BEE- 01
PRINCIPLES OF ELECTRICAL ENGINEERING

UNIT I

D C Circuit Analysis and Network Theorems: Circuit Concepts: Concepts of network, Active and passive elements, Voltage and current sources, Concept of linearity and linear network, Unilateral and bilateral elements, R, L and C as linear elements, Source transformation Kirchhoff‟s laws; Loop and nodal methods of analysis; Star-delta transformation Network theorems: Superposition theorem, Thevenin‟s theorem, Norton‟s theorem, Maximum Power Transfer theorem.

UNIT II

Steady- State Analysis of Single Phase AC Circuits: AC fundamentals: Sinusoidal, square and triangular waveforms – Average and effective values, Form and peak factors, Concept of phasor, phasor representation of sinusoidally varying voltage and current, Analysis of series, parallel and series-parallel RLC Circuits, Resonance in series and Parallel circuit Three Phase AC Circuits: Three phase system-its necessity and advantages, Star and delta connections, Balanced supply and balanced load, Line and phase voltage/current relations, Three-phase power and its measurement

UNIT III

Measuring Instruments, Magnetic Circuit & 1 phase Transformers: Types of instruments, Construction and working principles of PMMC and Moving Iron type voltmeters & ammeters, Use of shunts and multipliers. Magnetic circuit, concepts, analogy between electric & magnetic circuits, B-H curve, Hysteresis and eddy current losses. Single Phase Transformer: Principle of operation, Construction, EMF equation, Power losses, Efficiency, Introduction to auto transformer.

UNIT IV

Electrical Machines: Concept of electromechanical energy conversion DC machines: Types, EMF equation of generators and torque equation of motor, Characteristics and applications of DC Generators & motors Three Phase Induction Motor: Types, Principle of operation, Torque-slip characteristics, Applications Single Phase Induction motor: Principle of operation and introduction to methods of starting, applications. Three Phase Synchronous Machines: Principle of operation of alternator, emf equation, Principle of operation and starting of synchronous motor, their applications.

Text Books:

1.“Principles of Electrical Engineering”, V. Del Toro,; Prentice Hall International

2.“Basic Electrical Engineering”, D P Kothari, I.J. Nagarath; Tata McGraw Hill

3.“Basic Electrical Engineering”, S N Singh; Prentice Hall International

4.“Fundamentals of Electrical Engineering” B Dwivedi, A Tripathi; Wiley India

5.“Electrical and Electronics Technology”, Edward Hughes; Pearson

CIRCUIT ELEMENTS

- An element is the basic building block of a circuit.
- An electric circuit is simply an interconnection of the elements.
- There are 2 types of elements found in electrical circuits.

Active elements (Energy sources): The elements which are capable of generating or delivering the energy are called active elements. E.g., Generators, Batteries

Passive element (Loads): The elements which are capable of receiving the energy are called passive elements. E.g., Resistors, Capacitors and Inductors

ENERGY SOURCES (ACTIVE ELEMENTS)

- Active element is also known as energy sources which can be voltage or current sources. There are two kinds of sources

a) Independent sources

b) Dependent sources

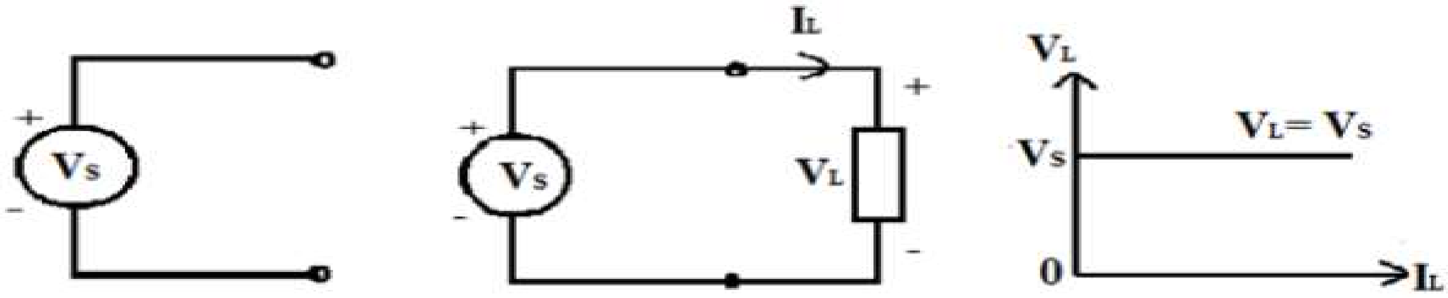
Ideal source

i) ideal voltage source

ii) Ideal current source

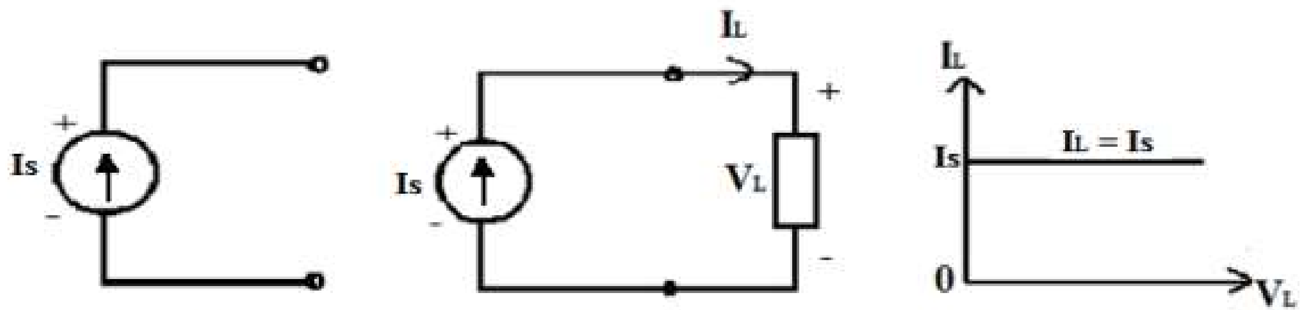
<u>Ideal Independent Voltage Source:</u>

An ideal independent voltage source is an active element that gives a constant voltage across its terminals irrespective of the current drawn through its terminals.



(a) Symbol (b) Circuit (c) V-I Characteristics

- **Ideal Independent Current Source:** An ideal independent Current source is an active element that gives a constant current through its terminals irrespective of the voltage appearing across its terminals.



(a) Symbol (b) Circuit (c) V-I Characteristics

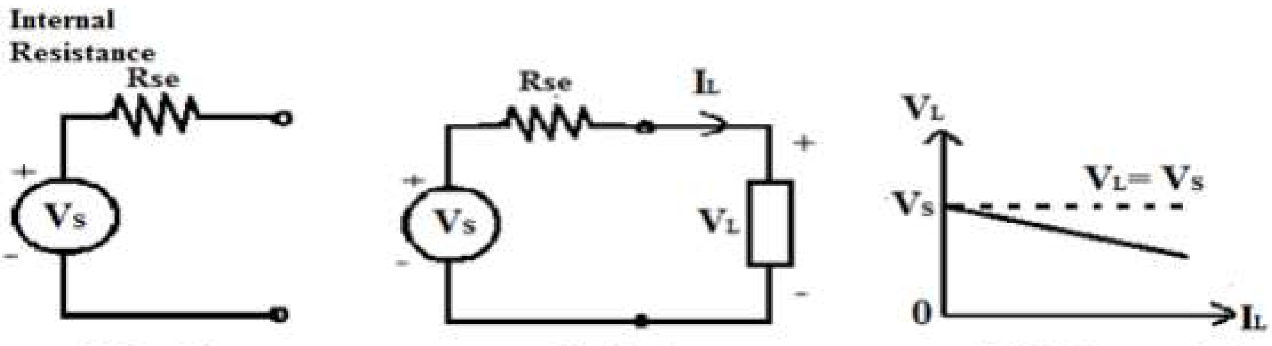
Practical source:

- Practical voltage source
- Practical current source

Practical Independent Voltage Source:

- Practically, every voltage source has some series resistance across its terminals known as internal resistance, and is represented by Rse.
- For ideal voltage source Rse = 0.
- But in practical voltage source Rse is not zero but may have small value. Because of this Rse voltage across the terminals decreases with increase in current as shown in Fig.
- Terminal voltage of practical voltage source is given by

$V_L = V_S - I_L R_{se}$

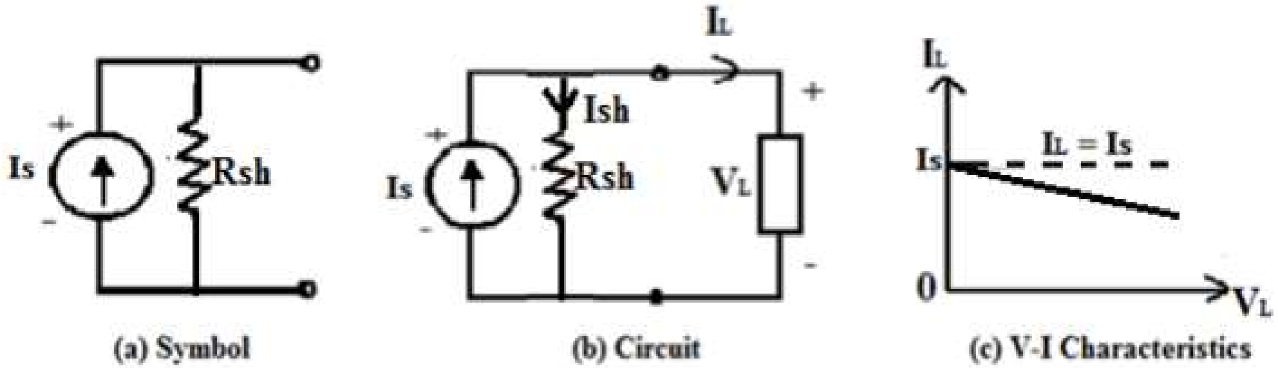


(a) Symbol (b) Circuit (c) V-I Characteristics

Practical Independent Current Source:

