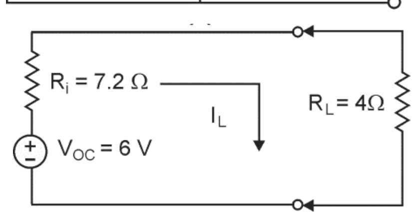


$$R_i = \frac{2 \times 3}{2 + 3} + 5 = 7.2\ \Omega$$

Draw the Thevenin's equivalent circuit,

$$\therefore \quad I_L = \frac{V_{OC}}{R_i + R_L}$$

$$= \frac{6}{7.2 + 4} = \frac{6}{11.2} = 0.535 \text{ Amp.}$$



(d)