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Information and
Communication Technology

DC Circuit

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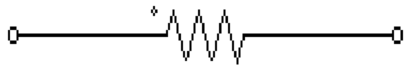
Electrical Engineering

Content

Electrical circuit elements

Resistance : “The opposition offered by a substance to the flow of electric current is called resistance .”

- When the potential difference is applied to a conductor , the current start to flow or the free electrons start moving.
- While moving , the free electrons collide with the atoms and molecules of the conductors .
- Because of collision the rate of flow of electrons or current is restricted.
- Resistance measured in ohm (Ω) and denoted with (R, r)



Symbolic representation of resistor

Factors affecting to Resistor

1) Length of conductor : when length of conductor is increased resistance increase . In other word we can say that resistance is directly proportional to length of the conductor.

2) Area of conductor : When area of conductor is changed whether increase or decrease resistance of conductor can change with decrease and increase. In simple world we can say that resistance is inversely proportional to the area .

3) Temperature : Resistance can increase if temperature is increase and can decrease as the temperature decrease

Mathematically, $R = \rho\, l/a \quad \Omega$

Inductance

- Inductance is the one kind of property of material which can store the energy in the form of magnetic energy . In circuit when the current is change with time at that time only inductor can exhibited.
- Inductance is the nature of the coil by which it opposes any small change of direction of the current when it flows through the coil.
- When the current is passing in to the coil it creates magnetic field around it and if the any change in the current magnitude, magnetic field also change according that induced emf also change .
- So we can understand that inductance of the coil depends upon the rate of change of current.

Image source : Google

Inductance

- Mathematically,

$$\mathbf{V = L(dI/dt)\ volt}$$

- Where V is the voltage, L is the inductance, I is the current and t is the time period.

- Inductance, ‘L’, is measured in Henrys, named after Joseph Henry, the American scientist who discovered electromagnetic induction.

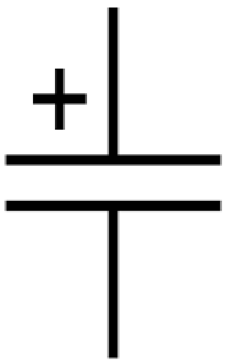
Capacitance

- Capacitance is a two-terminal element that has the capability of charge storage and so we can say that it can stored energy in the form of voltage.
- Mathematically, the *capacitance* of a conductor is defined by

  C= Q/V (farad)

- Where Q charges and V is the potential difference.
- The current through the capacitor is proportional to the derivative of voltage across capacitor and is given by expression

  I = C dv/dt amp



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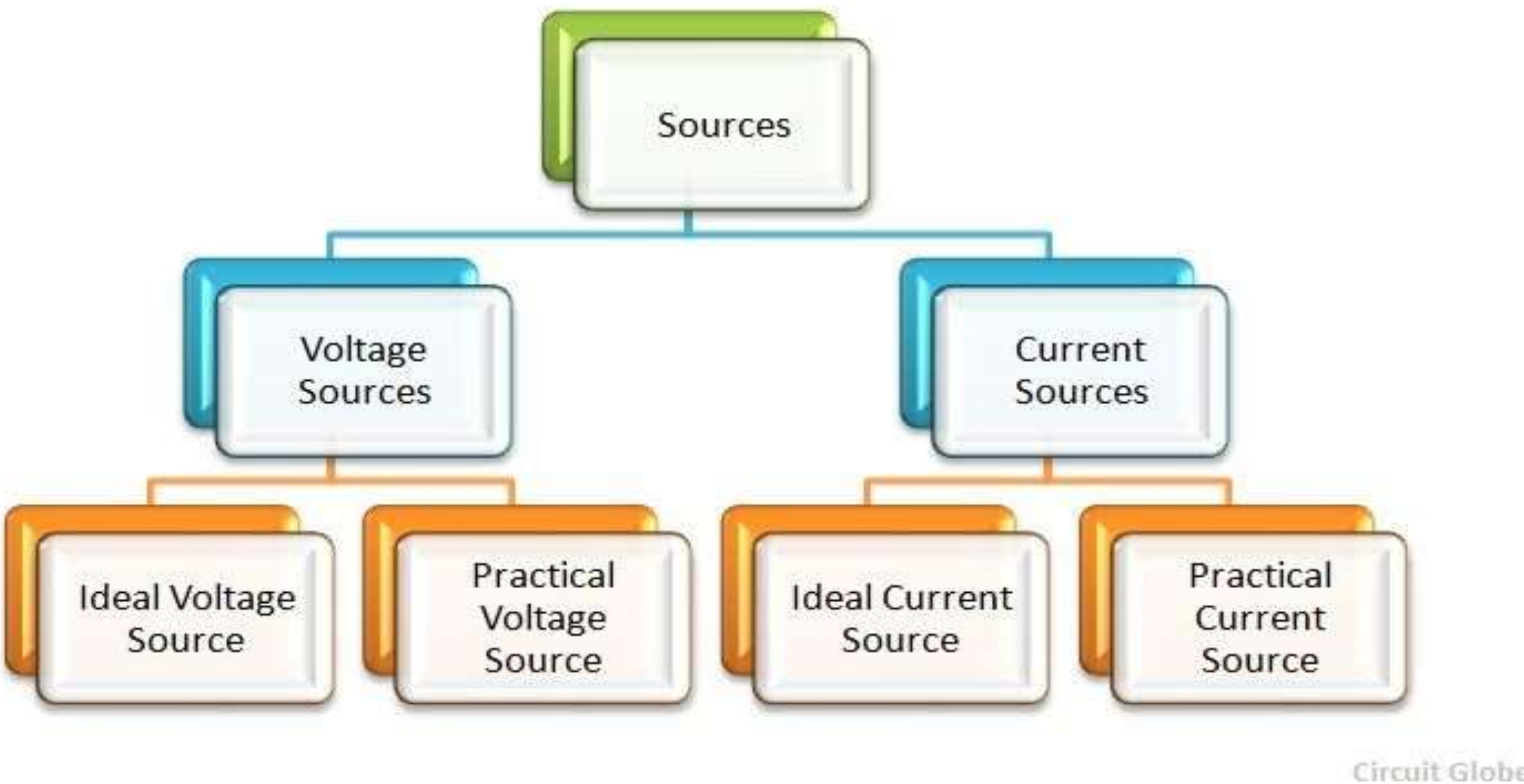
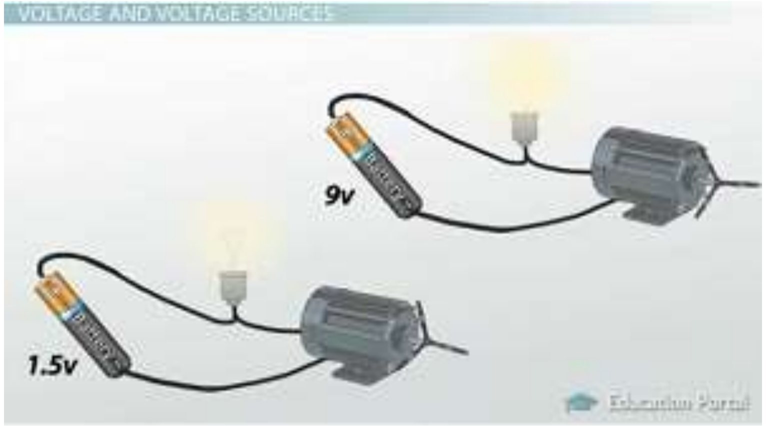
Classification of sources



Voltage Source

- Voltage source which is most commonly used. Voltage source is in fact a passive element which can create a continuous force for the movement of electrons through the wire in which it is connected. It is usually a two-terminal device.



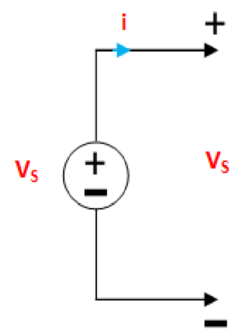
Types of Voltage Source

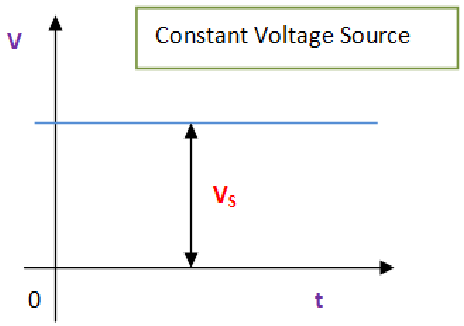
- Independent Voltage Source: They are of two types – Direct Voltage Source and Alternating Voltage Source.

- Dependent Voltage Source: They are of two types – Voltage Controlled Voltage Source and Current Controlled Voltage Source.

Independent Voltage Source

- The voltage source which can deliver steady voltage (fixed or variable with time) to the circuit and it does not depend on any other elements or quantity in the circuit.



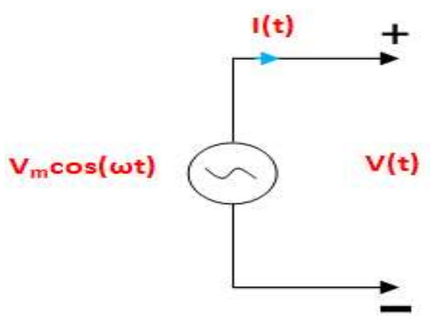


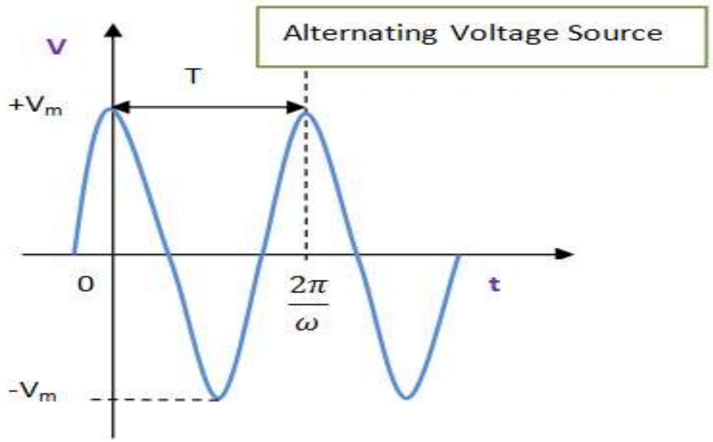
Direct Voltage Source or Time Invariant Voltage Source

- The voltage source which can produce or deliver constant voltage which can produce or deliver constant voltage as output is termed as Direct Voltage Source.
- The flow of electrons will be in one direction that is polarity will be always same.
- The movement of electrons or current which can produce or deliver constant voltage as output is termed as Direct Voltage Source.
- The flow of electrons will be in one direction that is polarity will be always same.
- The movement of electrons or current will be in one direction always. The value of voltage will not alter with time. Example: DC generator which can produce or deliver constant voltage as output is termed as Direct Voltage Source.
- The flow of electrons will be in one direction that is polarity will be always same. The movement of electrons or current will be in one direction always. The value of voltage will not alter with time. Example: DC generator, battery, Cells etc.

Alternating Voltage Source

- The voltage source which can produce or deliver alternating voltage as output is termed as Alternating Voltage Source. Here, the polarity gets reversed at regular intervals.
- This voltage causes the current to flow in a direction for a time and after that in a different direction for another time. That means it is time varying. Example: DC to AC converter, Alternator etc.



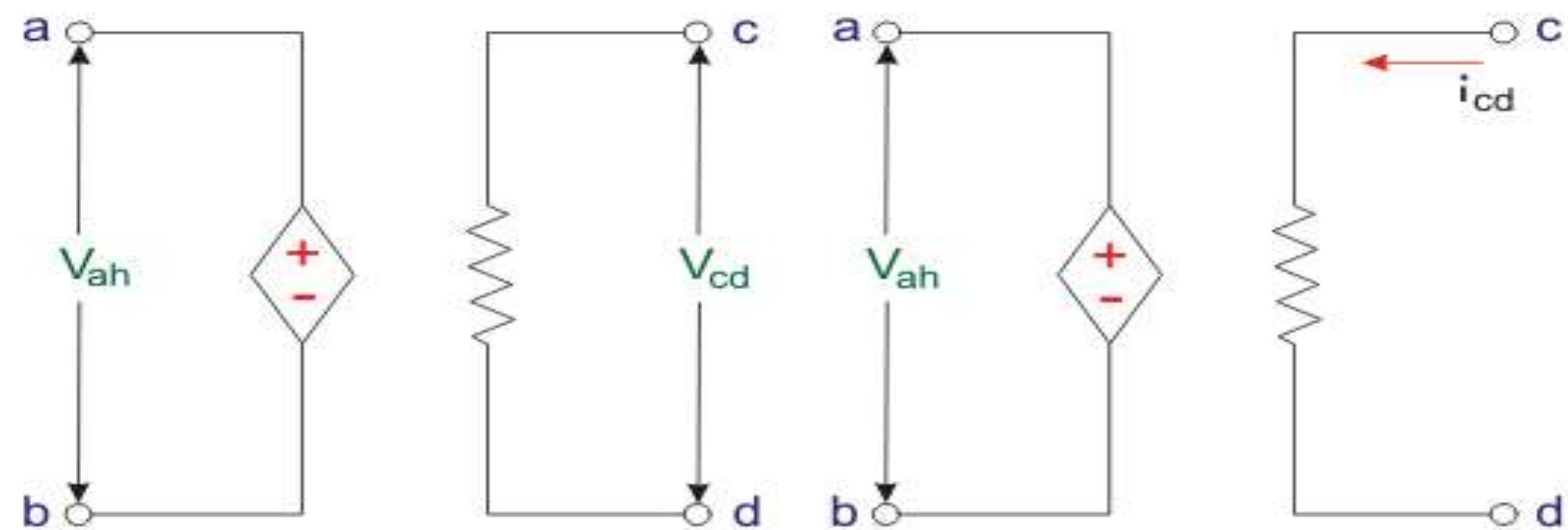


Dependent or Controlled Voltage Source

- The voltage source which delivers an output voltage which is not steady or fixed and it always depends on other quantities such as voltage or current in any other part of the circuit is termed as dependent voltage source. They have four terminals.

- When the voltage source depends on voltage in any other part of the circuit, then it is called Voltage Controlled Voltage Source (VCVS). When the voltage source depends on current in any other part of the circuit, then it is called Current Controlled Voltage Source (CCVS) (shown in figure below).