- Practically, every current source has some parallel/shunt resistance across its terminals known as internal resistance, and is represented by Rsh.
- For ideal current source Rsh = ∞ (infinity).
- But in practical voltage source Rsh is not infinity but may have a large value.
- Because of this Rsh current through the terminals slightly decreases with increase in voltage across its terminals as shown in Fig.
- Terminal current of practical current source is given by

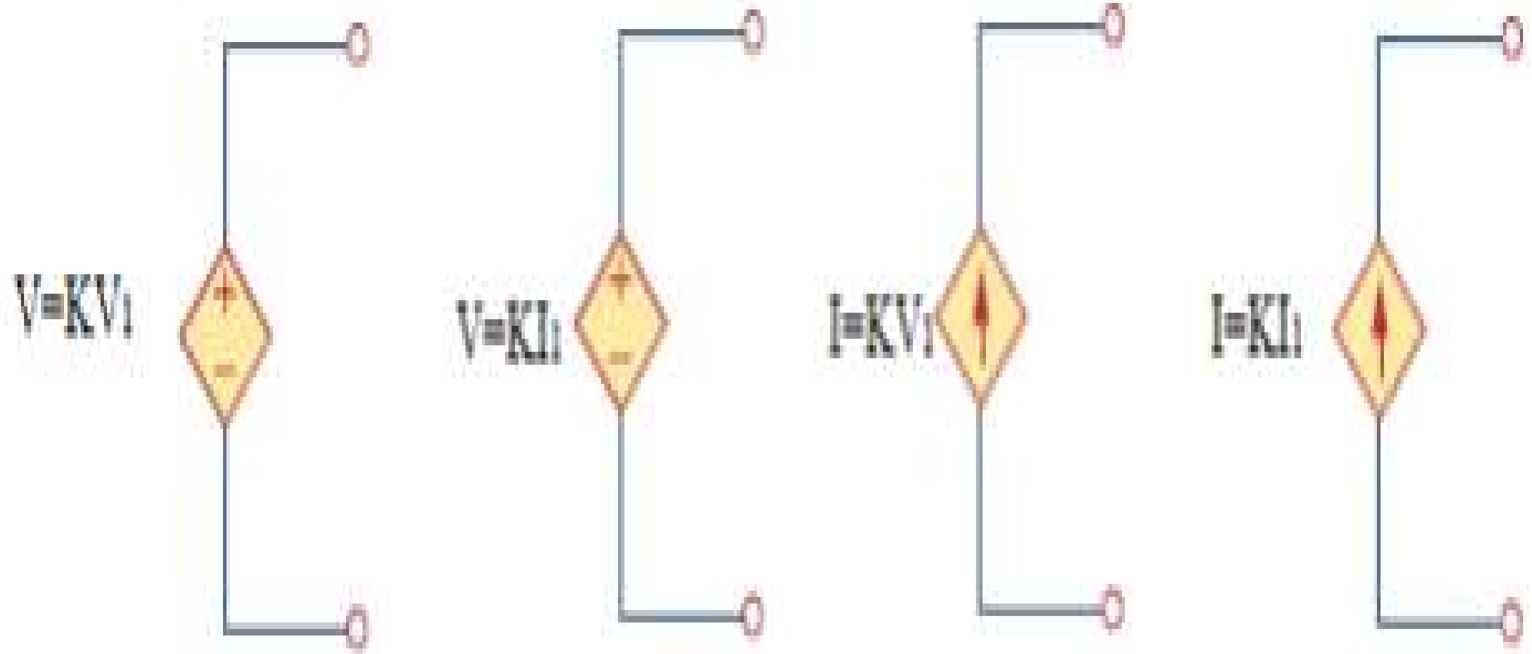
$$I_L = I_s - I_{sh}$$



Dependent source

- An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.
- there are four possible types of dependent sources, namely:

1. A voltage-controlled voltage source (VCVS)
2. A current-controlled voltage source (CCVS)
3. A voltage-controlled current source (VCCS)
4. A current-controlled current source (CCCS)



(a) VCVS (b)CCVS (c) VCCS (d)CCCS

PASSIVE ELEMENTS (LOADS)

- Passive elements are those elements which are capable of receiving the energy. Some passive elements like inductors and capacitors are capable of storing a finite amount of energy, and return it later to an external element.
- More specifically, a passive element is defined as one that cannot supply average power that is greater than zero over an infinite time interval. Resistors, capacitors, Inductors fall in this category.

NETWORK/CIRCUIT TERMINOLOGY

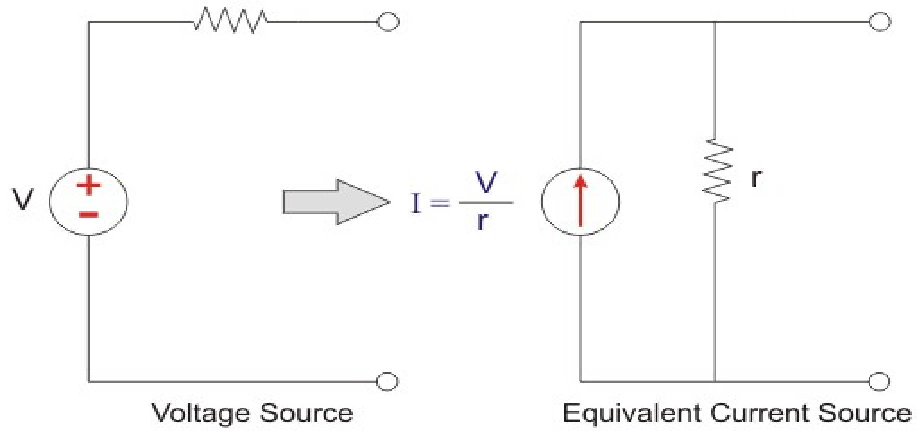
- **Network Elements:** The individual components such as a resistor, inductor, capacitor, diode, voltage source, current source etc. that are used in circuit are known as network elements.
- **Network:** The interconnection of network elements is called a network.
- **Circuit:** A network with at least one closed path is called a circuit. So, all the circuits are networks but all networks are not circuits.
- **Branch:** A branch is an element of a network having only two terminals.
- **Node:** A node is the point of connection between two or more branches. It is usually indicated by a dot in a circuit.
- **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.
- **Mesh or Independent Loop:** Mesh is a loop which does not contain any other loops in it.

Source Transformation

- **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:

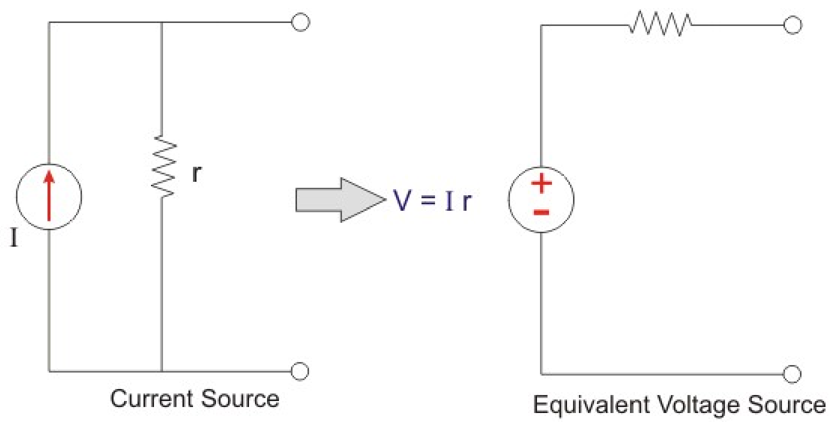
$$I = \frac{V}{r}$$



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

$$V = Ir$$



KIRCHHOFF'S LAWS

- **KIRCHHOFF'S CURRENT LAW (KCL)** This is also called as Kirchhoff's first law or Kirchhoff's nodal law. Kirchhoff's first law is based on the law of conservation of charge, which requires that the algebraic sum of charges within a system cannot change.
- Statement: Algebraic sum of the currents meeting at any junction or node is zero. The term 'algebraic' means the value of the quantity along with its sign, positive or negative

Mathematically, KCL implies that

$$\sum_{n=1}^{N} i_n = 0$$

Where N is the number of branches connected to the node and is the nth current entering (or leaving) the node. By this law, currents entering a node may be regarded as positive, while currents leaving the node may be taken as negative or vice versa.

Alternate Statement: Sum of the currents flowing towards a junction is equal to the sum of the currents flowing away from the junction.

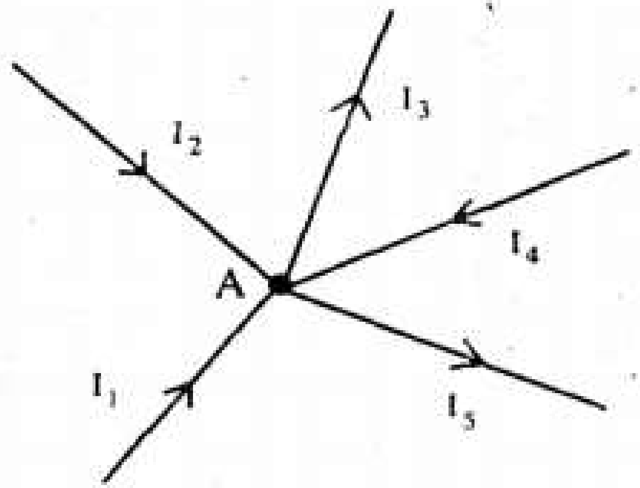


Fig 1.16 Currents meeting in a junction

Consider Fig. 1.16 where five branches of a circuit are connected together at the junction or node A. Currents I_1, I_2 and I_4 are flowing towards the junction whereas currents I_3 and I_5 are flowing away from junction A. If a positive sign is assigned to the currents I_2 and I_4 that are flowing into the junction then the currents I_3 and I_4 flowing away from the junction should be assigned with the opposite sign i.e. the negative sign.

Applying Kirchhoff's current law to the junction A

$$I_1 + I_2 - I_3 + I_4 - I_5 = 0 \text{ (algebraic sum is zero)}$$

The above equation can be modified as $I_1 + I_2 + I_4 = I_3 + I_5$ (sum of currents towards the junction = sum of currents flowing away from the junction).

