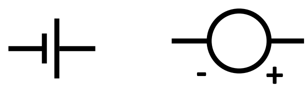
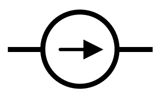
21EES101J - BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

Unit-1

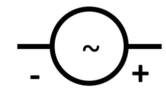
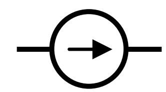
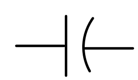
ELECTRIC CIRCUITS

Electric circuits are broadly classified as Direct Current (D.C.) circuits and Alternating Current (A.C.) circuits. The following are the various elements that form electric circuits.

D.C. Circuits

Elements	Representation
Voltage source	
Current source	
Resistor	

A.C. Circuits

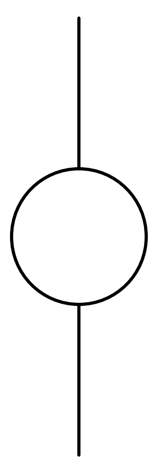
Elements	Representation
Voltage source	
Current source	
Resistor	
Inductor	
Capacitor	

We also will classified sources as **Independent** and **Dependent** sources

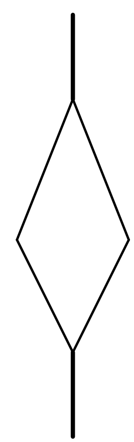
Independent source establishes a voltage or a current in a circuit without relying on a voltage or current elsewhere in the circuit

Dependent sources establishes a voltage or a current in a circuit whose value depends on the value of a voltage or a current elsewhere in the circuit

We will use circle to represent **Independent source** and diamond shape to represent **Dependent sources**



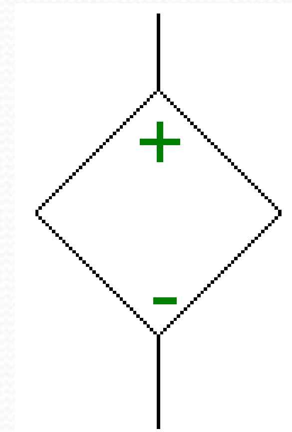
Independent source



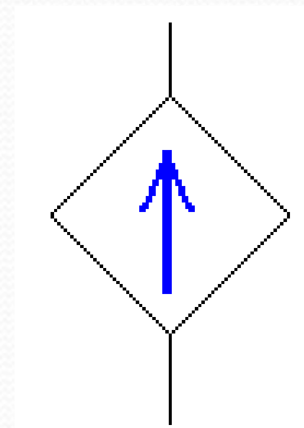
Dependent sources

Dependent Power Sources

- Voltage controlled voltage source
  - (VCVS)
- Current controlled voltage source
  - (CCVS)



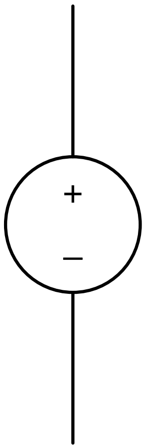
- Voltage controlled current source
  - (VCCS)
- Current controlled current source
  - (CCCS)



Summary

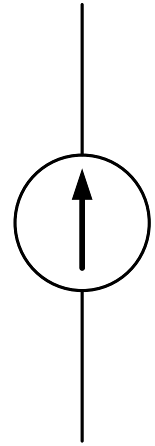
- Dependent sources are voltage or current sources whose output is a function of another parameter in the circuit.
  - Voltage controlled voltage source (VCVS)
  - Current controlled current source (CCCS)
  - Voltage controlled current source (VCCS)
  - Current controlled voltage source (CCVS)
- Dependent sources only produce a voltage or current when an independent voltage or current source is in the circuit.
- Dependent sources are treated like independent sources when using nodal or mesh analysis, but **not** with superposition.

Independent and dependent voltage and current sources can be represented as



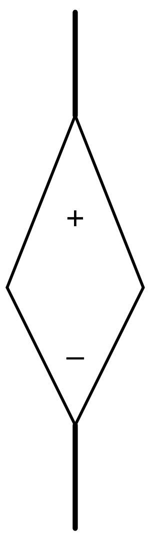
5 V

Independent voltage source



3 A

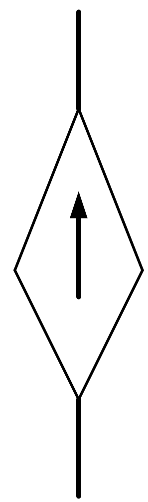
Independent current source



4 $\boldsymbol{i_x}$ ***V***

were i_x is some current
through an element

Dedependent voltage source
Voltage depend on current

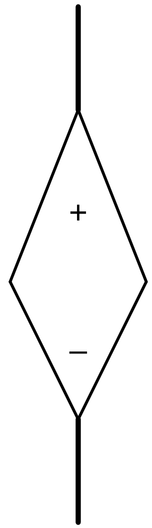


4 $\boldsymbol{v_x}$ ***A***

were v_x is some voltage
across an element

Dedependent current source
Current depend on voltage

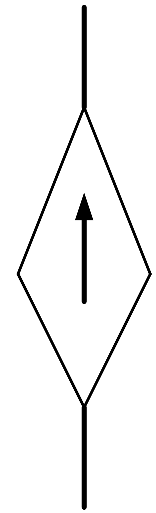
The dependent sources can be also as



$\boldsymbol{4\, v_x \quad V}$

were v_x is some current through an element

Dedependent voltage source
Voltage depend on voltage



$\boldsymbol{7\, i_x \quad A}$

were i_x is some voltage across an element

Dedependent current source
Current depend on current

First we shall discuss about the analysis of DC circuit. The voltage across an element is denoted as E or V. The current through the element is I.