Dependent or Controlled Voltage Source



$V_{ah} = k\, V_{cd}$

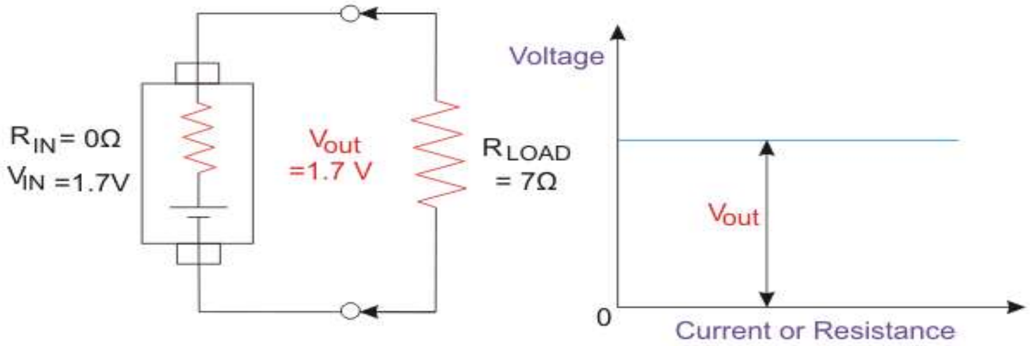
Voltage Controlled Voltage Source

$V_{ah} = r\, i_{cd}$

Current Controlled Voltage Source

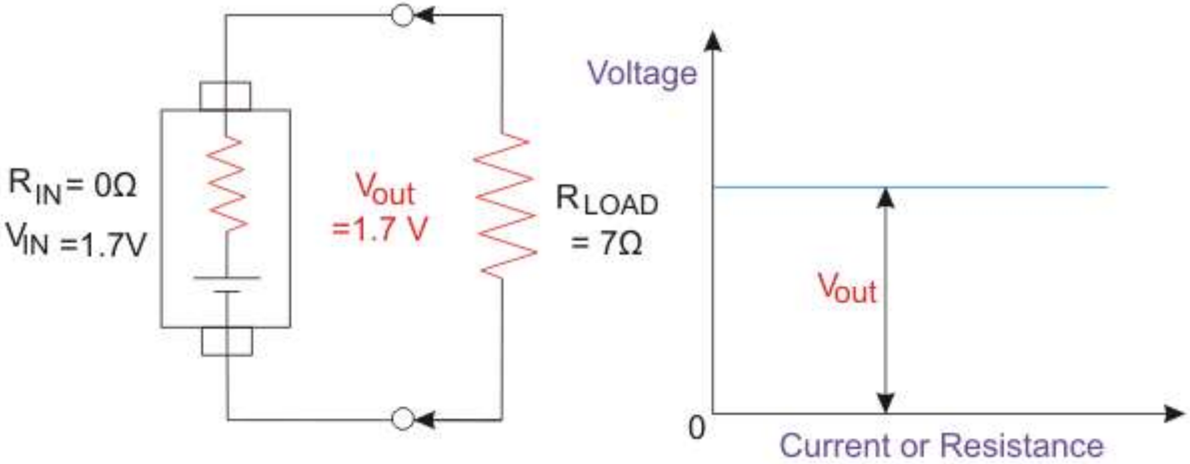
Ideal Voltage Source

- The voltage source which can deliver constant voltage to the circuit and it is also referred as independent voltage source as it is independent of the current that the circuit draws.
- The value of internal resistance is zero here. That is, no power is wasted owing to internal resistance.
- In spite of the load resistance or current in the circuit, this voltage source will give steady voltage. It performs as a 100% efficient voltage source.



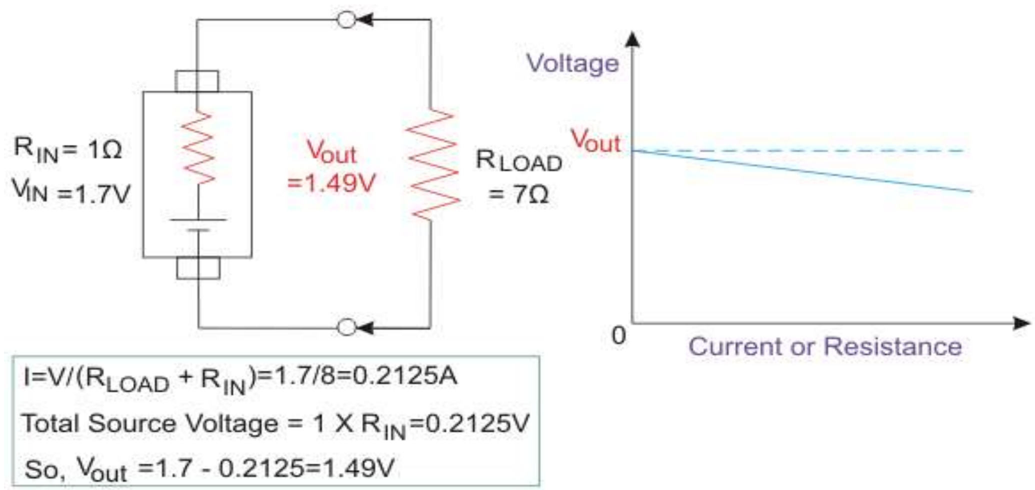
Ideal Voltage Source

- For understanding the ideal voltage source, we can take an example of a circuit shown above.
- The battery shown here is an ideal voltage source which delivers 1.7V. The internal resistance RIN = 0Ω. The resistance load in the circuit RLOAD = 7Ω. Here, we can see the load will receives all of the 1.7V of the battery.



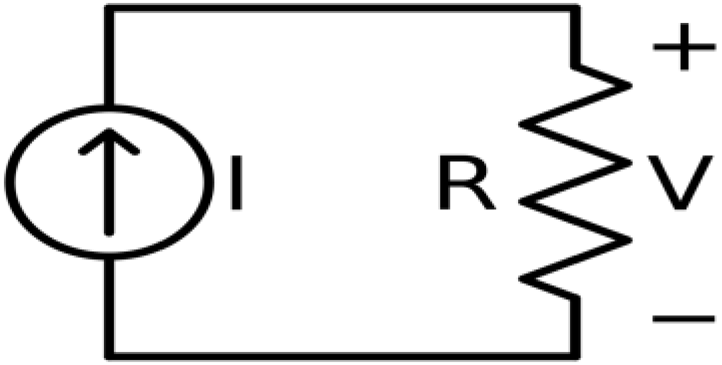
Real or Practical Voltage Source

- Next, we can consider a circuit with practical voltage source having an internal resistance of 1Ω in the similar circuit which is explained above.
- Due to the internal resistance, there will be small amount of voltage drop in the RIN. So, the output voltage will be reduced to 1.49V from 1.7V. So in practical cases there will be reduction in source voltage due to the internal resistance.



Current source

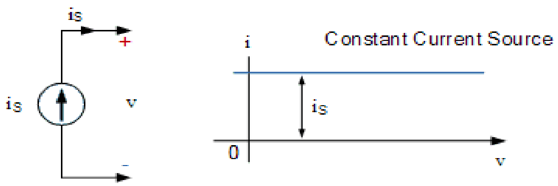
- In an electrical network, current source and voltage source are the basic concepts behind many electrical applications.



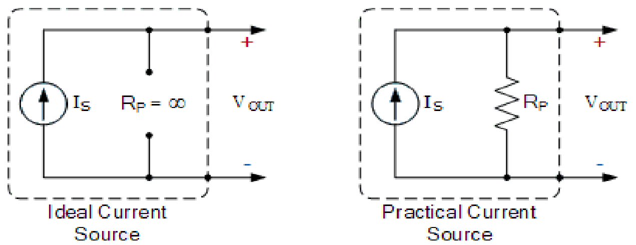
Ideal current source

- A current source which supplies the constant current to connected across the load circuit regardless of the voltage developed across its terminals.
- The loads may be resistive load or inductive load or capacitive load etc. The current source's internal resistance should be infinity. But in practice, we cannot construct ideal current source.

Ideal Current Sources

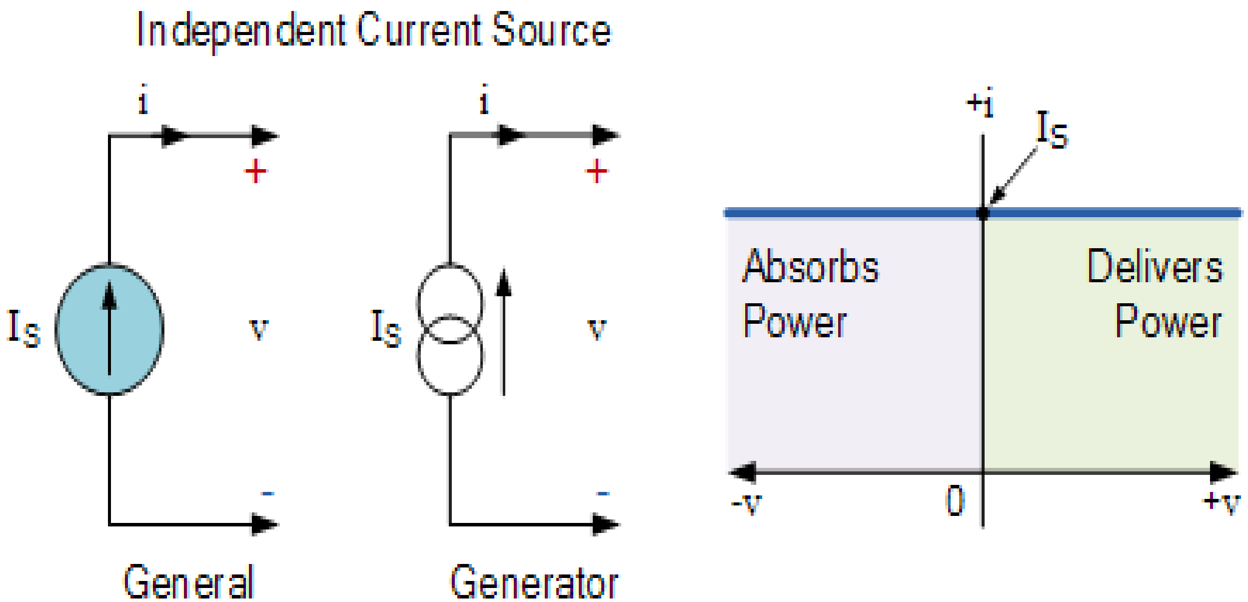


Ideal Current Sources vs Practical Current Sources



Independent current source

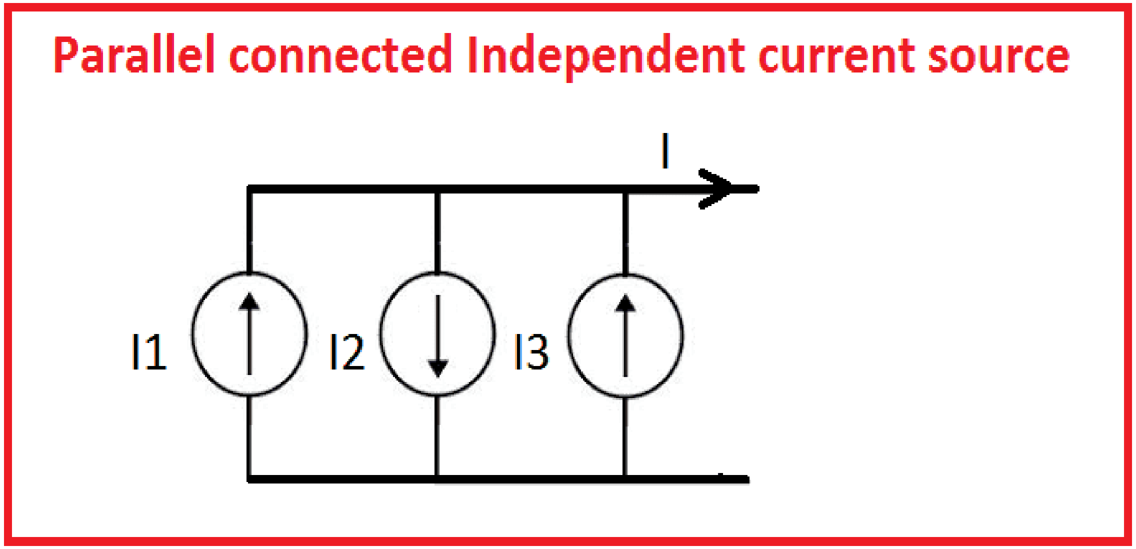
- Supplies constant current to the circuit regardless of the load and the direction of the voltage appearing across its terminal.



Parallel connected Independent current source

- The parallel connected current sources is equivalent to the algebraic sum of single current sources.

$$I = I_1 - I_2 + I_3$$



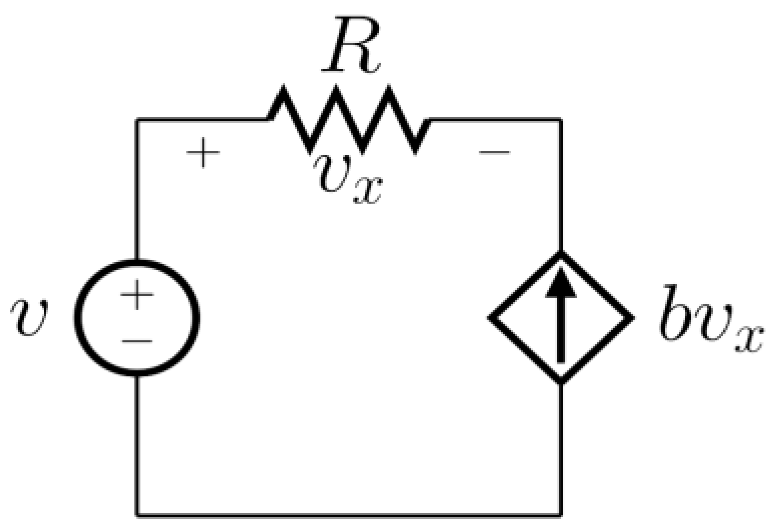
Dependent current sources

- In this, the current source is depending upon a circuit's existing current or voltage sources (the source will be placed in the same circuit, some other location)

- Voltage controlled Current source.
- Current controlled current source.

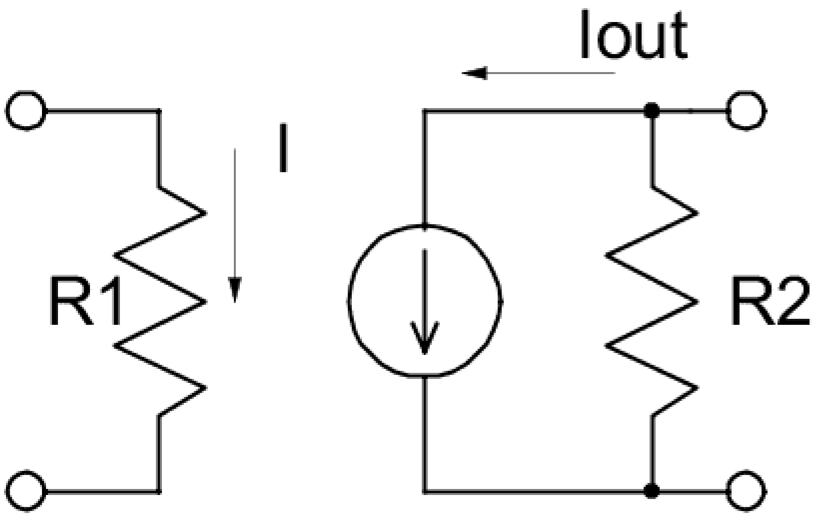
Voltage controlled Current source

- The source delivers the current (flow of electron) as per the voltage of the dependent element in the same network



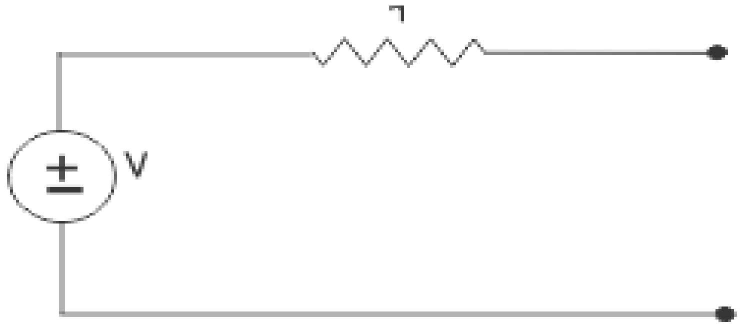
Current Controlled current source

- The source delivers current as per the current of the dependent element in the circuit.