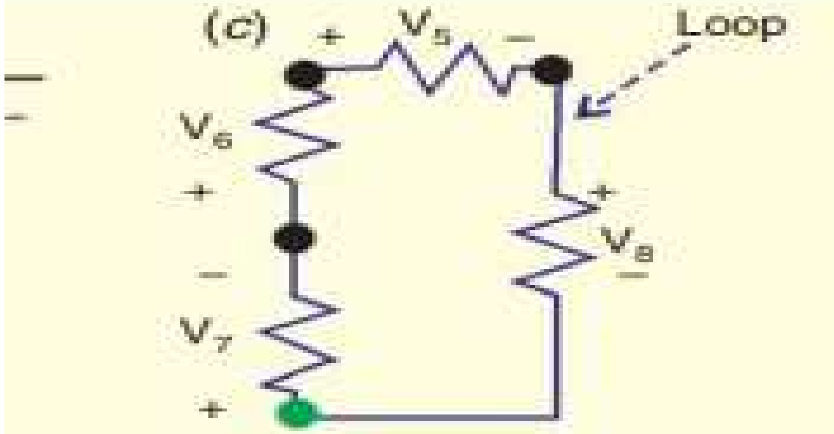
KIRCHHOFF’S VOLTAGE LAW (KVL)

- This is also called as Kirchhoff's second law or Kirchhoff's loop or mesh law. Kirchhoff’s second law is based on the principle of conservation of energy.
- Statement: Algebraic sum of all the voltages around a closed path or closed loop at any instant is zero. Algebraic sum of the voltages means the magnitude and direction of the voltages; care should be taken in assigning proper signs or polarities for voltages in different sections of the circuit.

Mathematically, KVL implies that

$$\sum_{n=1}^{N} V_n = 0$$

Where N is the number of voltages in the loop (or the number of branches in the loop) and V_n is the nth voltage in a loop.



Sum Voltages (counterclockwise order) :

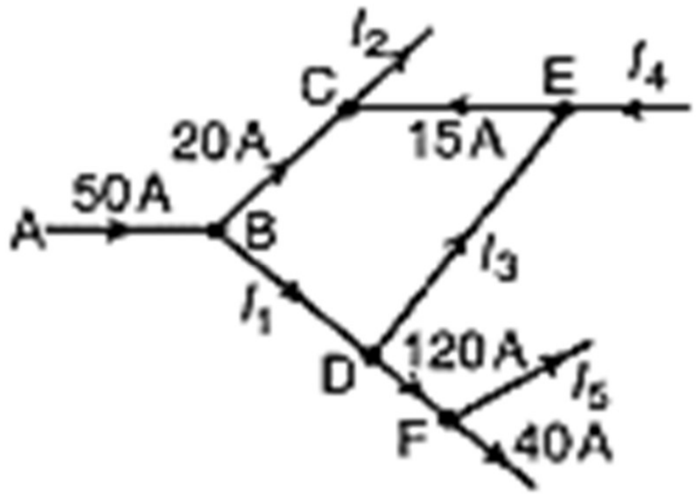
$$V_5 + V_6 + V_7 + V_8 = 0 \text{ volts}$$

Sum Voltages (Clockwise order):

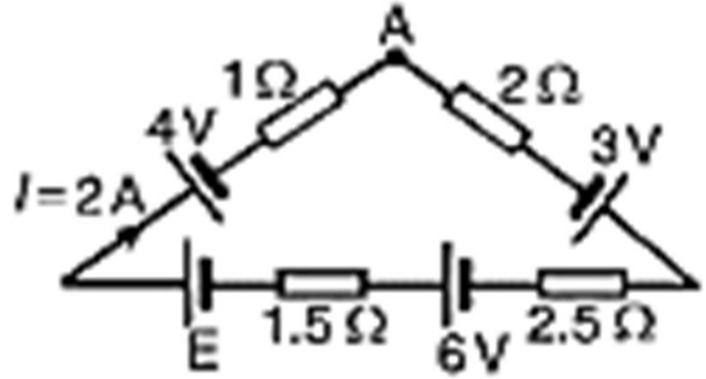
$$-V_5 - V_8 - V_7 + V_6 = 0 \text{ volts}$$

Kirchhoff's Voltage Law

Find the unknown currents marked in Figure (a) .
(b) Determine the value of e.m.f. E in Figure (b) .



(a)



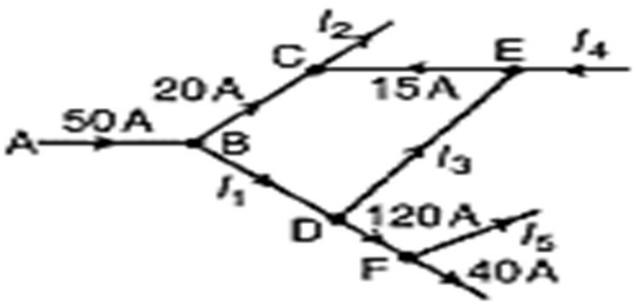
(b)

Solution

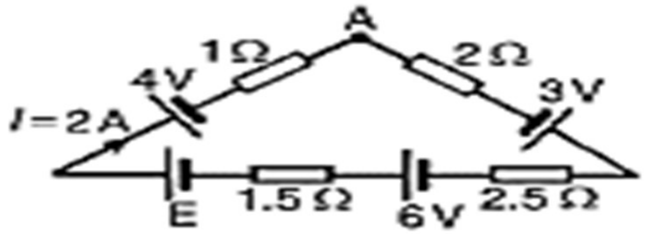
(a) Applying Kirchhoff's current law:

For junction B: $50 = 20 + I_1$. $\boldsymbol{I_1 = 30}$ **A**

For junction C: $20 + 15 = I_2$. $\boldsymbol{I_2 = 35}$ **A**



(a)



(b)

For junction D: $I_1 = I_3 + 120$

i.e., $30 = I_3 + 120$. $\boldsymbol{I_3 = -90\,A}$

(i.e., in the opposite direction to that shown in Figure (a)

For junction E: $I_4 + I_3 = 15$

i.e., $I_4 = 15 - (-90)$.

$\boldsymbol{I_4 = 105\,A}$

For junction F: $120 = I_5 + 40$. $\boldsymbol{I_5 = 80\,A}$

(b) Applying Kirchhoff's voltage law and moving clockwise around the loop of Fig (b) starting at point A:

$$3 + 6 + E - 4 = (I)(2) + (I)(2.5) + (I)(1.5) + (I)(1)$$
$$= I(2 + 2.5 + 1.5 + 1)$$

i.e., $5 + E = 2(7)$, since $I = 2\,A$

$$\boldsymbol{E = 14 - 5 = 9\,V}$$

Ohm’s Law

Ohm’s law is named after the scientist Ohm who gave this law.

According to the Ohm’s law current flowing through a conductor is directly $\propto$ to the potential difference applied between the ends of the conductor.

This means if the potential difference applied at the ends increases then the current flowing through the conductor also increases and vice-versa.

Mathematically

Current flowing through the conductor $I \propto V$ where V is the potential difference applied at the ends of the conductor.

Or $I=(\text{constant})\ V$ where constant = 1/R where R =resistance of the conductor

$I=(1/R)V$

$\mathbf{V=IR}$

Resistors In series

Resistors in Series: A series circuit is a circuit in which resistors are arranged in a single chain, resulting in common current flowing through them.

Circuit Diagram

1. ‘N’ number of resistors can be joined together.
2. As all the resistors are connected to each other as a result same amount of current flows through each resistor.
3. But the Potential difference will be different in each resistor.
4. Consider current flowing through all the resistors =I,Resistance across first resistor=R_1.
5. Potential difference across resistor $R_1$is $V_{1,}$ V_1=IR_1(By ohm’s Law)
6. Similarly V_2=IR_2, V_3= IR_3 and so on.
7. Therefore Total Voltage $V=V_1+V_2+V_3+\ldots\ldots +V_n$
8. $IR_{equivalent} =IR_1+IR_2+IR_3+\ldots. +IR_n$ where $R_{equivalent}$ is the equivalent resistance of the circuit.
9. =>$\mathbf{R_{equivalent} =(R_1+ R_2+ R_3+\ldots.+R_n)}$

Therefore if the resistances are connected in series then the total equivalent resistance of the circuit is equal to the sum of all the resistors in the circuit.

Resistors in Parallel

A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together.

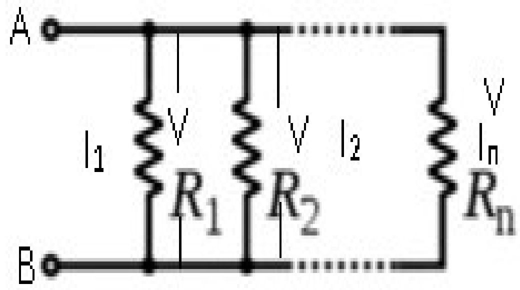
1. The potential difference(V)across each resistoris same.
2. The amount of current flowing is different. This means $I= I_1+I_2+I_3+\ldots+I_n$
3. From Ohm's law –

$$(V/R_{equivalent}) = (V/R_1)+(V/R_2)+(V/R_3)+\ldots\ldots+(V/R_n)$$

$$\mathbf{1/\ R_{equivalent} =(1/\ R_1+1/\ R_2+1/R_3+\ldots.+1/R_n)}$$

Therefore if the resistances are connected in parallel then the total equivalent resistance of the circuit is equal to the sum of the reciprocal of all the resistors connected in the circuit.