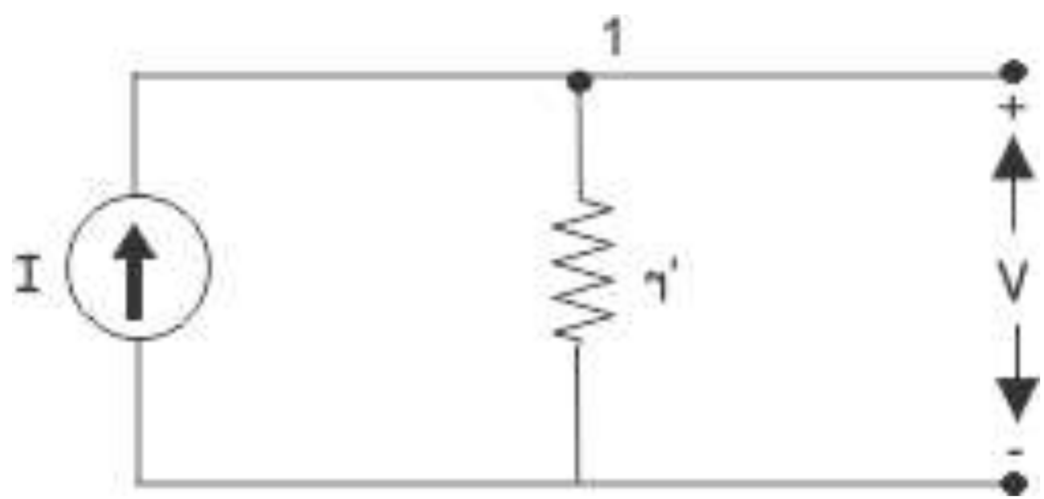
Source Transformation

- Electrical source transformation is a method of replacing voltage source in a circuit by its equivalent current source and current source by its equivalent voltage source.
- The source transformation technique is required to simplify an electric circuit for analysis.
- Let us take a simple voltage source. Let us take a simple voltage source along with a resistance connected in series with it. This series resistance normally represents the internal resistance of a practical voltage source.



Source Transformation

- Now, let us take a current source.
- Now, let us take a current source of same current I which produces same open circuit voltage at its open terminals as shown below,



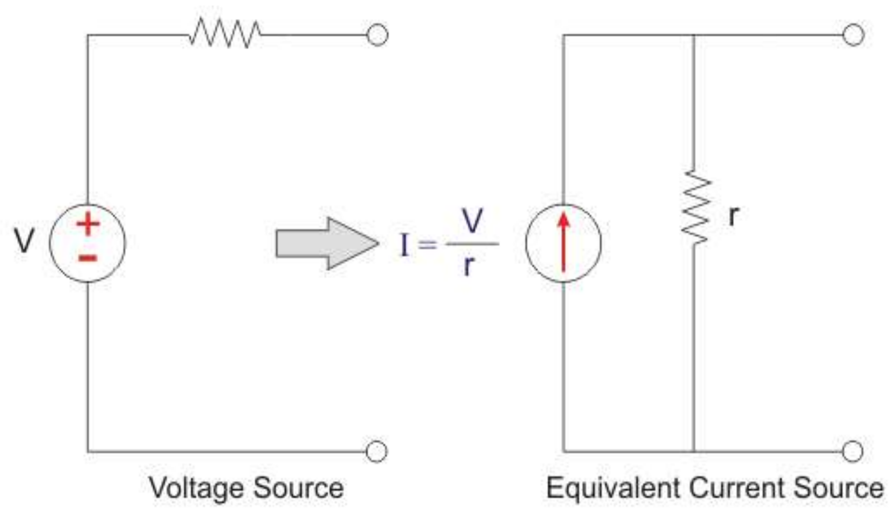
Voltage Source to Current Source Conversion

- Assume a voltage source with terminal voltage V and the internal resistance r.
- This resistance is in series. The current supplied by the source is equal to:
-

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

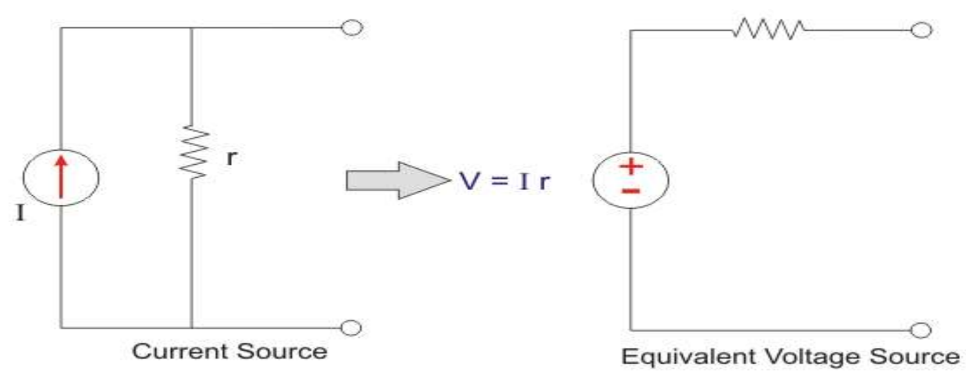
Voltage Source to Current Source Conversion

- When the source of the terminals are shorted.
- This current is supplied by the equivalent current source and the same resistance r will be connected across the source.
- The voltage source to current source conversion is shown in the following figure.



Current Source to Voltage Source Conversion

- Similarly, assume a current source with the value I and internal resistance r.
- Now according to the Ohm's law, the voltage across the source can be calculated as
- Hence, voltage appearing, across the source, when terminals are open, is V.



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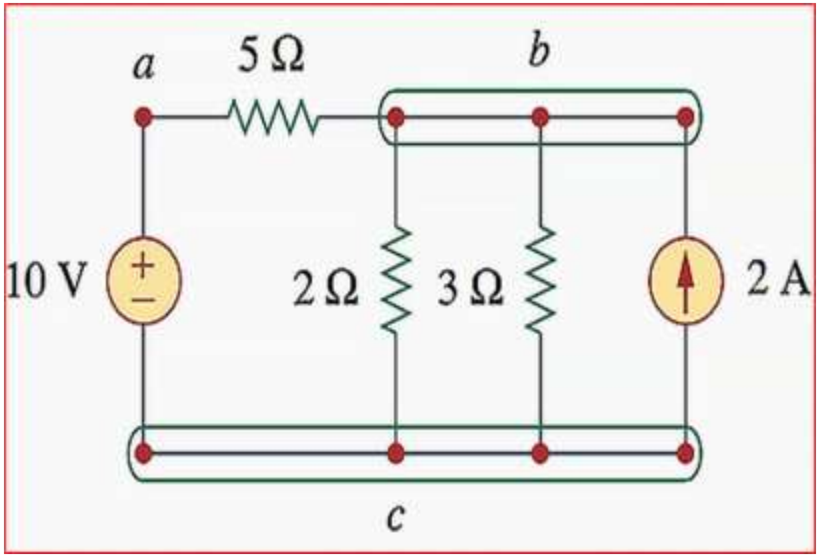
Concept of loop, branches, node

- A branch represents a single element such as a voltage source or a resistor. In other words, a branch represents any two-terminal element.

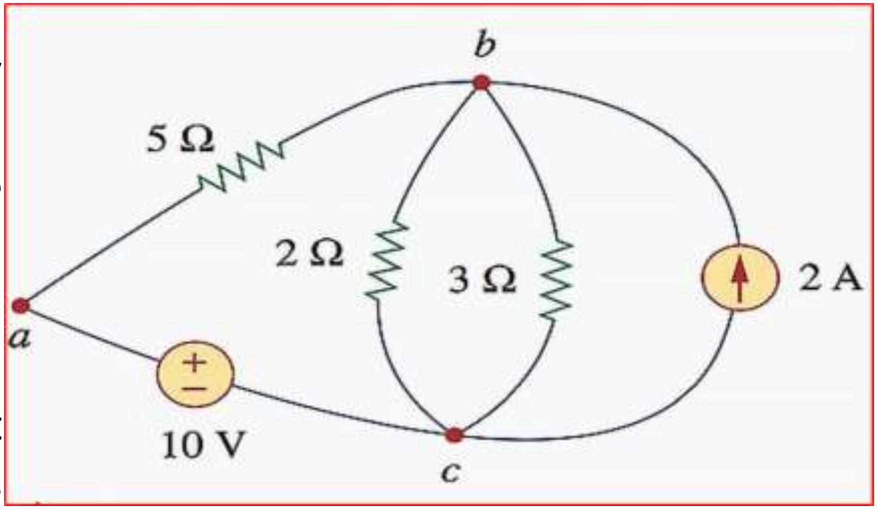
- A node is the point of connection between two or more branches.



What is Loop?

- A loop is any closed path in a circuit.

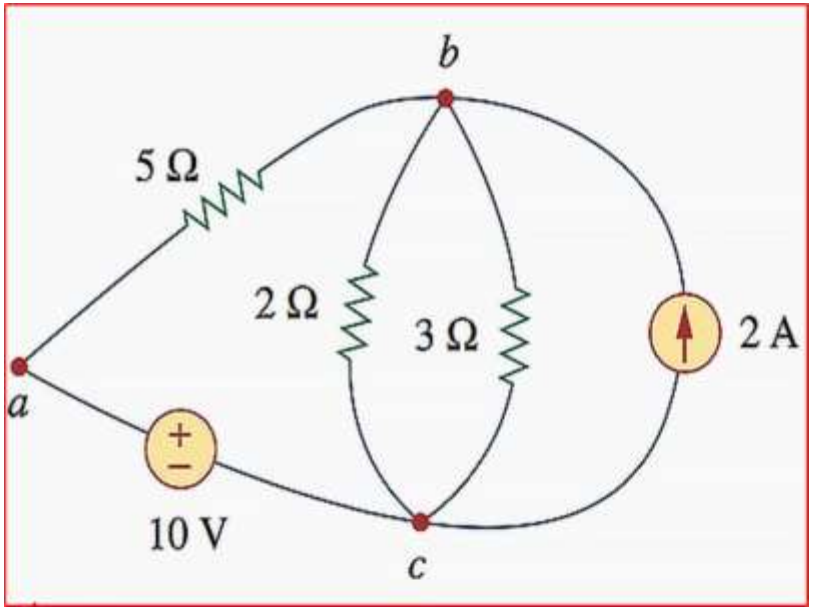
- A loop is a closed path formed by starting at a node, passing through a set of nodes, and returning to the starting node without passing through any node more than once.



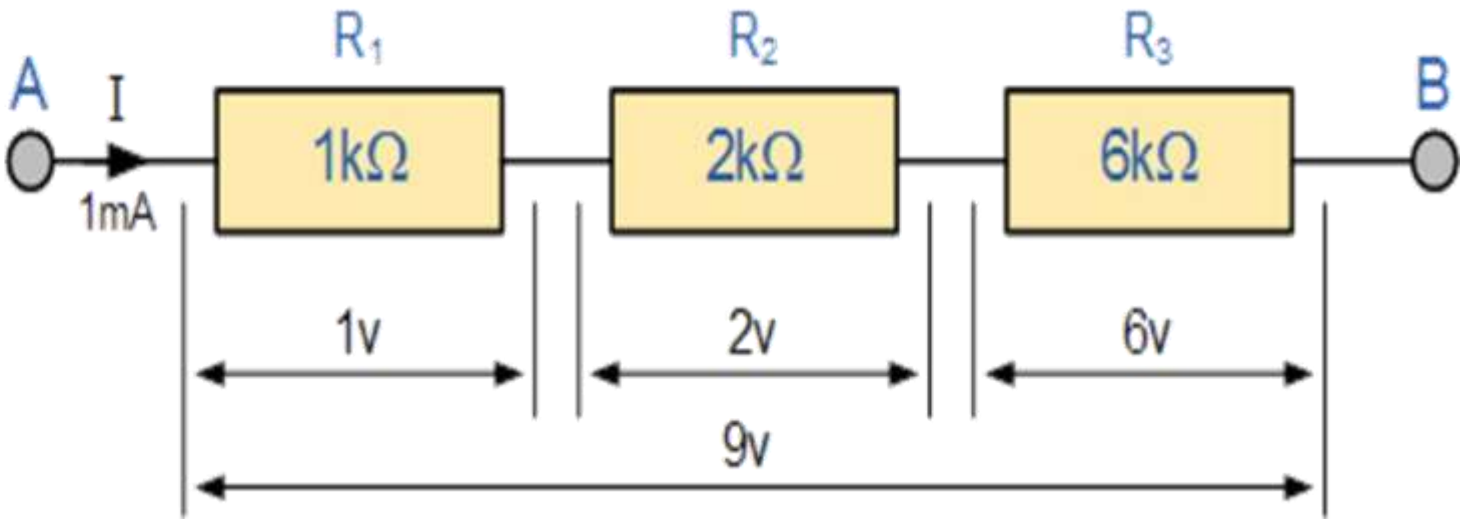
- A loop is said to be independent if it contains at least one branch which is not a part of any other independent loop.
- Independent loops or paths result in independent sets of equations.

Loop concept in diagram

- It is possible to form an independent set of loops where one of the loops does not contain such a branch.
- In Fig. 2, abca with the 2Ω resistor is independent.
- A second loop with the 3Ω resistor and the current source is independent.
- The third loop could be the one with the 2Ω resistor in parallel with the 3Ω resistor. This does form an independent set of loops.



Resistance Connected in series



Resistance Connected in series

- Total resistance in series circuit
- Rt = R1 + R2 + R3

Using Ohm's Law, the voltage across the individual resistors can be calculated as:

Voltage across R1 = IR1 = 1mA x 1kΩ = 1V

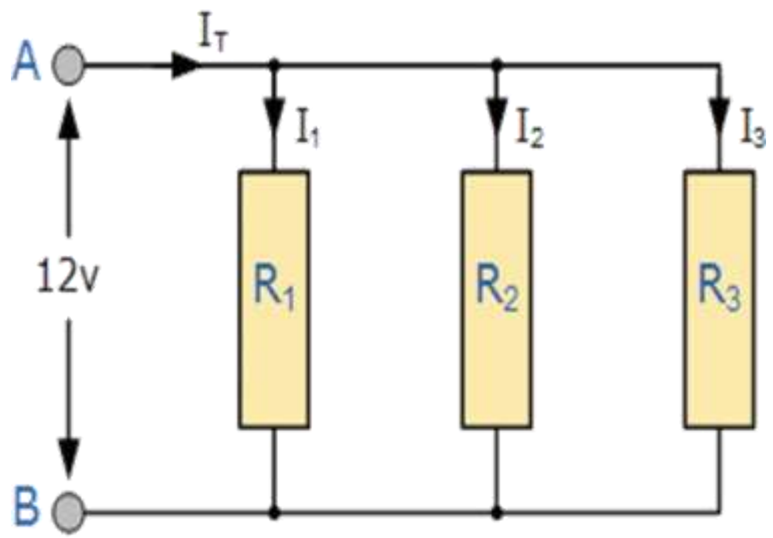
Voltage across R2 = IR2 = 1mA x 2kΩ = 2V

Voltage across R3 = IR3 = 1mA x 6kΩ = 6V

Resistance In Parallel

TOTAL RESISTANCE IN PARALLEL CIRCUITS

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots\ldots + \frac{1}{R_n} \text{ etc}$$

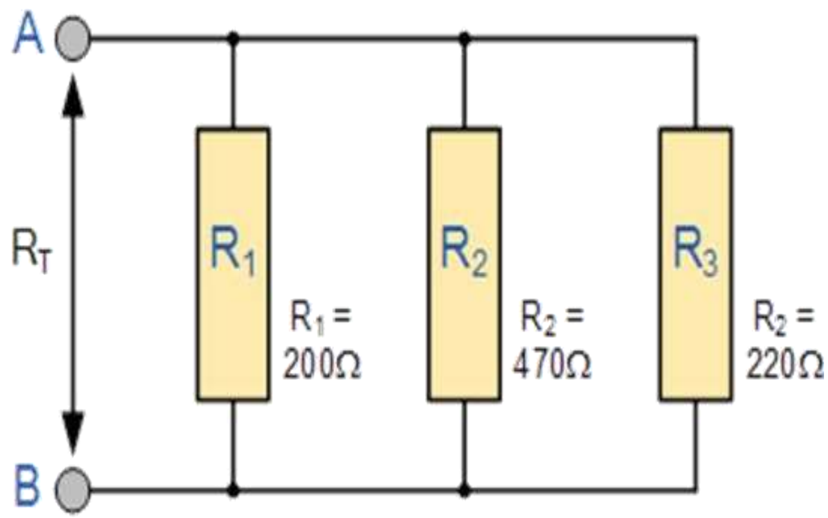


Example Of Parallel Circuit

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{200} + \frac{1}{470} + \frac{1}{220} = 0.0117$$

$$\text{therefore: } R_T = \frac{1}{0.0117} = 85.67\Omega$$



Kirchhoff's Current Law

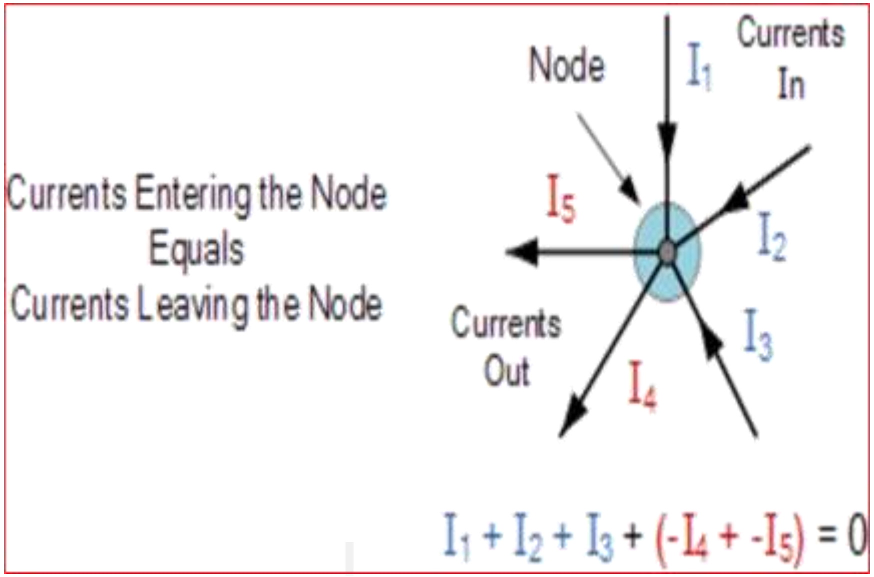
- Kirchhoff's Current Law or KCL,
- states that the "total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node".