- Circuit diagram

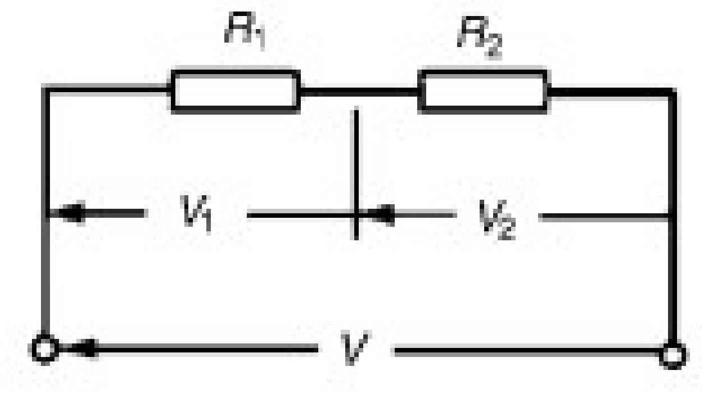


Voltage divider rule

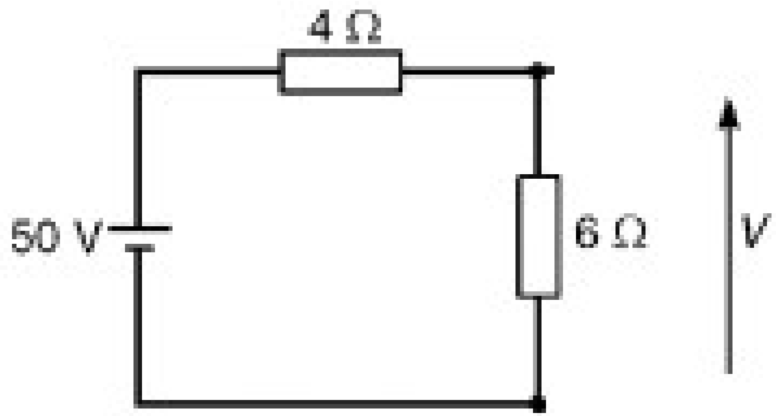
The voltage distribution for the circuit shown in Figure is given by:

$$V_1 = \left(\frac{R_1}{R_1 + R_2} \right) \mathrm{V}$$

$$V_2 = \left(\frac{R_2}{R_1 + R_1} \right) \mathrm{V}$$

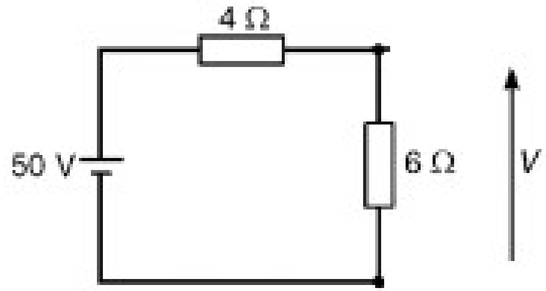


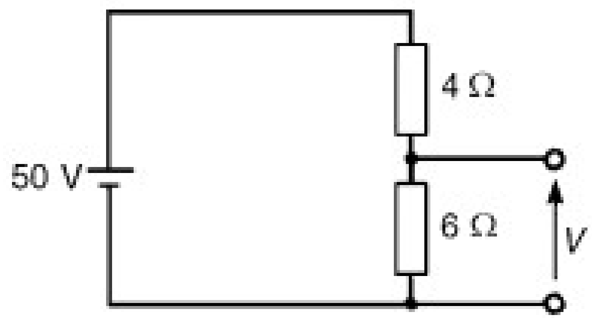
Determine the value of voltage V shown in Figure



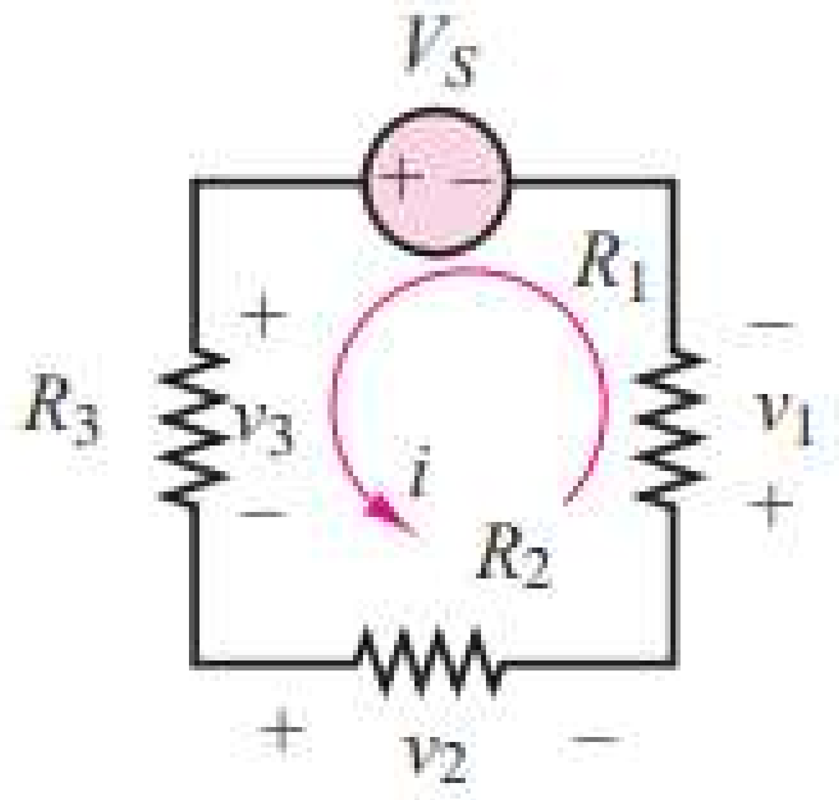
Sol.

$$V = \left(\frac{6}{6+4}\right)(50) = \mathbf{30\ V}$$



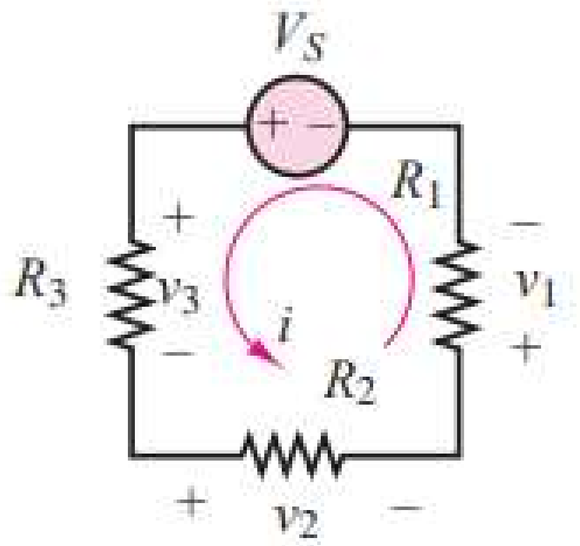


Determine the voltage v_3 in the circuit



Schematics, Diagrams, Circuits, and Given Data: R1 = 10 Ω ; R2 = 6 Ω; R3 = 8 Ω; VS = 3 V

Analysis: Figure indicates a reference direction for the current (dictated by the polarity of the voltage source). Following the passive sign convention, we label the polarities of the three resistors, and apply KVL to determine that

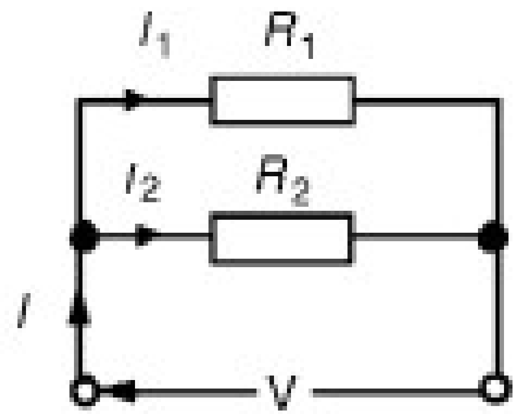


$$V_S - v_1 - v_2 - v_3 = 0$$

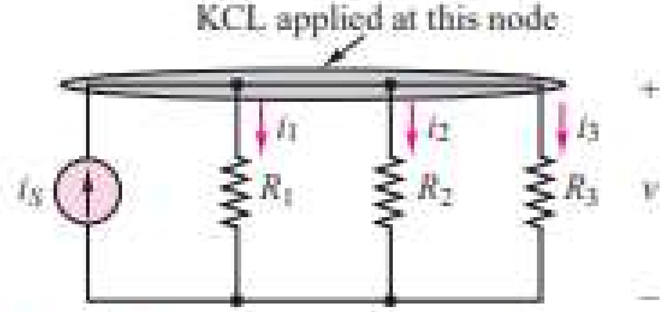
The voltage divider rule tells us that

$$v_3 = V_S \times \frac{R_3}{R_1 + R_2 + R_3} = 3 \times \frac{8}{10 + 6 + 8} = 1 \text{ V}$$

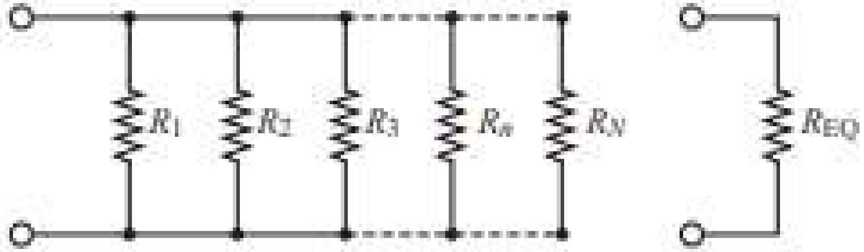
Current Division rule



$$I_1 = \left(\frac{R_2}{R_1 + R_2}\right)(I) \quad \text{and} \quad I_2 = \left(\frac{R_1}{R_1 + R_2}\right)(I)$$



The voltage v appears across each parallel element; by KCL, $i_S = i_1 + i_2 + i_3$



N resistors in parallel are equivalent to a single equivalent resistor with resistance equal to the inverse of the sum of the inverse resistances.