- In other words, the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, I(exiting) + I(entering) = 0.

Kirchhoff's Current Law

- Here, the three currents entering the node, I1, I2, I3 are all positive in value and the two currents leaving the node, I4 and I5 are negative in value.
- Then this means we can also rewrite the equation as;
- I1 + I2 + I3 – I4 – I5 = 0

- KCL applying in parallel circuits.

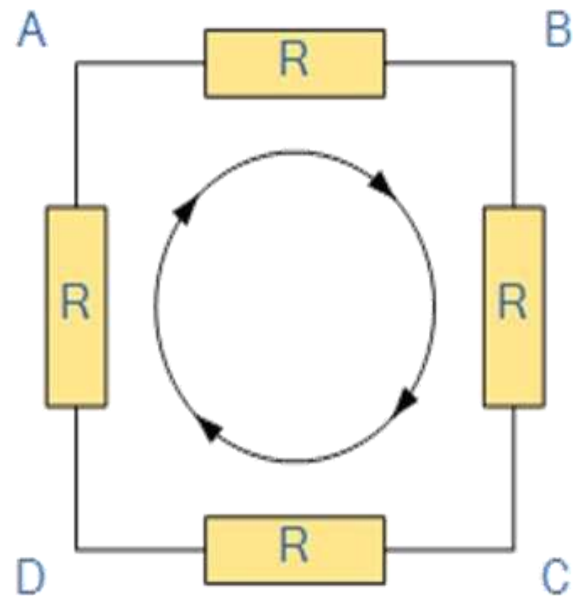


Kirchhoff's Voltage Law

- Kirchhoffs Voltage Law or KVL, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero.
- In other words, the algebraic sum of all voltages within the loop must be equal to zero.

KVL Proof

The sum of all the Voltage Drops around the loop is equal to Zero



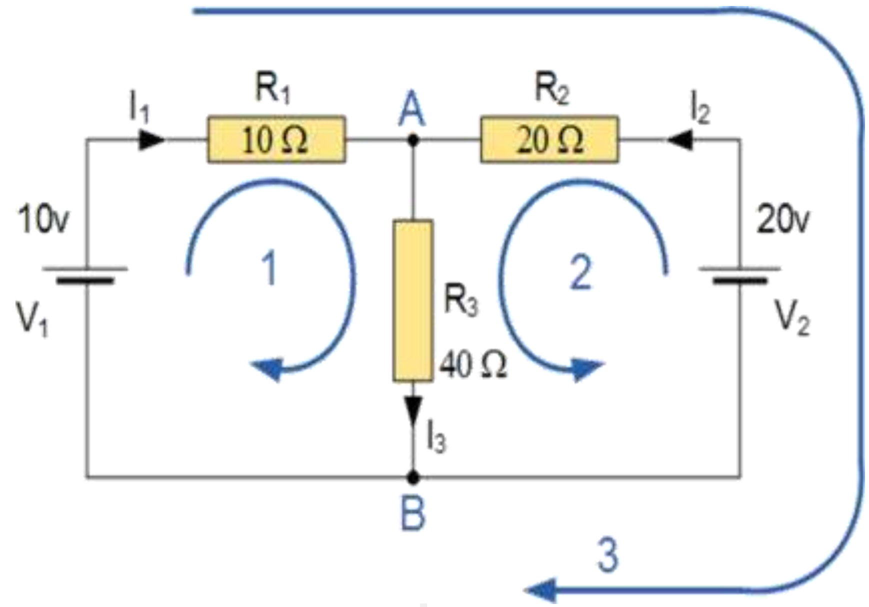
$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

KVL Proof

- Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point.
- It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero.
- We can use Kirchhoff’s voltage law when analysing series circuits.

KVL Proof With Example

- The circuit has 3 branches, 2 nodes (A and B) and 2 independent loops.
- Using Kirchhoff's Current Law, KCL the equations are given as:



At node A : I1 + I2 = I3

At node B : I3 = I1 + I2

KVL Proof With Example

Using Kirchhoff's Voltage Law, KVL the equations are given as:

Loop 1 is given as : $10 = R1\ I1 + R3\ I3 = 10I1 + 40I3$

Loop 2 is given as : $20 = R2\ I2 + R3\ I3 = 20I2 + 40I3$

Loop 3 is given as : $10 – 20 = 10I1 – 20I2$

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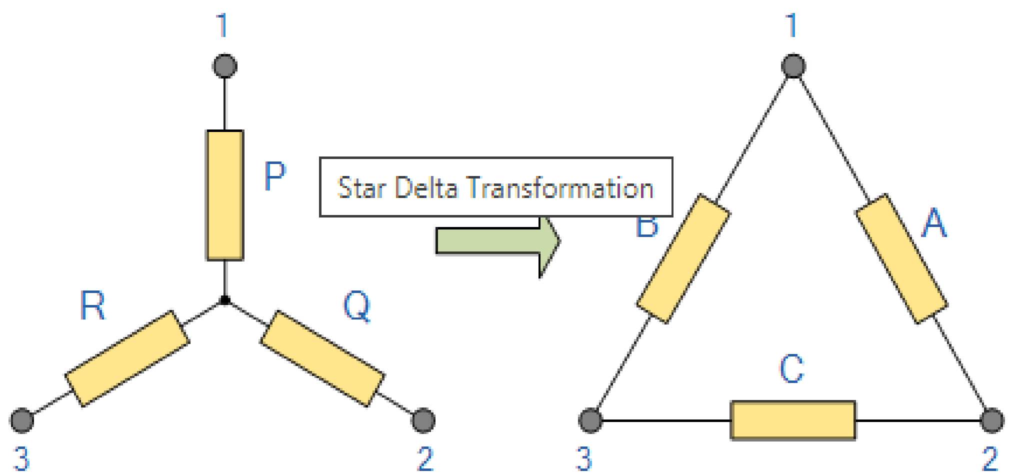
Star-Delta transformation

- The value of the resistor on any one side of the delta, Δ network is the sum of all the two-product combinations of resistors in the star network divide by the star resistor located "directly opposite" the delta resistor being found.
- For example, resistor A is given as:



Star-Delta transformation

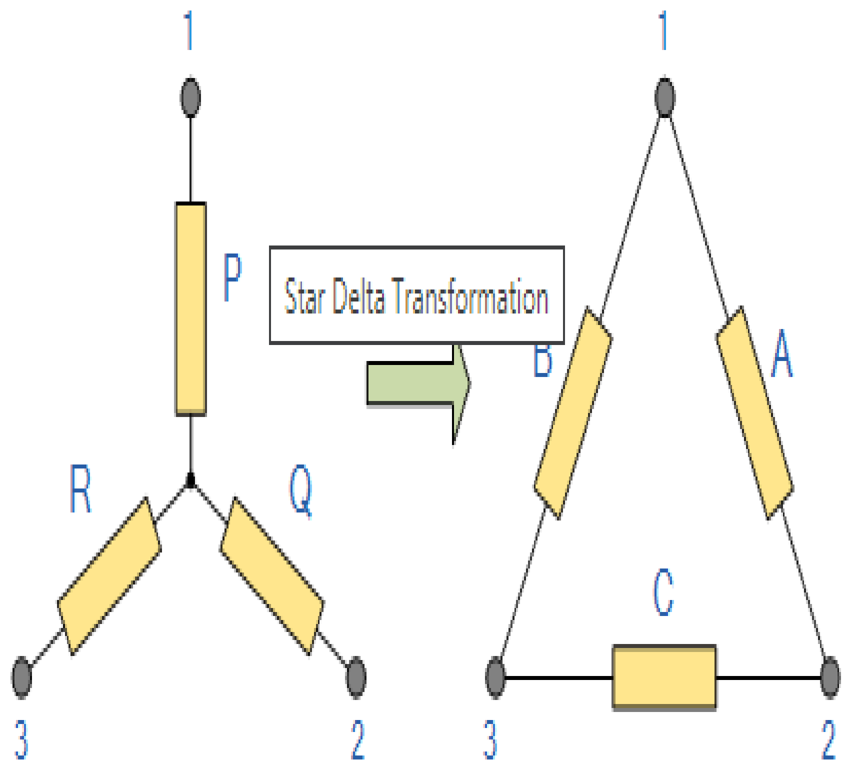
$$A = \frac{PQ + QR + RP}{R}$$

with respect to terminal 3 and resistor B is given as:

$$B = \frac{PQ + QR + RP}{Q}$$

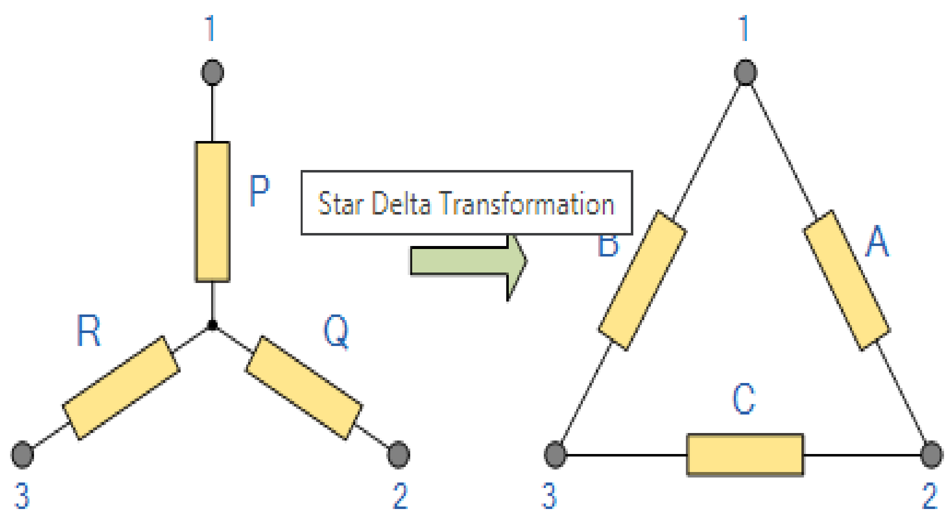
with respect to terminal 2 with resistor C given as:

$$C = \frac{PQ + QR + RP}{P}$$



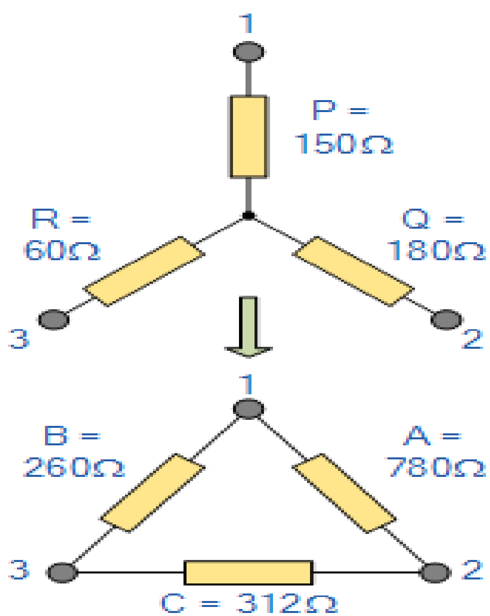
Star-Delta transformation

$$A = \frac{PQ}{R} + Q + P \qquad B = \frac{RP}{Q} + P + R \qquad C = \frac{QR}{P} + Q + R$$



Star – Delta Example

- Convert the following Star Resistive Network into an equivalent Delta Network.



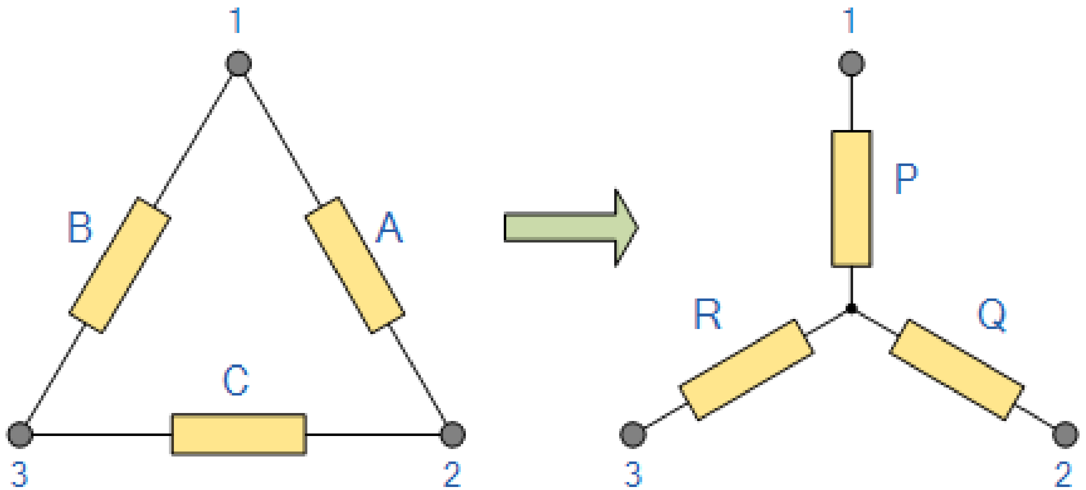
$$A = \frac{QP}{R} + Q + P = \frac{180 \times 150}{60} + 180 + 150 = 780\Omega$$

$$B = \frac{RP}{Q} + R + P = \frac{60 \times 150}{180} + 60 + 150 = 260\Omega$$

$$C = \frac{QR}{P} + Q + R = \frac{180 \times 60}{150} + 180 + 60 = 312\Omega$$

Delta-Star transformation

- To convert a delta network to an equivalent star network we need to derive a transformation formula for equating the various resistors to each other between the various terminals. Consider the circuit below.



Delta-Star transformation

From which gives us the final equation for resistor P as:

$$P = \frac{AB}{A+B+C}$$

Then to summarize a little about the above maths, we can now say that resistor P in a Star network can be found as Equation 1 plus (Equation 3 minus Equation 2) or Eq1 + (Eq3 – Eq2).