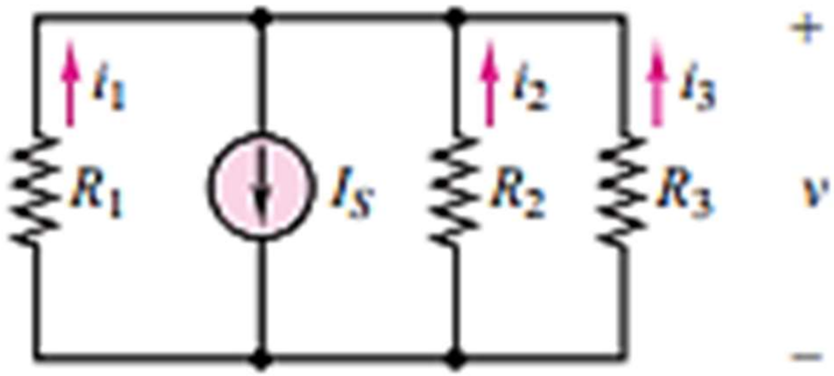
$$i_2 = \frac{1/R_2}{1/R_1 + 1/R_2 + 1/R_3} i_S$$

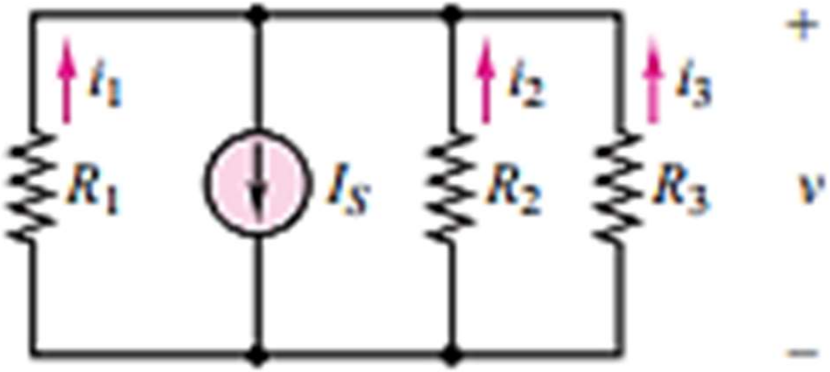
$$i_3 = \frac{1/R_3}{1/R_1 + 1/R_2 + 1/R_3} i_S$$

$$\boxed{i_n = \frac{1/R_n}{1/R_1 + 1/R_2 + \cdots + 1/R_n + \cdots + 1/R_N} i_S \quad \text{Current divider}}$$

Determine the current i1 in the circuit of Figure.

- Known Quantities: Source current; resistance values.
- Find: Unknown current i1.
- Schematics, Diagrams, Circuits, and Given Data: R1 = 10 Ω; R2 = 2 Ω ; R3 = 20 Ω;
- IS = 4 A.





Analysis: Application of the current divider rule yields

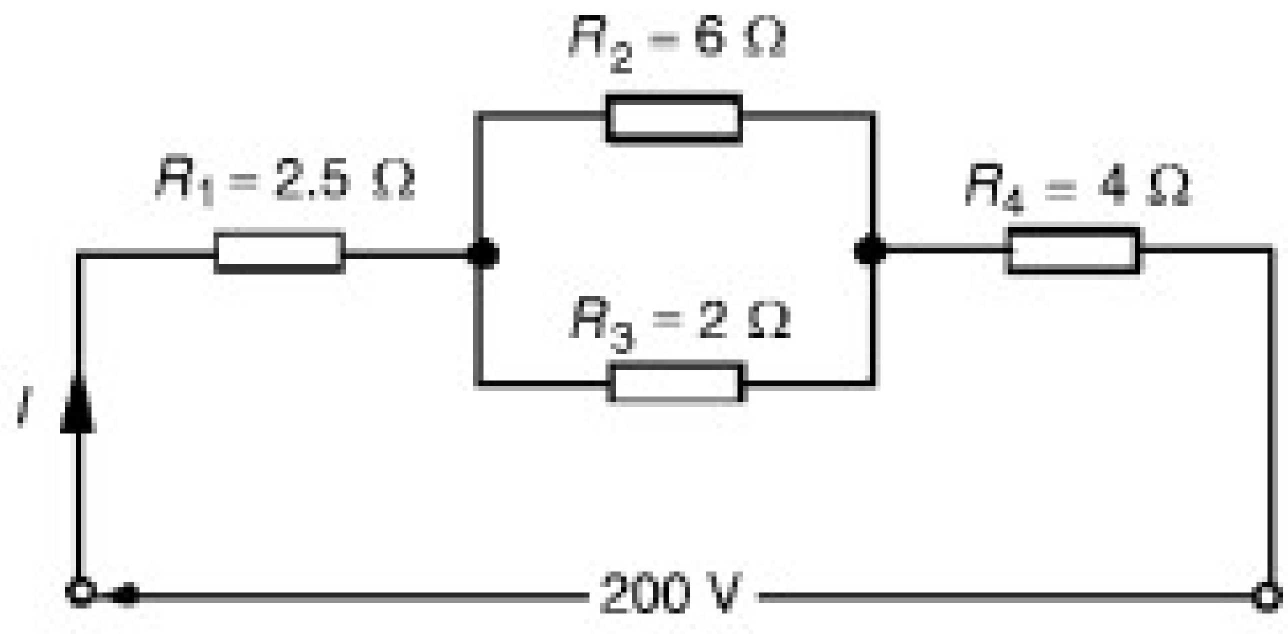
$$i_1 = I_S \times \frac{1/R_1}{1/R_1 + 1/R_2 + 1/R_3} = 4 \times \frac{\frac{1}{10}}{\frac{1}{10} + \frac{1}{2} + \frac{1}{20}} = 0.6154\ \text{A}$$

For the series-parallel arrangement shown in Figure, find

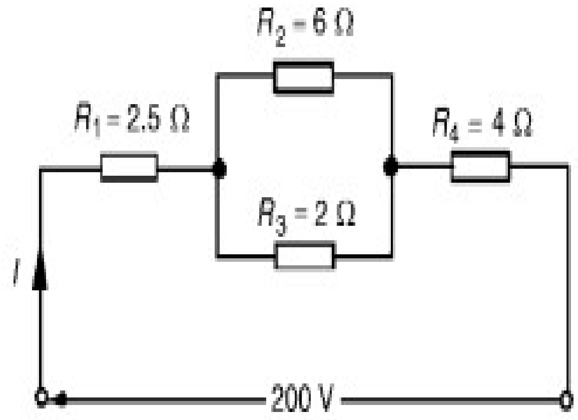
(a) the supply current,

(b) the current flowing through each resistor and

(c) the voltage across each resistor.



(a) The equivalent resistance R_x of R_2 and R_3 in parallel is:



$$R_x = \frac{6 \times 2}{6 + 2} = \frac{12}{8} = 1.5\,\Omega$$

The equivalent resistance R_T of R_1, R_x and R_4 in series is:

$$R_T = 2.5 + 1.5 + 4 = 8\,\Omega$$

Supply current $I = \dfrac{V}{R_T} = \dfrac{200}{8} = \mathbf{25\ A}$

(b) The current flowing through R_1 and R_4 is 25 A. The current flowing through R_2

$$= \left(\frac{R_3}{R_2 + R_3}\right) I = \left(\frac{2}{6+2}\right) 25$$

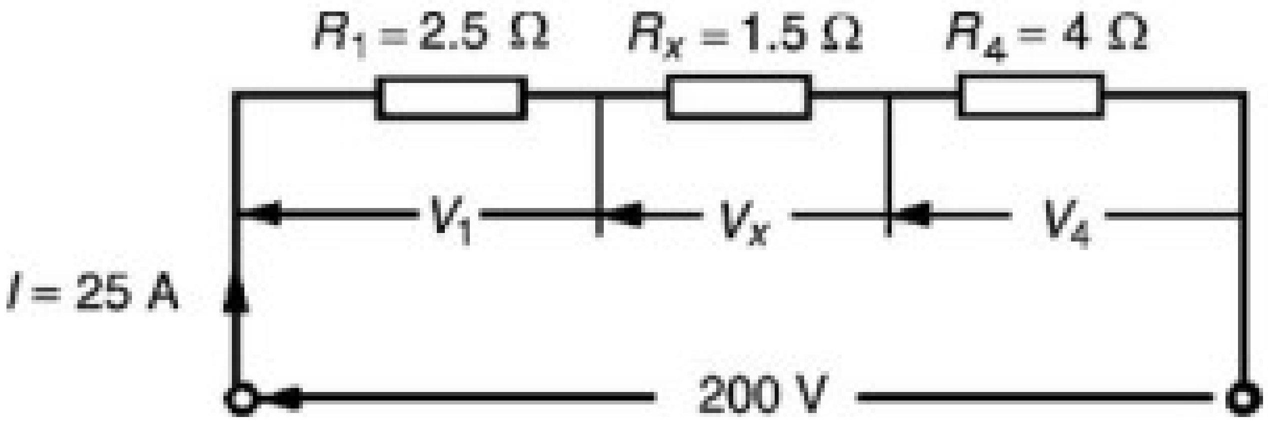
$= \mathbf{6.25\ A}$

The current flowing through R_3

$$= \left(\frac{R_2}{R_2 + R_3}\right) I = \left(\frac{6}{6+2}\right) 25$$

$= \mathbf{18.75\ A}$

(Note that the currents flowing through R_2 and R_3 must add up to the total current flowing into the parallel arrangement, i.e., 25 A.)