Delta-Star transformation

Similarly, to find resistor Q in a star network, is equation 2 plus the result of equation 1 minus equation 3 or Eq2 + (Eq1 – Eq3) and this gives us the transformation of Q as:

$$Q = \frac{AC}{A + B + C}$$

and again, to find resistor R in a Star network, is equation 3 plus the result of equation 2 minus equation 1 or Eq3 + (Eq2 – Eq1) and this gives us the transformation of R as:

$$R = \frac{BC}{A + B + C}$$

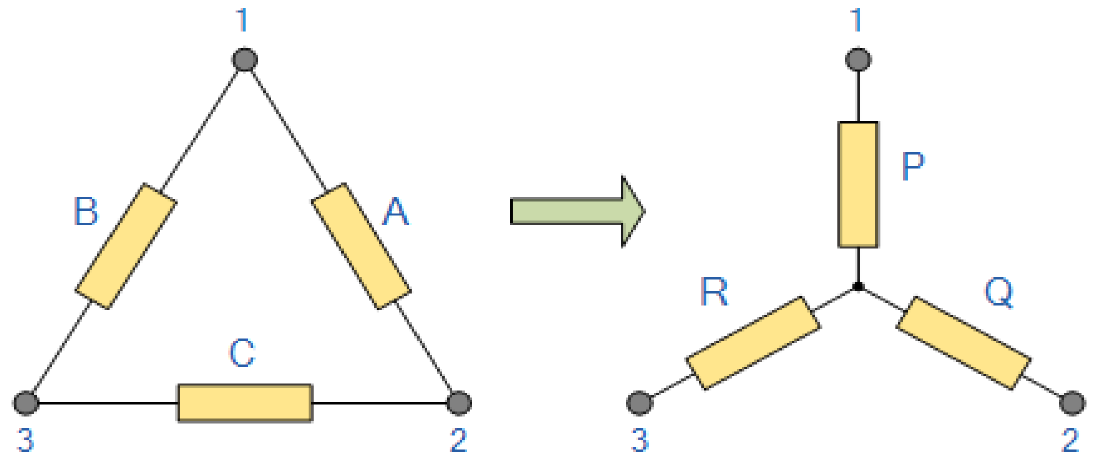
Delta-Star transformation

- When converting a delta network into a star network the denominators of all of the transformation formulas are the same: A + B + C, and which is the sum of ALL the delta resistances.

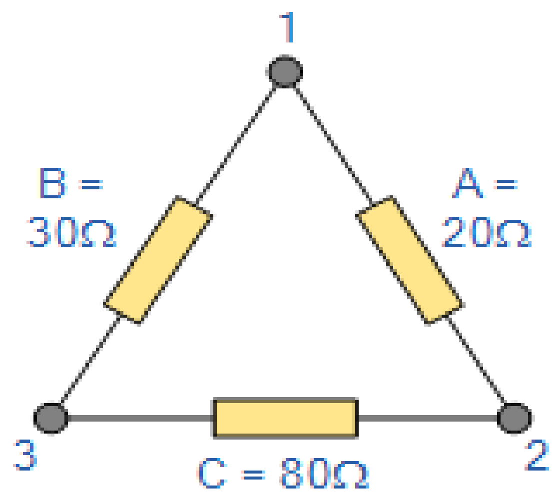
- Then to convert any delta connected network to an equivalent star network we can summarized the above transformation equations as:

Delta-Star transformation

$$P = \frac{AB}{A+B+C} \quad Q = \frac{AC}{A+B+C} \quad R = \frac{BC}{A+B+C}$$



Delta-Star Example



$$Q = \frac{AC}{A+B+C} = \frac{20\times 80}{130} = 12.31\Omega$$

$$P = \frac{AB}{A+B+C} = \frac{20\times 30}{130} = 4.61\Omega$$

$$R = \frac{BC}{A+B+C} = \frac{30\times 80}{130} = 18.46\Omega$$

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DC Circuit

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Content

Statement of Superposition Theorem

- Superposition theorem states that in any linear, active, bilateral network with more than one source, the response across any component is the sum of the responses obtained from each source considered separately and their internal resistance is replaced by all other sources.

- **Limitation of Superposition theorem**

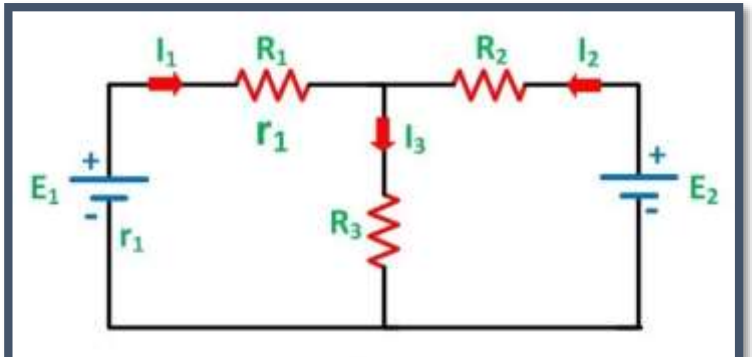
The theorem of superposition is used to resolve the network where two or more sources exist and are connected.

Steps for solving Theorem

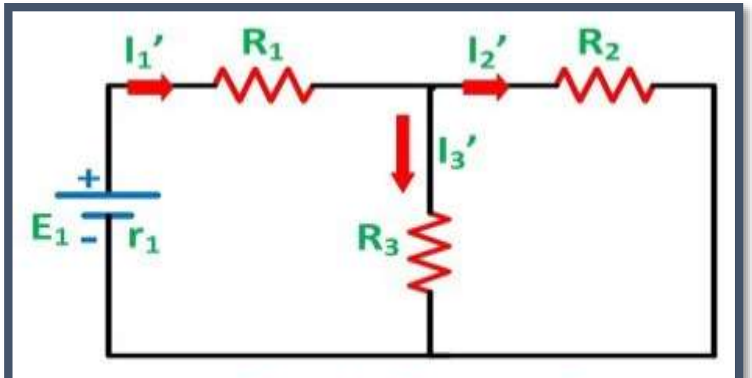
Step 1 – Take only one independent source of voltage or current and deactivate the other sources.

Step 2 – In the circuit diagram B shown above, consider the source E1 and replace the other source E2 by its internal resistance. If its internal resistance is not given, then it is taken as zero and the source is short-circuited.

Step 3 – If there is a voltage source than short circuit it and if there is a current source then just open circuit it.



Circuit Diagram A



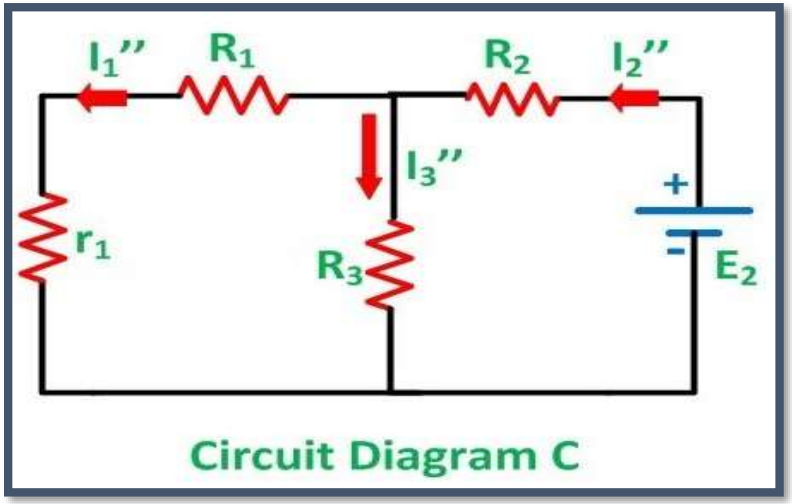
Circuit Diagram B

Steps for solving Theorem

Step 4 – Thus, by activating one source and deactivating the other source find the current in each branch of the network. Taking the above example find the current I_1', I_2'and I_3'.

Step 5 – Now consider the other source E_2 and replace the source E_1 by its internal resistance r_1 as shown in the circuit diagram C.

Step 6 – Determine the current in various sections, I_1'', I_2'' and I_3''.



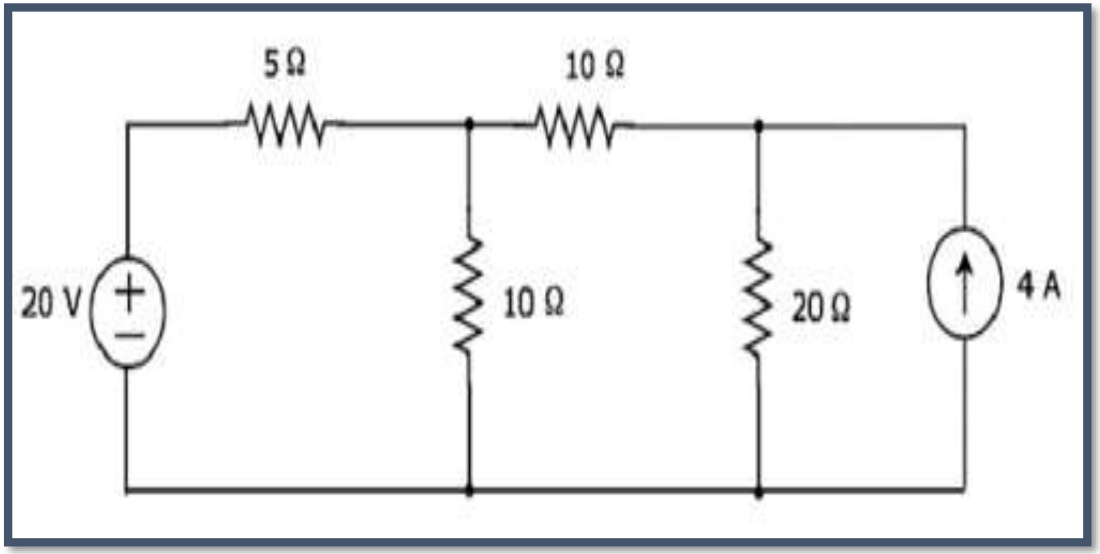
Steps for solving Theorem

Step 7 – Now to determine the net branch current utilizing the superposition theorem, add the currents obtained from each individual source for each branch.

Step 8 – If the current obtained by each branch is in the same direction then add them and if it is in the opposite direction, subtract them to obtain the net current in each branch.

Examples of Superposition Theorem

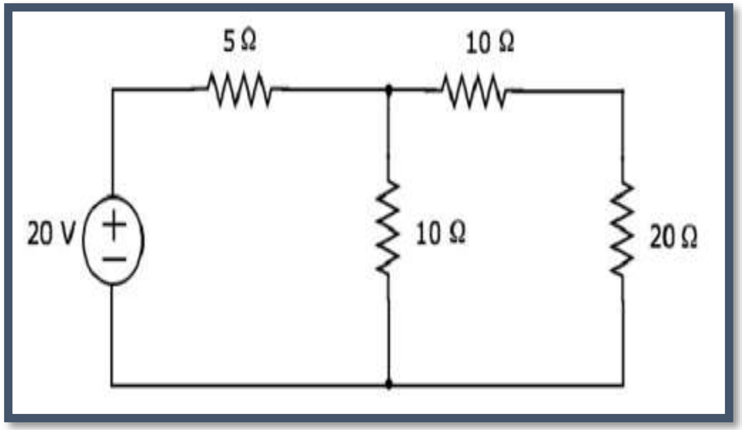
- Find the current flowing through 20 Ω resistor of the following circuit using superposition theorem.



Examples of Superposition Theorem

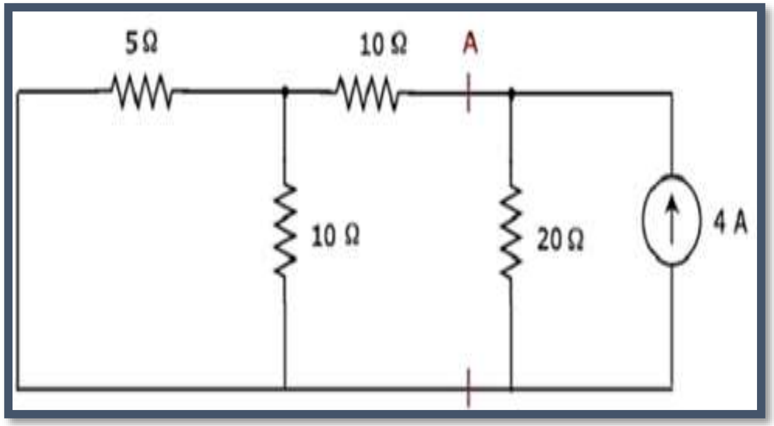
- Let us find the current flowing through 20 Ω resistor by considering only 20 V voltage source.

- In this case, we can eliminate the 4 A current source by making open circuit of it.



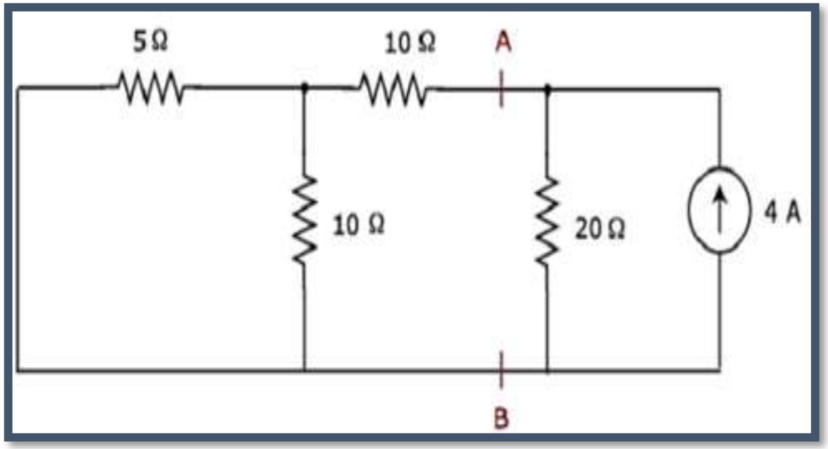
Examples of Superposition Theorem

- Let us find the current flowing through 20 Ω resistor by considering only 4 A current source.
-
- In this case, we can eliminate the 20 V voltage source by making short-circuit of it.



Examples of Superposition Theorem

- There are three resistors to the left of terminals A & B.
- We can replace these resistors with a single equivalent resistor.
- Here, 5 Ω & 10 Ω resistors are connected in parallel and the entire combination is in series with 10 Ω resistor.

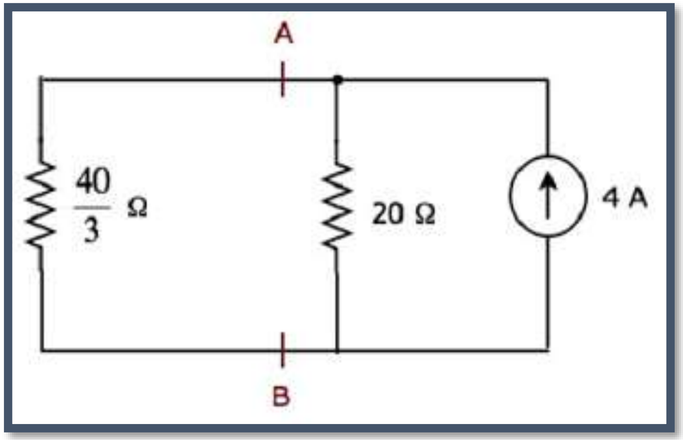


$$R_{AB} = [(5\times10)/(5+10)\square+10$$
$$=10/3+10$$
$$=40/3\Omega$$

Examples of Superposition Theorem

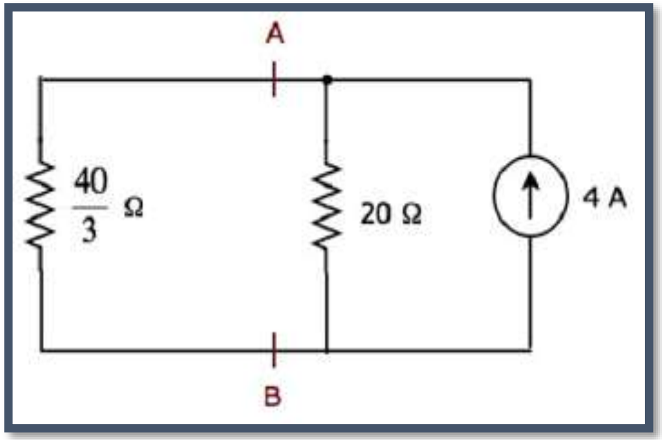
- We can find the current flowing through 20 Ω resistor, by using current divider rule(CDR).

- The current flowing through 20 Ω resistor is 1.6 A, when only 4 A current source is considered.



Examples of Superposition Theorem

- Now, we can make algebraic sum of currents obtained by both the source individually.
- It will provide the actual current passing through 20 ohm resistor.



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DC Circuit

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Content

Statement of Thevenin's Theorem

- Thevenin's Theorem states that any linear active network consisting of independent or dependent voltage and current source and the network elements can be replaced by voltage source in series with resistance.

- Where the voltage source being the open-circuited voltage across the open-circuited load terminals and the resistance being the internal resistance of the source.

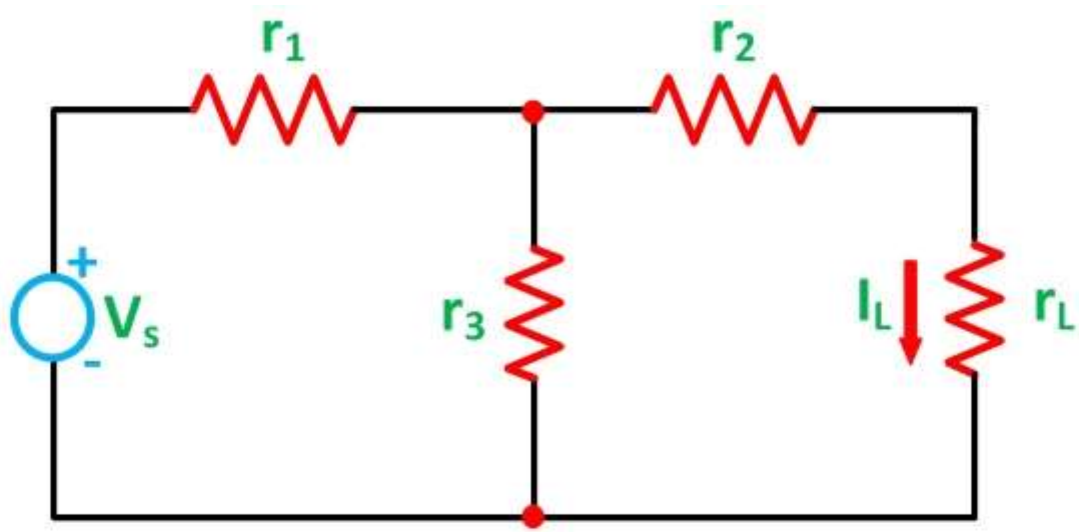
Statement of Thevenin's Theorem

- In other words, the current flowing through a resistor connected across any two terminals of a network by an equivalent circuit having a voltage source Vth in series with a resistor Rth.

- Where Vth is the open-circuit voltage between the required two terminals called the Thevenin voltage And Rth is the equivalent resistance of the network as seen from the two-terminal with all other sources replaced by their internal resistances called Thevenin resistance.

Steps for solving Thevenin’s Theorem

- Let us consider a simple DC circuit as shown in the figure above, where we have to find the load current IL by the Thevenin’s theorem.



Steps for solving Thevenin's Theorem

Step 1 – First of all remove the load resistance RL of the given circuit.

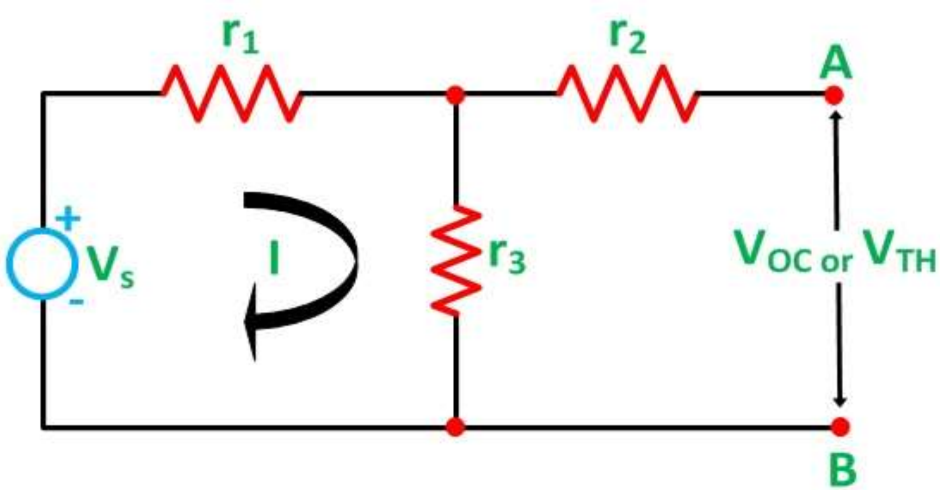
Step 2 – Replace all the sources by their internal resistance. If sources are ideal then short circuit the voltage source and open circuit the current source.

Step 3 – Now find the equivalent resistance at the load terminals, known as Thevenin's Resistance (Rth).

Step 4 – Draw the Thevenin's equivalent circuit by connecting the load resistance and after that determine the desired response.

Steps for solving Thevenin's Theorem

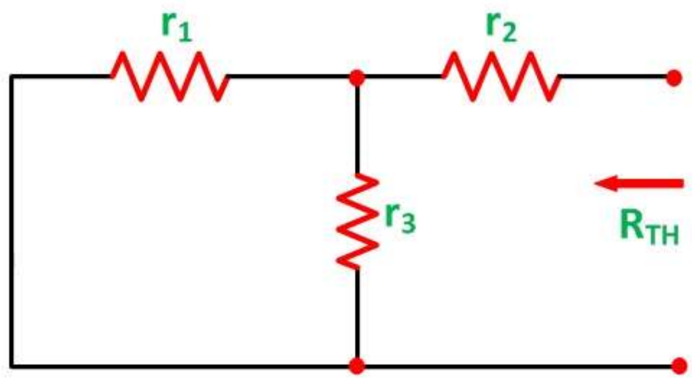
- In order to find the equivalent voltage source, RL is removed from the circuit as shown in the figure below and Voc or VTH is calculated.



$$V_{OC} = I\,r_3 = \frac{V_S}{r_1 + r_3}\,r_3$$

Steps for solving Thevenin's Theorem

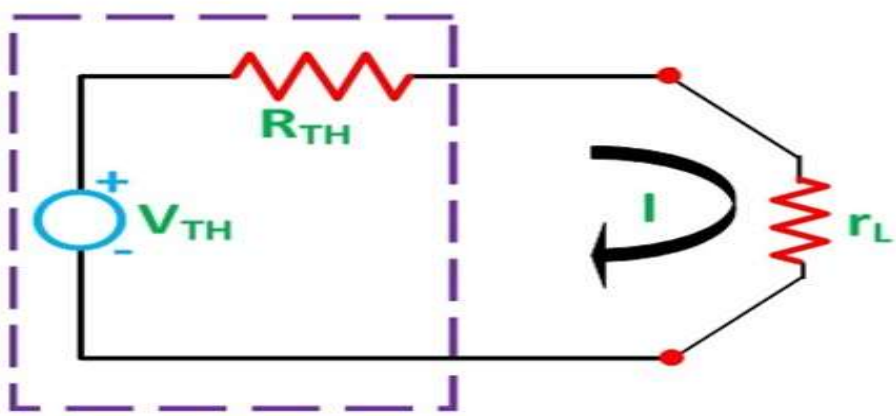
- Now, to find the internal resistance of the network (Thevenin's resistance or equivalent resistance) in series with the open-circuit voltage VOC , also known as Thevenin's voltage VTH, the voltage source is removed or we can say it is deactivated by a short circuit (as the source does not have any internal resistance) as shown in the figure below:



$$R_{TH} = r_2 + \frac{r_1 r_3}{r_1 + r_3}$$

Steps for solving Thevenin's Theorem

- As per Thevenin's Statement, the load current is determined by the circuit shown above and the equivalent Thevenin's circuit is obtained.
- The load current IL is given as:



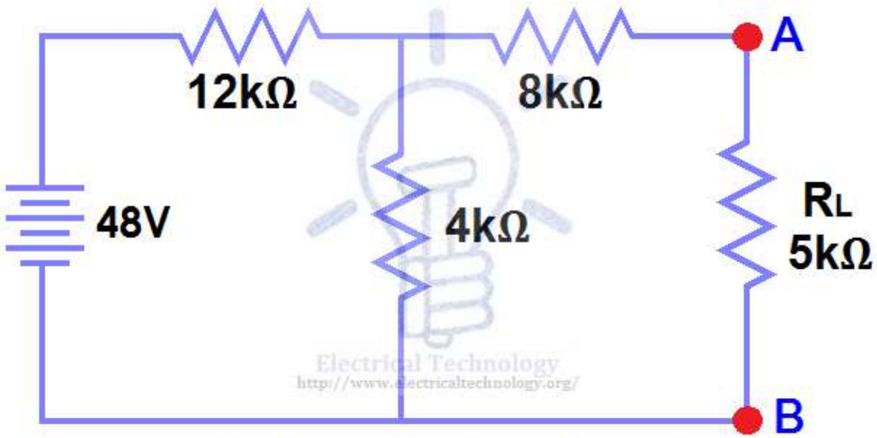
Steps for solving Thevenin's Theorem

- The load current IL is given a
- Where, VTH is the Thevenin's equivalent voltage. It is an open circuit voltage across the terminal AB known as load terminal.
- RTH is the Thevenin's equivalent resistance, as seen from the load terminals.
- RL is the load resistance

$$I_L = \frac{V_{TH}}{R_{TH} + r_L}$$

Example of Thevenin's Theorem

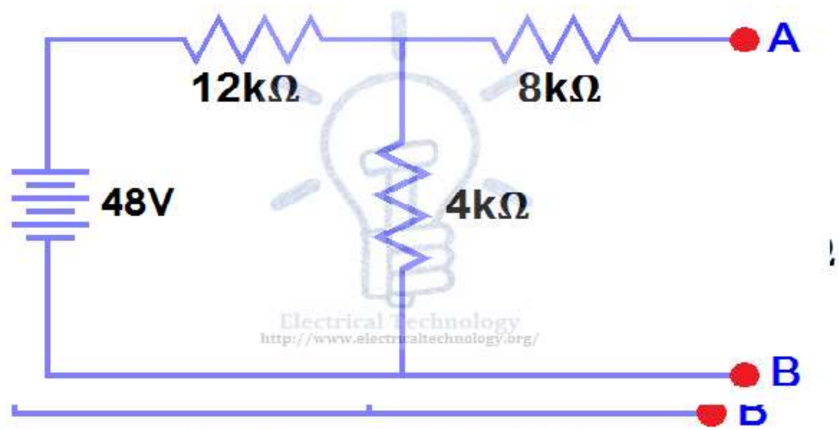
- Find VTH, RTH and the load current IL flowing through and load voltage across the load resistor in fig by using Thevenin's Theorem.



Thevenin's Theorem. Easy Step by Step Procedure with Example (Pictorial Views)

Example of Thevenin's Theorem

Step 1 : Open the 5kΩ load resistor



Thevenin's Theorem. Easy Step by Step Procedure with Example (Pictorial Views)

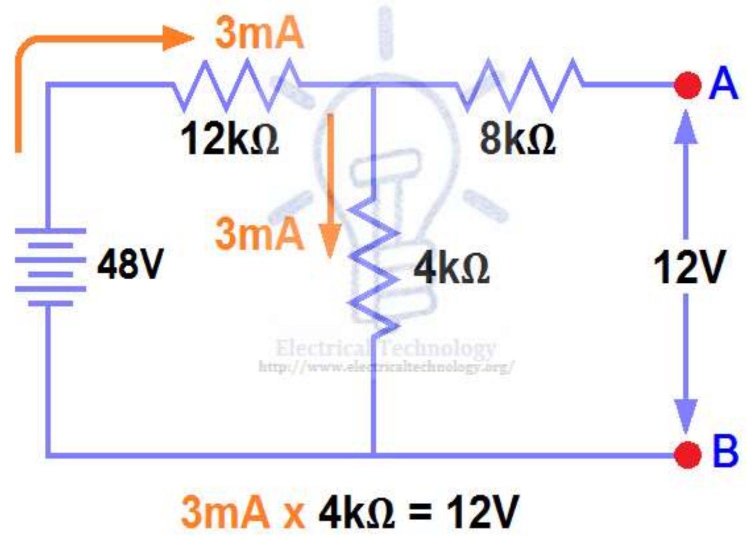
Example of Thevenin’s Theorem

Step 2 :

- Calculate / measure the open circuit voltage. This is the Thevenin Voltage (VTH) Now we have to calculate the Thevenin’s Voltage.
- Since, 3mA current flows in both 12kΩ and 4kΩ resistors as this is a series circuit and current will not flow in the 8kΩ resistor as it is open.
- Total current is = 16k-ohm/48 v = 3 mA

Example of Thevenin’s Theorem

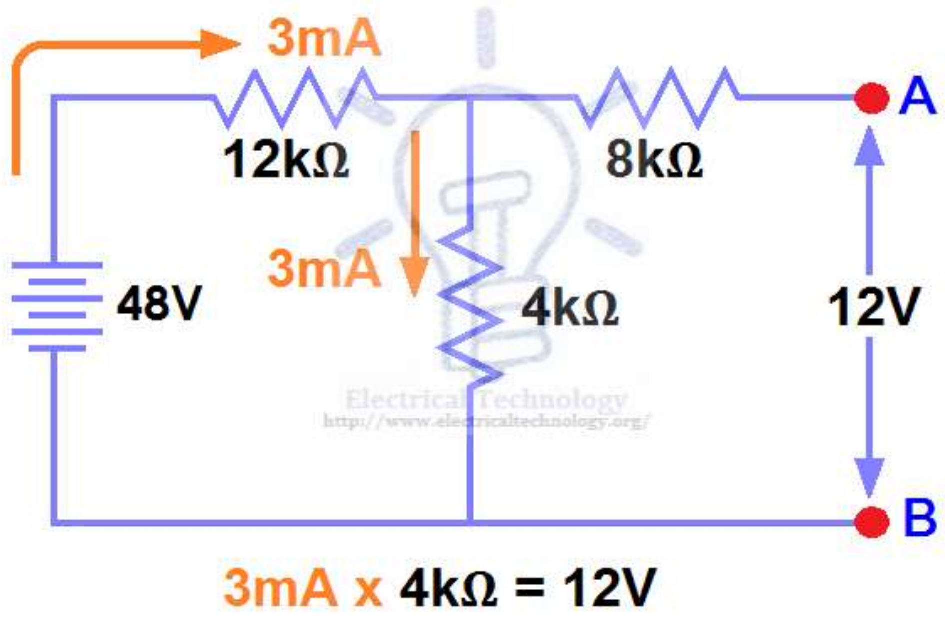
- Since 3mA current flows in both 12 kΩ and 4 kΩ resistors as this is a series circuit and current will not flow in the 8 kΩ resistor as it is open.