(c) The equivalent circuit of Figure 3.19 is shown in Figure 3.20.

voltage across R_1, i.e., $V_1 = IR_1 = (25)(2.5) = \mathbf{62.5\,V}$

voltage across R_x, i.e., $V_x = IR_x = (25)(1.5) = \mathbf{37.5\,V}$

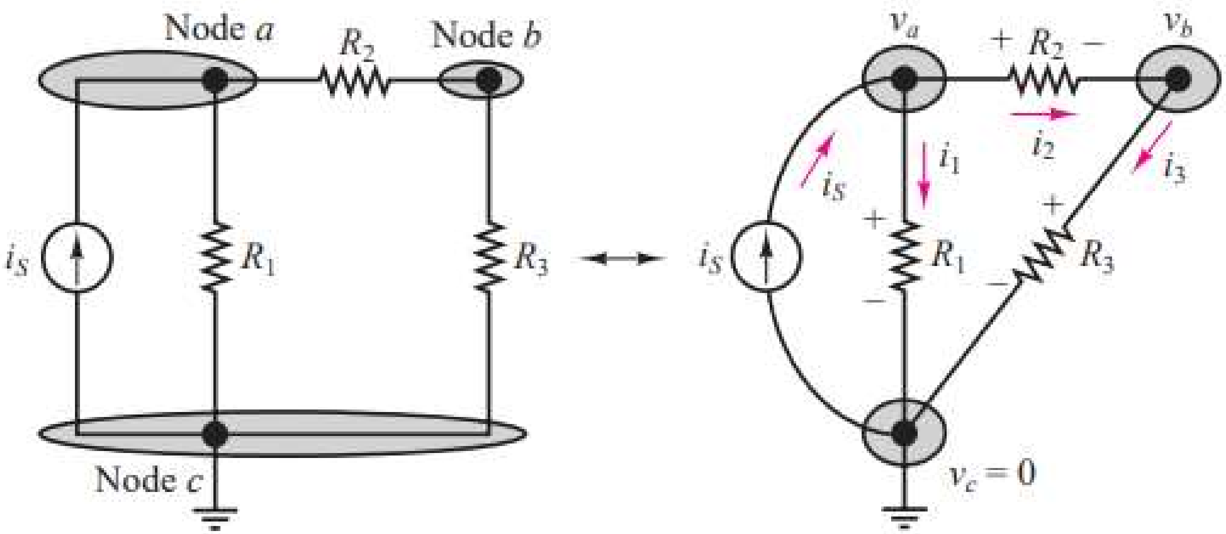
voltage across R_4, i.e., $V_4 = IR_4 = (25)(4) = \mathbf{100\,V}$

Hence, the voltage across R_2 = voltage across R_3 = **37.5 V**

Node voltage analysis

1. Identify the principle node
2. Assign node voltage
3. Write the node equation (with the help of KCL and Ohm's law.

Nodal analysis= KCL+Ohm's



In a circuit containing n nodes, we can write at most n − 1 independent.

$$i_1 = \frac{v_a - v_c}{R_1}$$

$$i_2 = \frac{v_a - v_b}{R_2}$$

$$i_3 = \frac{v_b - v_c}{R_3}$$

$$i_S - i_1 - i_2 = 0$$

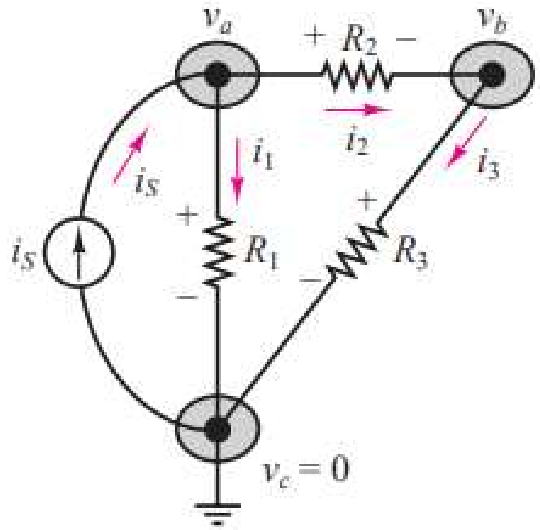
$$i_S - \frac{v_a}{R_1} - \frac{v_a - v_b}{R_2} = 0$$

$$i_2 - i_3 = 0$$

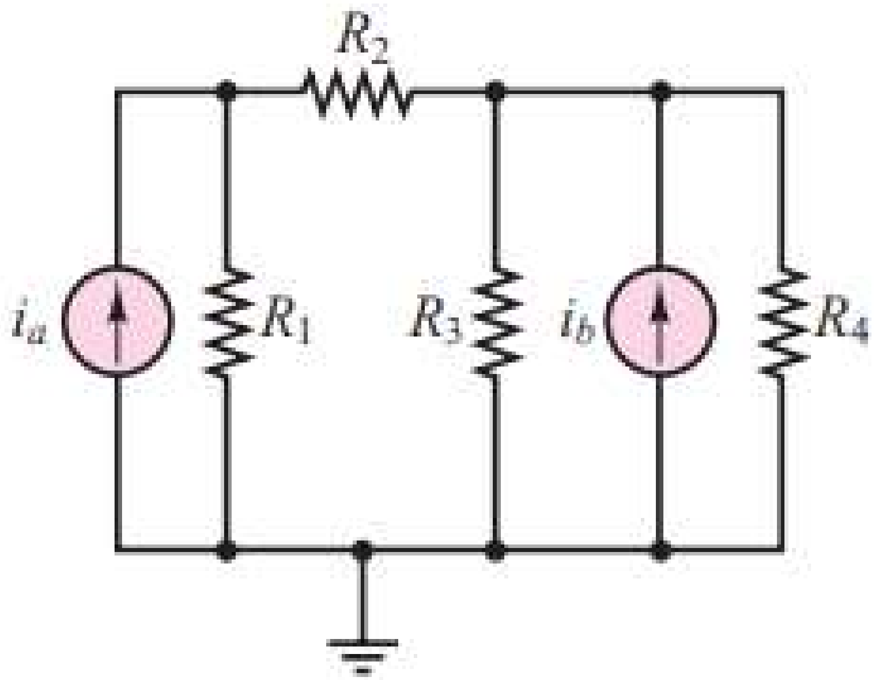
$$\frac{v_a - v_b}{R_2} - \frac{v_b}{R_3} = 0$$

$$\left(\frac{1}{R_1} + \frac{1}{R_2}\right) v_a + \left(-\frac{1}{R_2}\right) v_b = i_S$$

$$\left(-\frac{1}{R_2}\right) v_a + \left(\frac{1}{R_2} + \frac{1}{R_3}\right) v_b = 0$$



Node Analysis



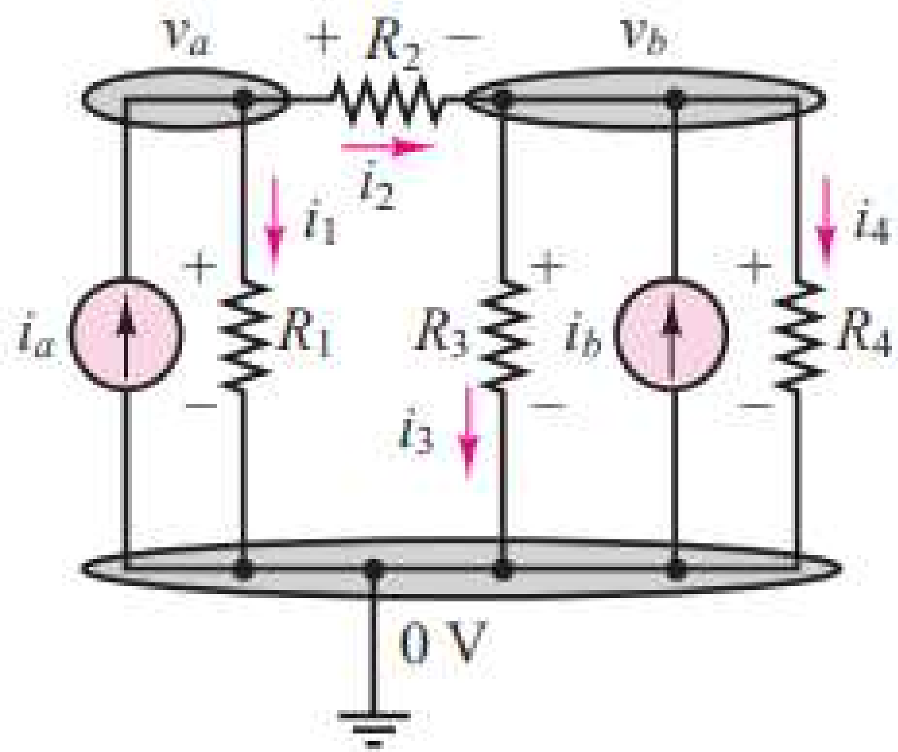
Schematics, Diagrams, Circuits, and Given Data: ia = 1 mA; ib = 2 mA; R1 = 1 kΩ; R2 = 500 Ω ; R3 = 2.2 k Ω; R4 = 4.7 k Ω

- Analysis: We follow the steps of the Focus on Methodology box.

1. The reference (ground) node is chosen to be the node at the bottom of the circuit.

2. See Figure. Two nodes remain after the selection of the reference node. Let us label these a and b and define voltages va and vb. Both nodes are associated with independent variables.

3. We apply KCL at each of nodes a and b:



$$i_a - \frac{v_a}{R_1} - \frac{v_a - v_b}{R_2} = 0 \qquad \text{node } a$$

$$\frac{v_a - v_b}{R_2} + i_b - \frac{v_b}{R_3} - \frac{v_b}{R_4} = 0 \qquad \text{node } b$$

and rewrite the equations to obtain a linear system:

$$\left(\frac{1}{R_1} + \frac{1}{R_2}\right) v_a + \left(-\frac{1}{R_2}\right) v_b = i_a$$

$$\left(-\frac{1}{R_2}\right) v_a + \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) v_b = i_b$$

4. Substituting the numerical values in these equations, we get

$$3 \times 10^{-3} v_a - 2 \times 10^{-3} v_b = 1 \times 10^{-3}$$

$$-2 \times 10^{-3} v_a + 2.67 \times 10^{-3} v_b = 2 \times 10^{-3}$$

or

$$3v_a - 2v_b = 1$$

$$-2v_a + 2.67 v_b = 2$$

The solution $v_a = 1.667$ V, $v_b = 2$ V may then be obtained by solving the system of equations.