Example of Thevenin's Theorem

- This way, 12 V (3mA x 4 kΩ) will appear across the 4 kΩ resistor. We also know that current is not flowing through the 8kΩ resistor as it is an open circuit, but the 8 kΩ resistor is in parallel with 4 k resistor.
- So the same voltage 12 V will appear across the 8 kΩ resistor as well as 4 kΩ resistor.
- Therefore, 12V will appear across the AB terminals.
- VTH = 12V

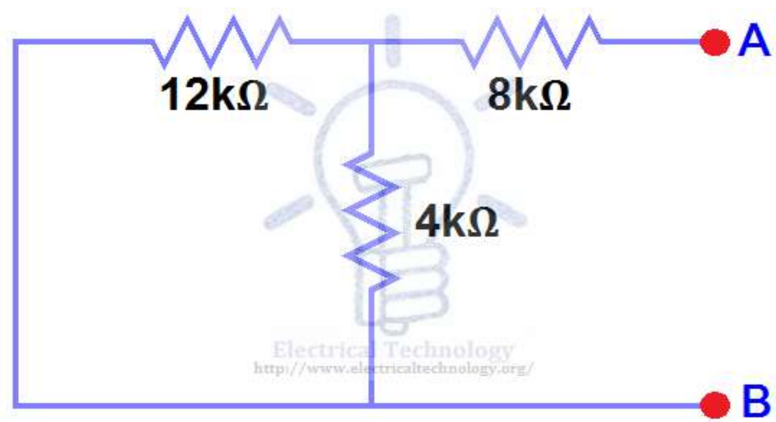
Example of Thevenin’s Theorem



Example of Thevenin's Theorem

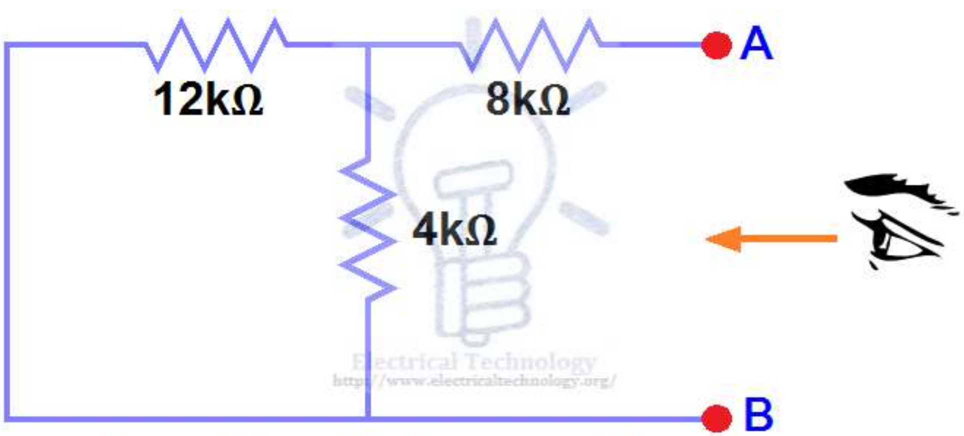
Step. 3

- Open current sources and short voltage sources as shown below Calculate / measure the open circuit resistance. This is the Thevenin Resistance (RTH)



Example of Thevenin's Theorem

- Step. 3
- We have removed the 48V DC source to zero as equivalent i.e. 48V DC source has been replaced with a short in step 3.
- We can see that 8kΩ resistor is in series with a parallel connection of 4kΩ resistor and 12kΩ resistor

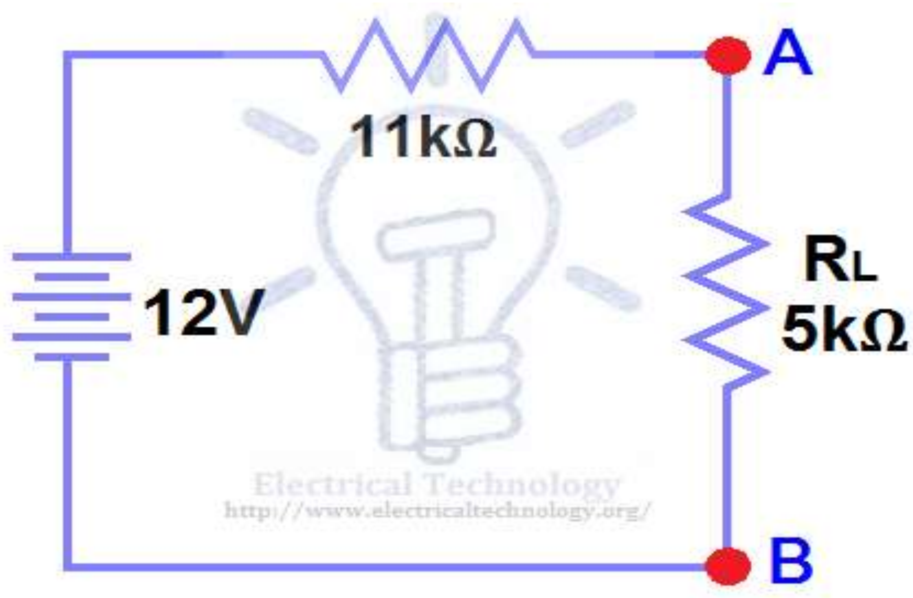


$= 8k\Omega + (4k\ \Omega \parallel 12k\Omega) \rightarrow = 8k\Omega + 3k\Omega$

$\boxed{R_{TH} = 11k\Omega}$

Example of Thevenin's Theorem

- Connect the RTH in series with Voltage Source VTH and re-connect the load resistor.
- This makes Thevenin circuit with load resistor.
- This the Thevenin's equivalent circuit.



Example of Thevenin’s Theorem

Step. 4

Now apply the last step i. e Ohm’s law .
Calculate the total load current and load voltage as shown in fig:

IL = VTH / (RTH + RL)
IL = 12 V / (11 kΩ + 5 kΩ) → = 12/16 kΩ
IL = 0.75 mA

And

VL = IL x RL
VL = 0.75 mA x 5 kΩ

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DC Circuit

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Content

Statement of Norton’s Theorem

- Norton’s Theorem states that – A linear active network consisting of the independent or dependent voltage source and current sources and the various circuit elements can be substituted by an equivalent circuit consisting of a current source in parallel with a resistance.

- The current source being the short-circuited current across the load terminal and the resistance being the internal resistance of the source network.

Statement of Norton’s Theorem

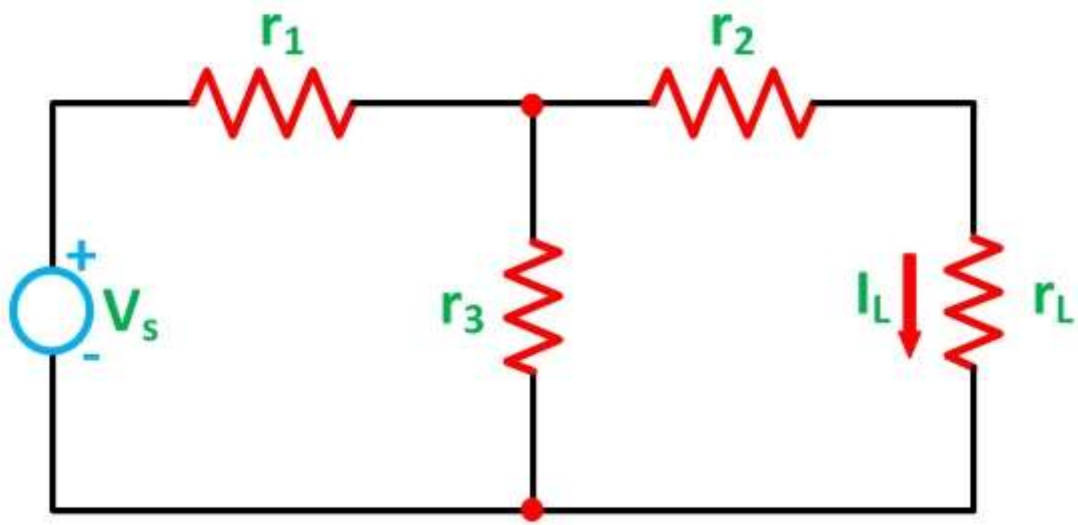
- The Norton’s theorems reduce the networks equivalent to the circuit having one current source, parallel resistance and load. Norton’s theorem is the converse of Thevenin’s Theorem.

- It consists of the equivalent current source instead of an equivalent voltage source as in Thevenin’s theorem.

- In the final stage that is in the equivalent circuit, the current is placed in parallel to the internal resistance in Norton’s Theorem whereas in Thevenin’s Theorem the equivalent voltage source is placed in series with the internal resistance.

Steps for solving Norton’s Theorem

- Let us consider a simple DC circuit as shown in the figure above, where we have to find the load current IL by the Thevenin’s theorem.

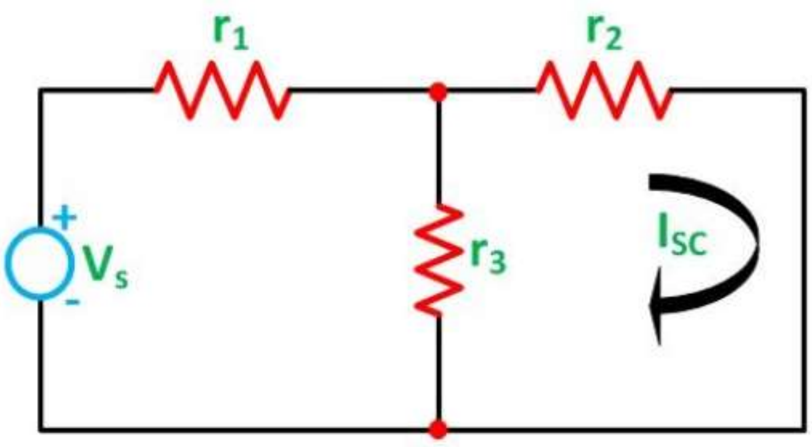


Steps for solving Norton's Theorem

- Step 1 – Remove the load resistance of the circuit.
- Step 2 –Now short the load terminals and find the short circuit current ISC flowing through the shorted load terminals using conventional network analysis methods.
- Step 3 – Norton's equivalent resistance found by removing all the sources present in the circuit.
- Step 4 – Reconstruct the circuit by connecting current source with magnitude of Isc, Norton's equivalent resistance and load resistance RL in parallel with each other and find load current.

Steps for solving Norton's Theorem

- In order to find the current through the load resistance IL as shown in the circuit diagram above, the load resistance has to be short-circuited as shown in the diagram below:



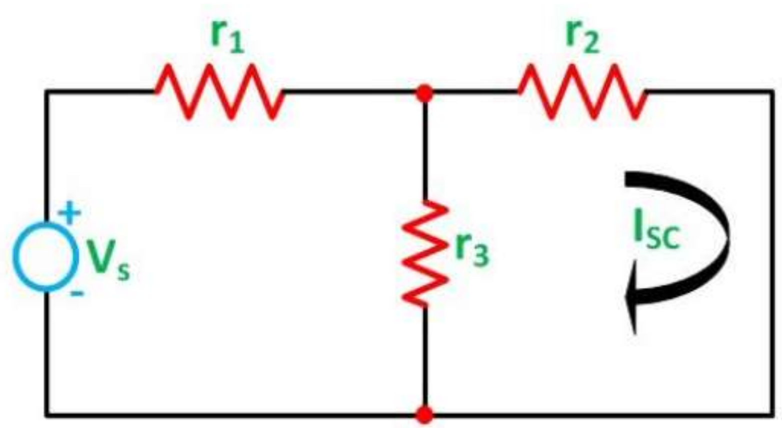
Steps for solving Norton's Theorem

- Now, the value of current I flowing in the circuit is found out by the equation

$$I = \frac{V_S}{r_1 + \frac{r_2 r_3}{r_2 + r_3}}$$

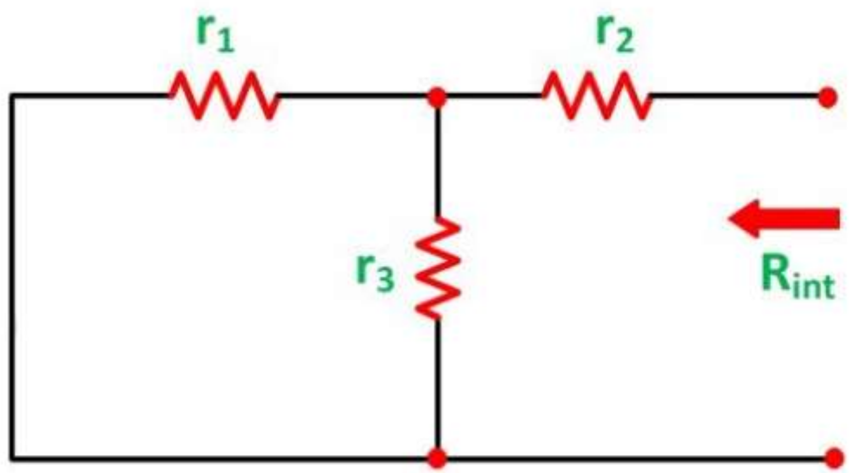
- And the short-circuit current ISC is given by the equation shown below:

$$I_{sc} = I \frac{r_3}{r_3 + r_2}$$



Steps for solving Norton's Theorem

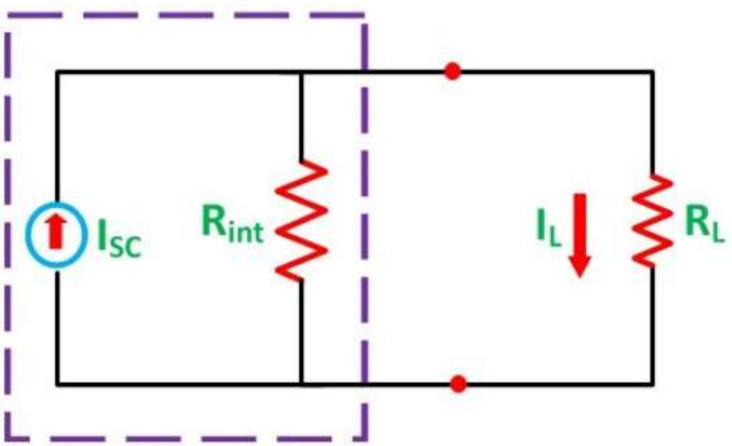
- Now the short circuit is removed, and the independent source is deactivated as shown in the circuit diagram below and the value of the internal resistance is calculated by:



$$R_{int} = r_2 + \frac{r_1 r_3}{r_1 + r_3}$$

Steps for solving Norton's Theorem

- As per Norton's Theorem, the equivalent source circuit would contain a current source in parallel to the internal resistance, the current source being the short-circuited current across the shorted terminals of the load resistor. The Norton's Equivalent circuit is represented as



Steps for solving Norton's Theorem

- Finally, the load current IL calculated by the equation shown below

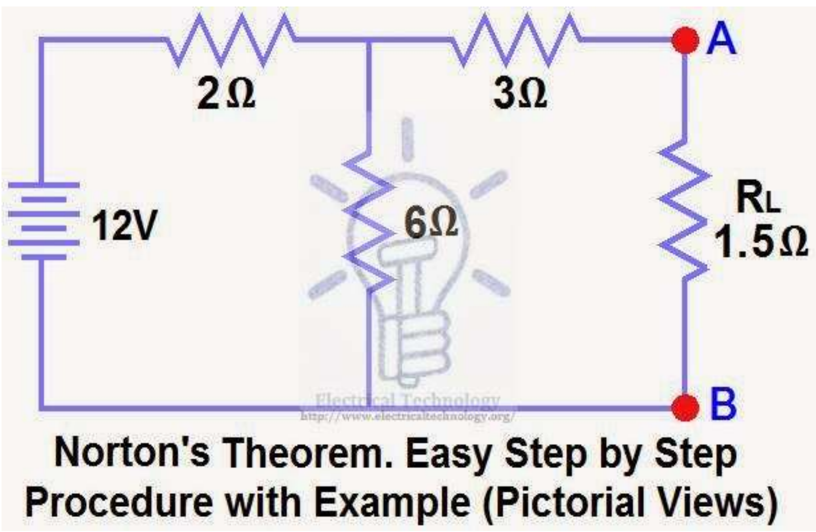
$$I_L = I_{sc} \frac{R_{int}}{R_{int} + R_L}$$