Superposition Theorem

- Total current through or voltage across a resistor or branch
  - Determine by adding effects due to each source acting independently
- Replace a voltage source with a short
- Replace a current source with an open
- Find results of branches using each source independently
  - Algebraically combine results

STEP TO APPLY SUPERPOSITION THEOREM

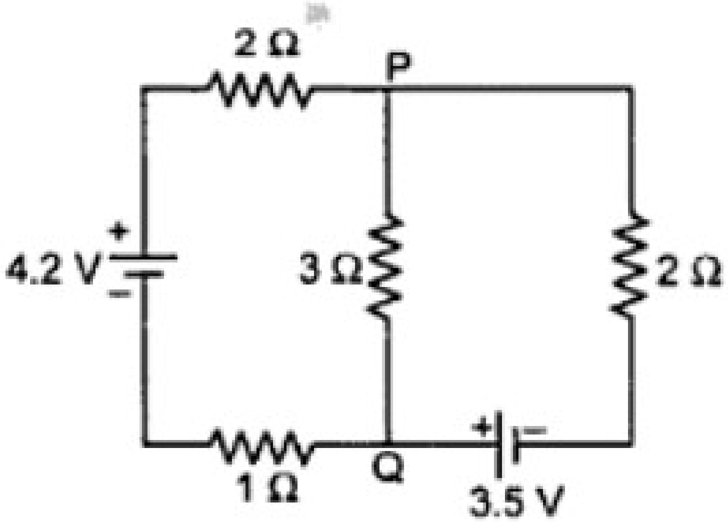
Step 1 : Select a single source acting alone. Short the other voltage sources and open the current sources, if internal resistances are not known. If known, replace them by their internal resistances.

Step 2 : Find the current through or the voltage across the required element, due to the source under consideration, using a suitable network simplification technique.

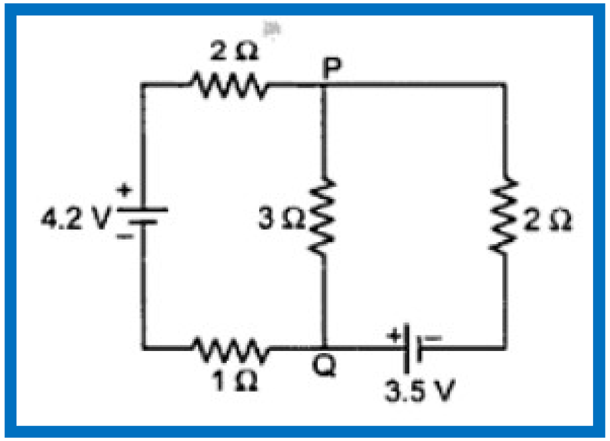
Step 3 : Repeat the above two steps for all the sources

Step 4 : Add the individual effects produced by individual sources, to obtain the total current in or voltage across the element.

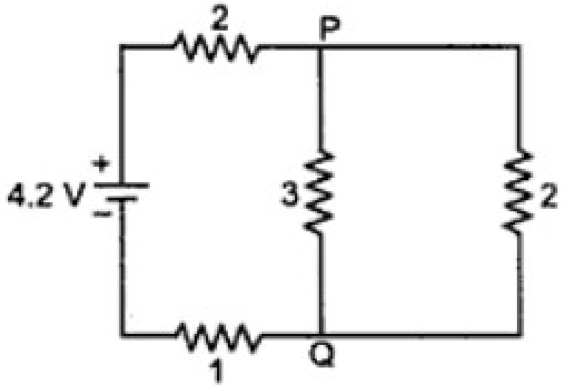
Problem: Cal. the current in branch PQ.



Solution



Step 1 : Let us consider 4.2 V, replacing other by short circuit.



The resistances 3 Ω and 2 Ω are in parallel

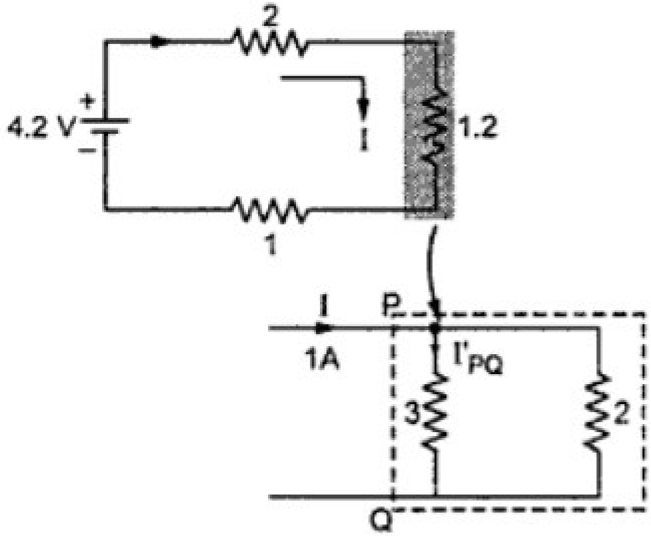
$$\therefore \quad 3 \parallel 2 = \frac{3\times 2}{3+2} = 1.2\ \Omega$$

$$\therefore \quad I = \frac{4.2}{(2+1.2+1)} = 1\ \text{A}$$

Now we want I_{PQ}, hence using current division formula,

$$I'_{PQ} = 1\ \text{A} \times \frac{2}{2+3} = 0.4\ \text{A} \downarrow$$

... due to 4.2 V alone



Step 2 :

Now consider 3.5 V source, replacing other by a short circuit.

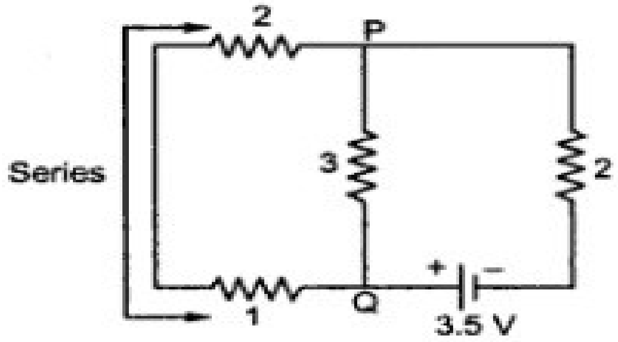
The resistances 2 and 1 are in series hence

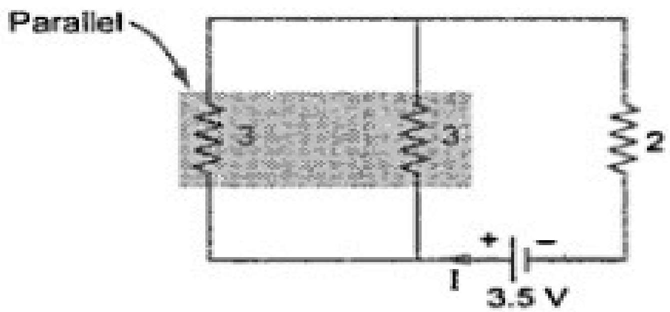
$$2 \text{ series } 1 = 2 + 1 = 3\ \Omega$$

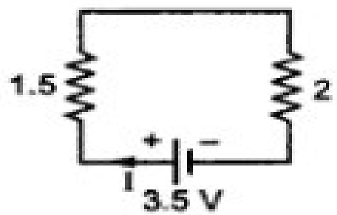
The resistances 3 and 3 are in parallel.

$$\therefore \qquad 3 \parallel 3 = \frac{3 \times 3}{3+3} = 1.5\ \Omega$$

$$I = \frac{3.5}{(2+1.5)} = 1\ A$$







But we want I_{PQ}, hence using current division formula we get,

$$I''_{PQ} = I \times \frac{3}{(3+3)}$$

$$= 1 \times \frac{3}{(3+3)}$$

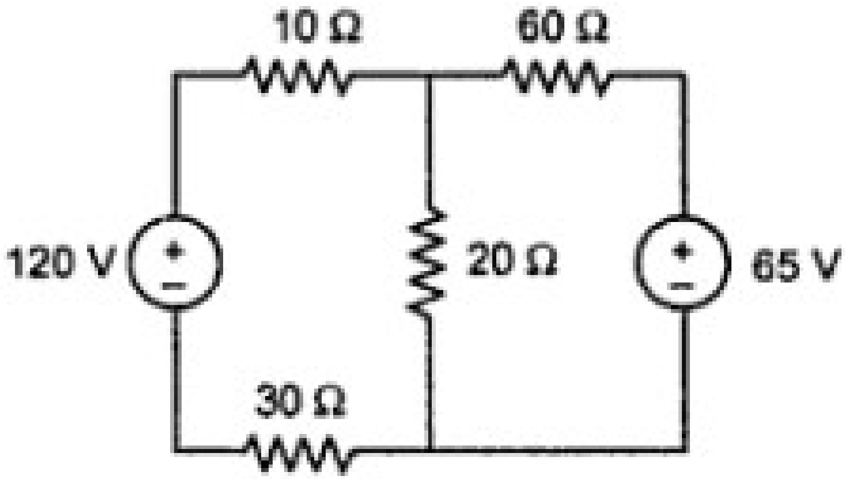
$$= \mathbf{0.5 \uparrow A}$$

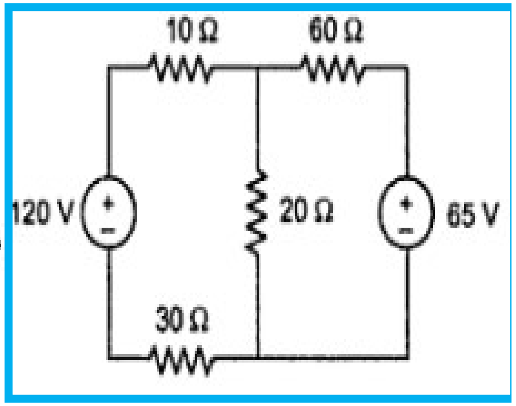
... due to 3.2 V alone

Hence total current through PQ branch

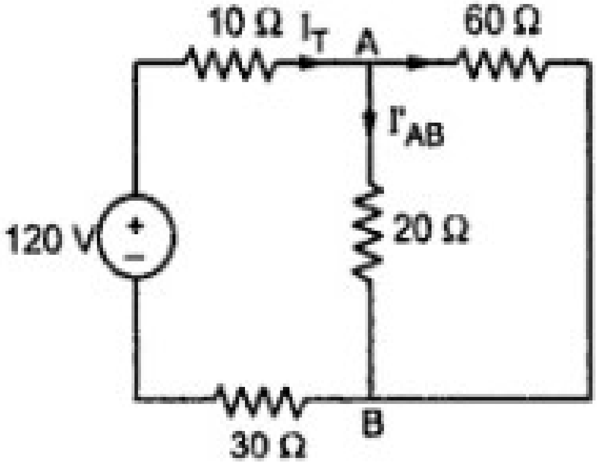
$$= 0.4 \text{ A} \downarrow + 0.5 \text{ A} \uparrow = \mathbf{0.1\ A} \uparrow$$

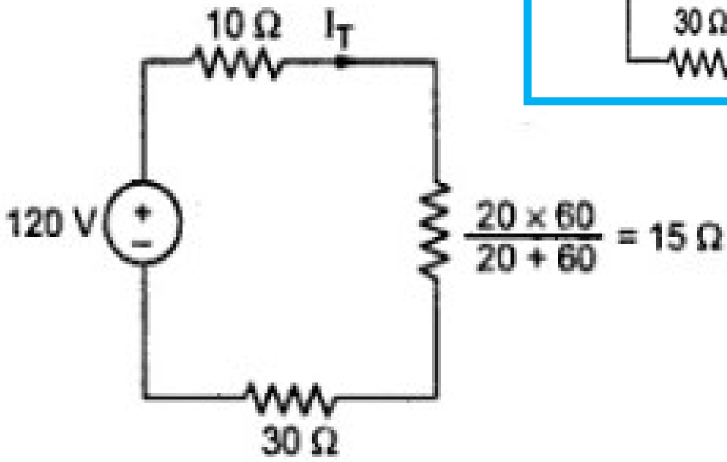
Problem: **Find the current through 20 Ohm resistance.**





Solution : **Step 1 :** Consider 120 V battery alone, shorting 65 V battery.

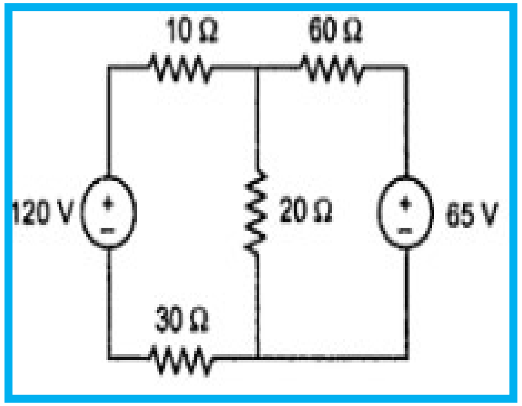




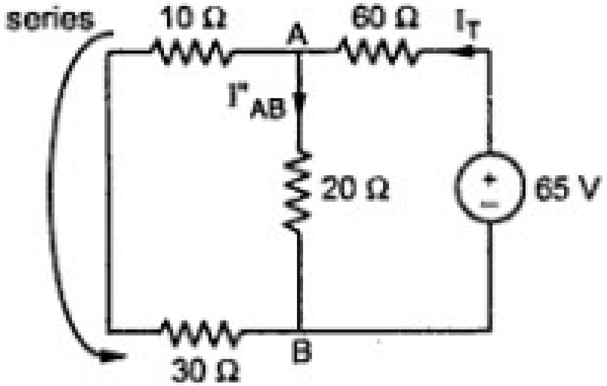
$$I_T = \frac{120}{10+15+30} = 2.1818 \text{ A}$$

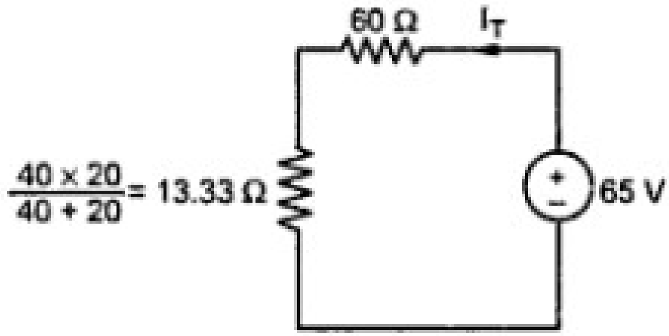
$$I'_{AB} = I_T \times \frac{60}{20+60} \qquad \text{... Current division rule}$$

$$= 1.6363 \text{ A due to 120 V battery} \downarrow$$



Step 2 : Consider 65 V battery alone, shorting 120 V battery.





$$I_T = \frac{65}{73.33} = 0.8863 \text{ A}$$

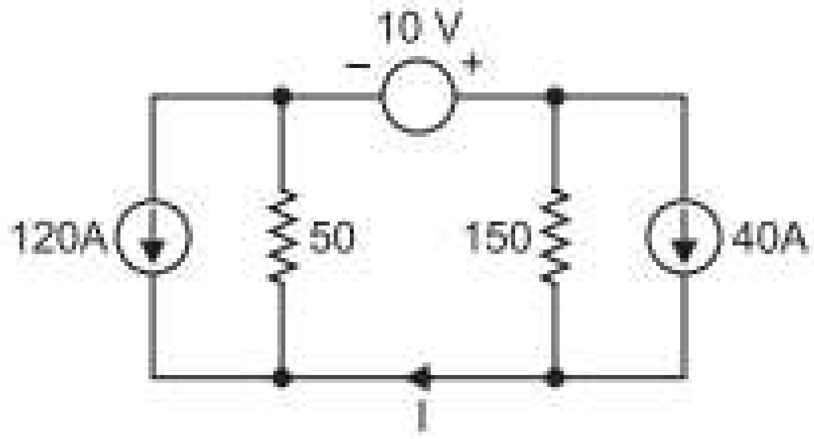
$$\therefore \qquad I''_{AB} = I_T \times \frac{40}{20+40} = \textbf{0.5909 A due to 65 V battery} \downarrow$$

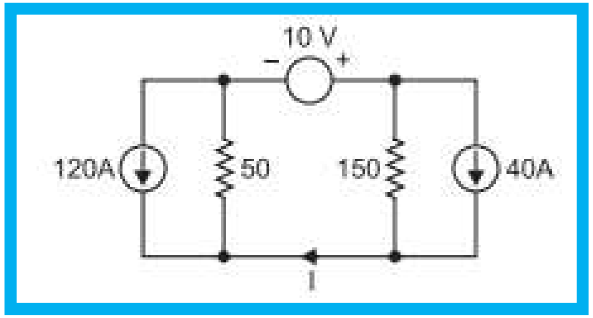
$\therefore$ Total current through 20 Ω resistance, according to Superposition theorem is,

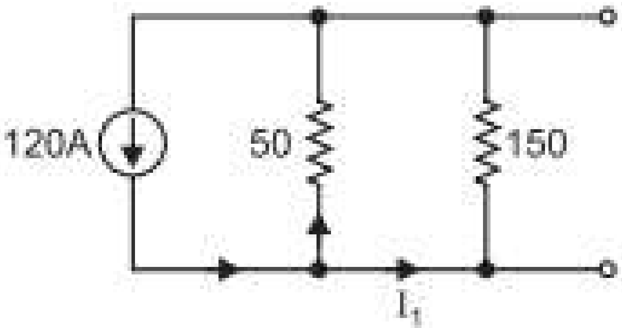
$$I_{20\Omega} = 1.6363 + 0.5909 \text{ both in same direction}$$

$$= \textbf{2.2272 A} \downarrow$$

Problem: Use superposition theorem to find current I in the circuit shown in Fig.. All resistances are in ohms.

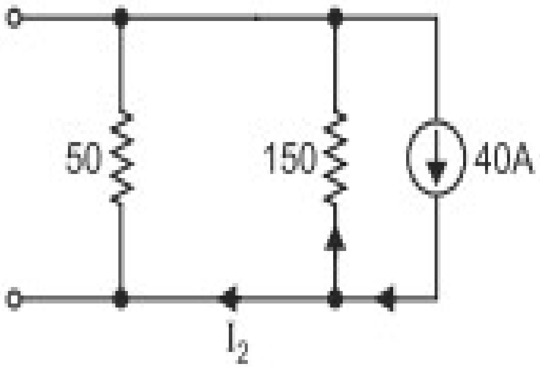






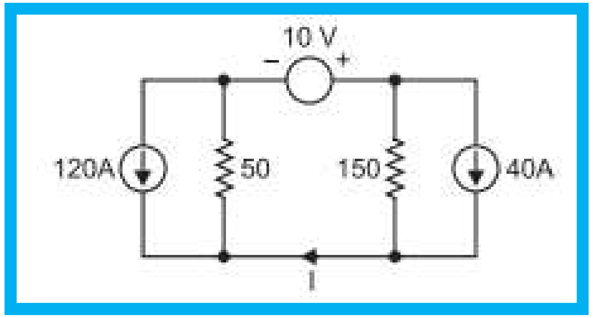
The 10V voltage source has been replaced by a short and the 40A current source by an open so that now only 120A current source is acting alone. By current-divider rule, I1 is given by ;

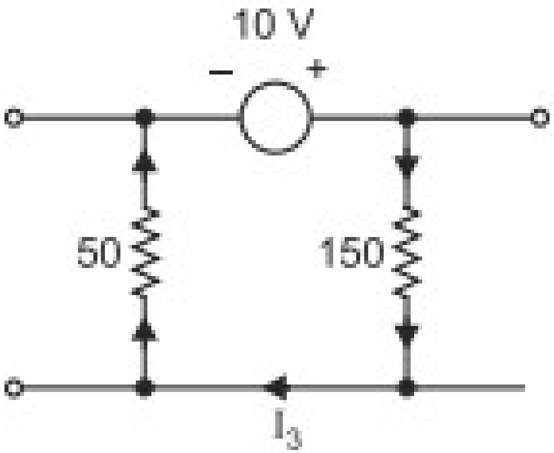
$$I_1 = 120 \times \frac{50}{50+150} = 30\text{ A}$$



40A current source is acting alone; 10 V voltage source being replaced by a short and 120A current source by an open. By current-divider rule, I2 is given by ;

$$I_2 = 40 \times \frac{150}{50+150} = 30\text{A}$$





10V voltage source is acting alone. By Ohm’s law, I3 is given by ;

$$I_3 = \frac{10}{50+150} = 0.05A$$

I = -I1+I2+I3 = -30+30+0.05=0.05