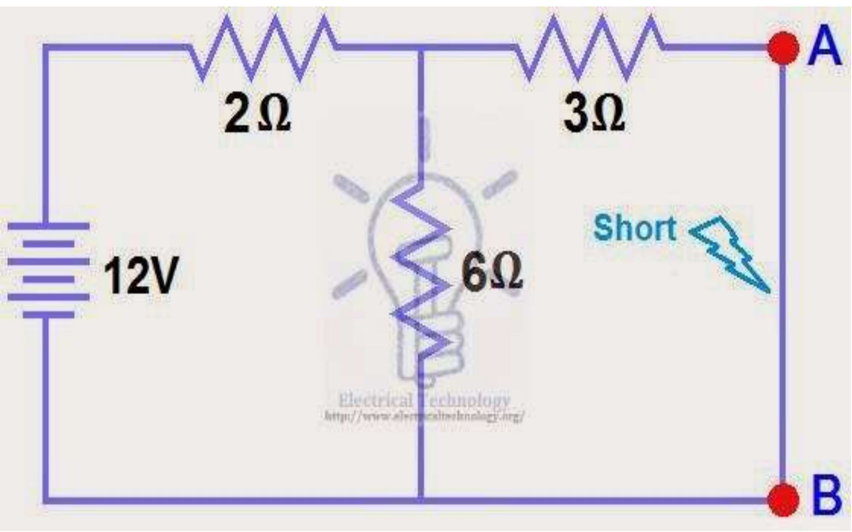
- Where,

- IL is the load current
- Isc is the short circuit current
- Rint is the internal resistance of the circuit
- RL is the load resistance of the circuit

Example of Norton's Theorem

- Step 1 : Short the 1.5Ω load resistor as shown in





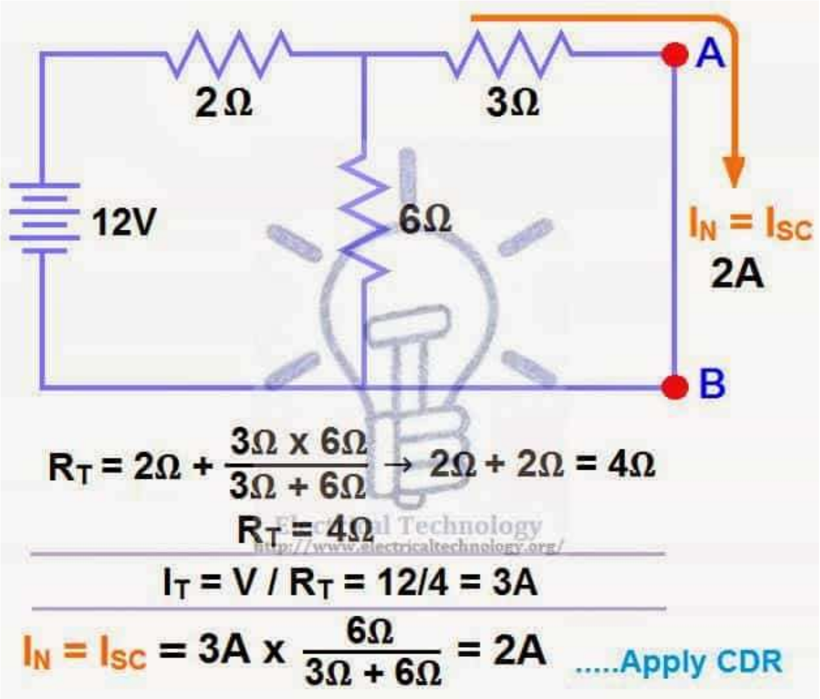
Example of Norton's Theorem

- Step 2
- Calculate / measure the Short Circuit Current. This is the Norton Current (IN).
- We have shorted the AB terminals to determine the Norton current, IN. The 6Ω and 3Ω are then in parallel and this parallel combination of 6Ω and 3Ω are then in series with 2Ω.

- So the total resistance of the circuit to the Source is:-
- 2Ω + (6Ω || 3Ω) ….. (|| = in parallel with).
- RT = 2Ω + [(3Ω x 6Ω) / (3Ω + 6Ω)] → IT = 2Ω + 2Ω = 4Ω.
- RT = 4Ω
- IT = V ÷ RT
- IT = 12V ÷ 4Ω
- IT = 3A..

Example of Norton's Theorem

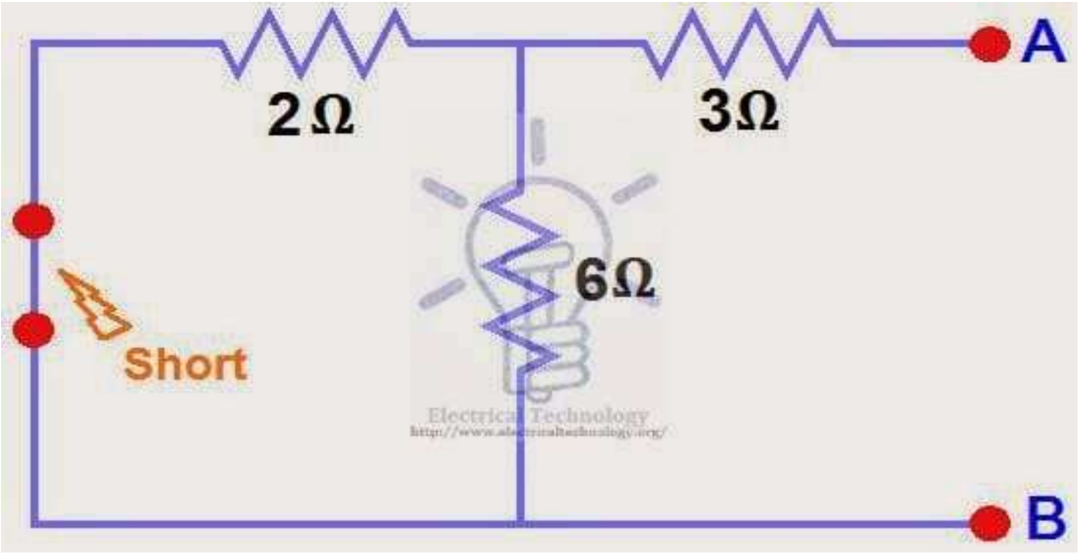
- Now, we have to find ISC = IN Apply CDR (Current Divider Rule)
- ISC = IN = 3A x [(6Ω ÷ (3Ω + 6Ω)] = 2A.
- ISC = IN = 2A.



Example of Norton's Theorem

Step 3.

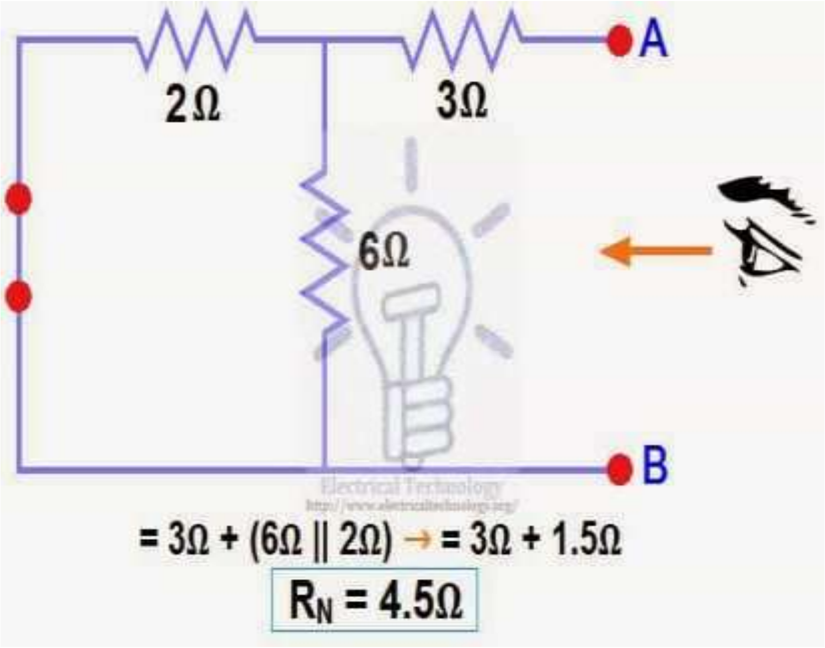
Open Current Sources, Short Voltage Sources and Open Load Resistor.



Example of Norton's Theorem

- Step 3
- Calculate /measure the Open Circuit Resistance. This is the Norton Resistance (RN)

- We have Reduced the 12V DC source to zero is equivalent to replace it with a short in step (3), as shown in figure. We can see that 3Ω resistor is in series with a parallel combination of 6Ω resistor and 2Ω resistor. i.e.:



- 3Ω + (6Ω || 2Ω) ….. (|| = in parallel with)

- RN = 3Ω + [(6Ω x 2Ω) ÷ (6Ω + 2Ω)]

- RN = 3Ω + 1.5Ω RN = 4.5Ω

Example of Norton's Theorem

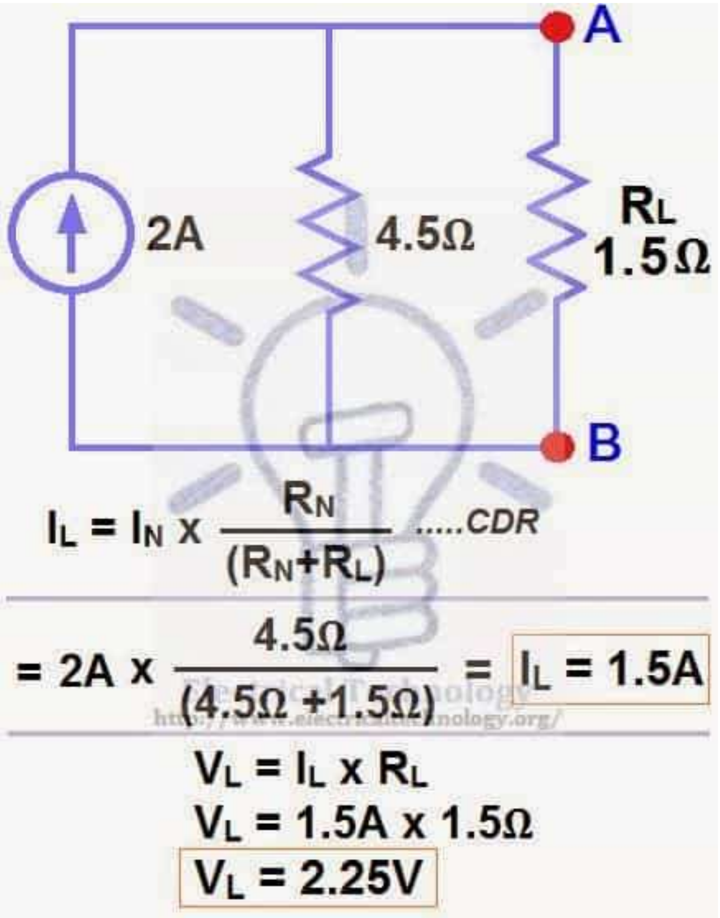
- **Step 4**
- Now apply the last step i.e. calculate the load current through and Load voltage across the load resistor by Ohm's Law as shown in fig 7.

- Load Current through Load Resistor…

- IL = IN x [RN ÷ (RN+ RL)]

= 2A x (4.5Ω ÷ 4.5Ω + 1.5Ω) →
= 1.5A

- IL = 1. 5A



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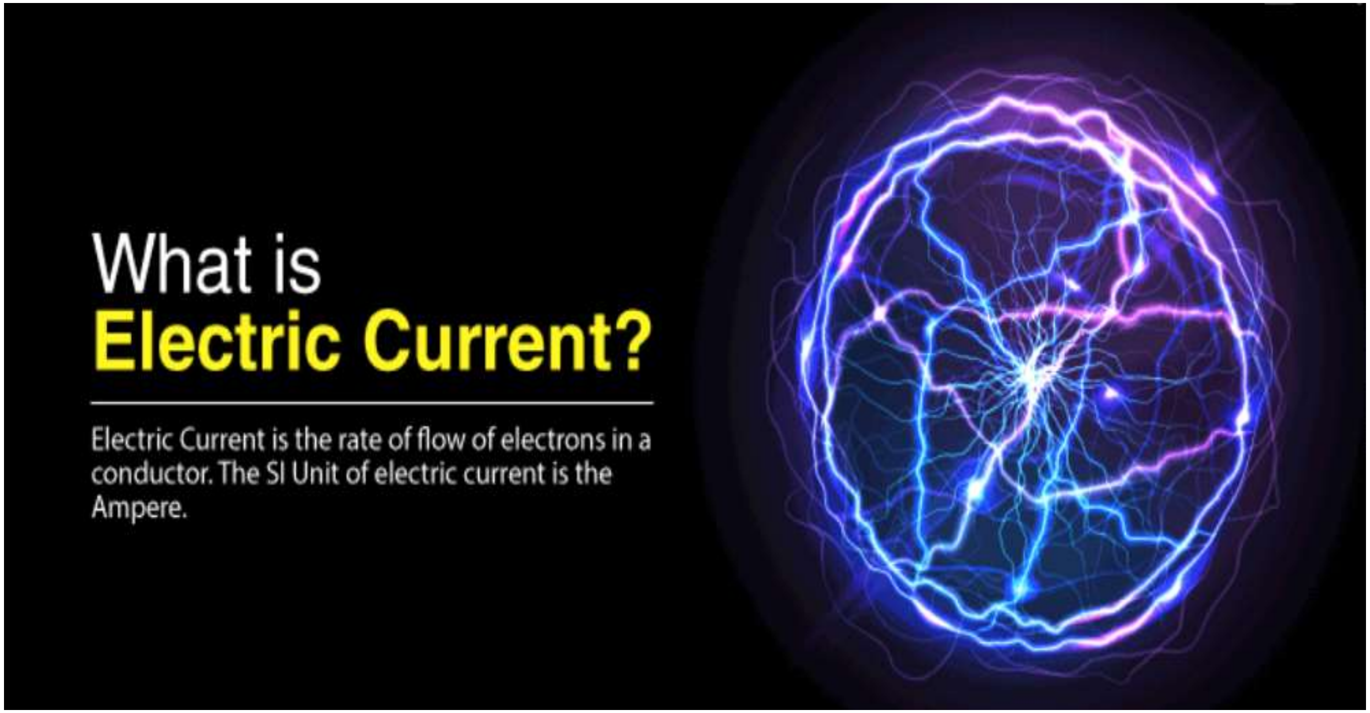
Electric Current



Electric Current is the rate of flow of electrons in a conductor.

Potential and Potential Difference

- Electric Potential is the amount of work done per unit charge to get that charge from infinity to a point in the electrostatic field while resisting the field force.

- Voltage is another term for electric potential. Volt is the SI unit for Electric Potential. Electric potential is a scalar quantity. The formula for Electric Potential is-

  Electric Potential = Work Done/ Unit charge

- The amount of work required to transfer a unit charge from one place in an electric field to another is defined as the potential difference.

Electric Power

- It is the rate of doing work. Its unit is watt (W) which represents 1 joule per second.

$$1\ \mathrm{W} = 1\ J/s\ .$$

- Electric Power can be mathematically given as

Power(P)=Voltage(V)*Current(I)

Ohm's Law

- The ratio of potential difference (V) between any two points on a conductor to the current (I) flowing between them, is constant provided the temperature of the conductor does not change.

- In other words, $\frac{V}{I} = constant$ or , $\frac{V}{I} = R$.

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