Conductor is used to carry current. When a voltage is applied across a conductor, current flows through the conductor. If the applied voltage is increased, the current also increases. The voltage current relationship is shown in Fig. 1.

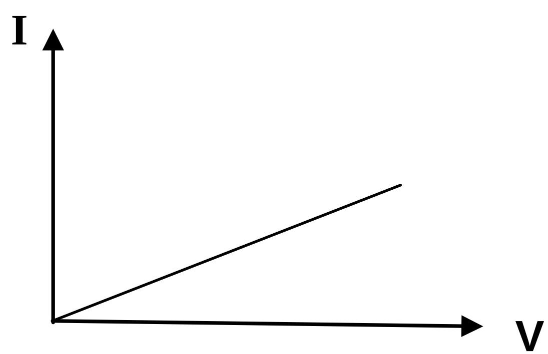
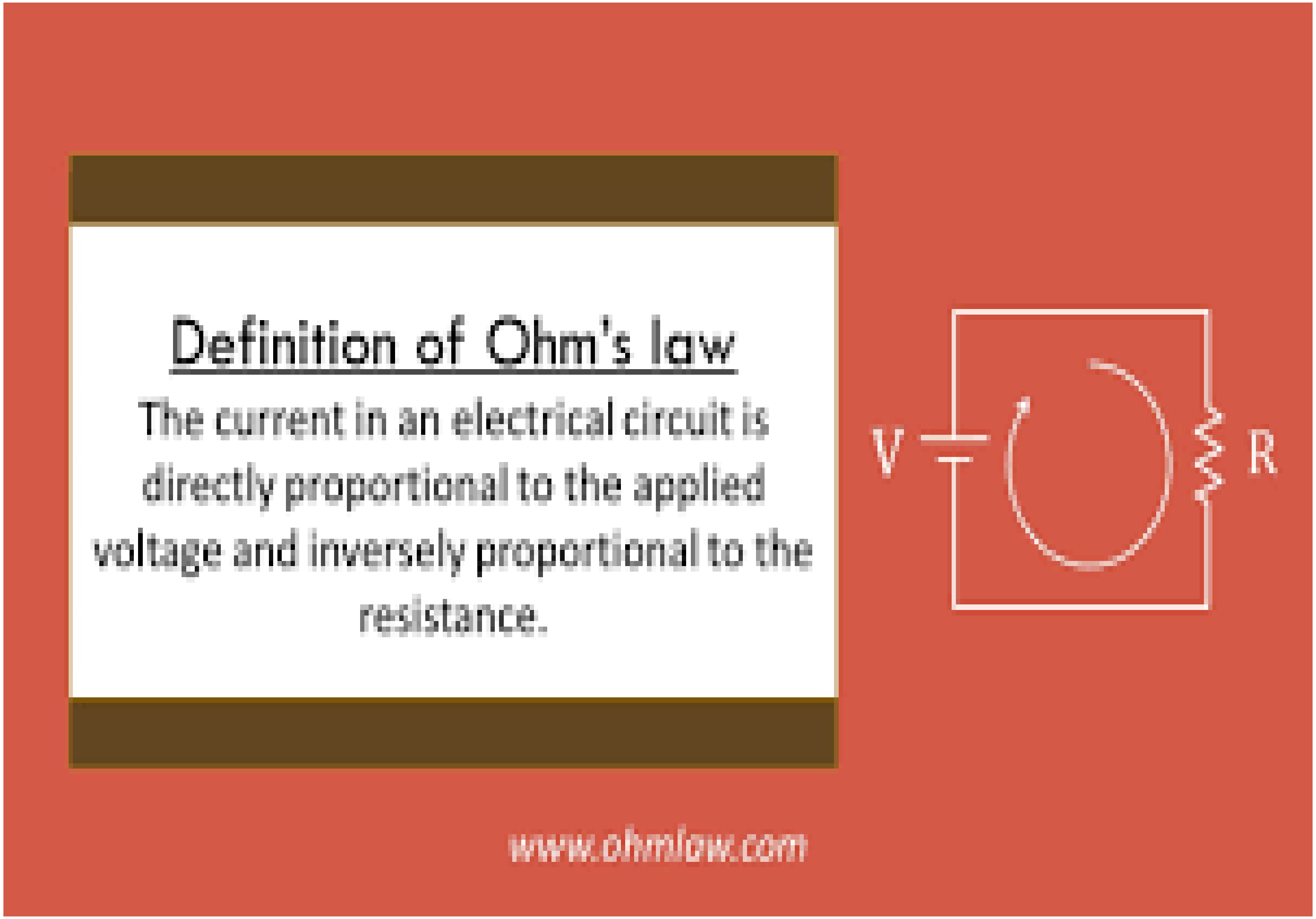


Fig. 1 Voltage – current relationship

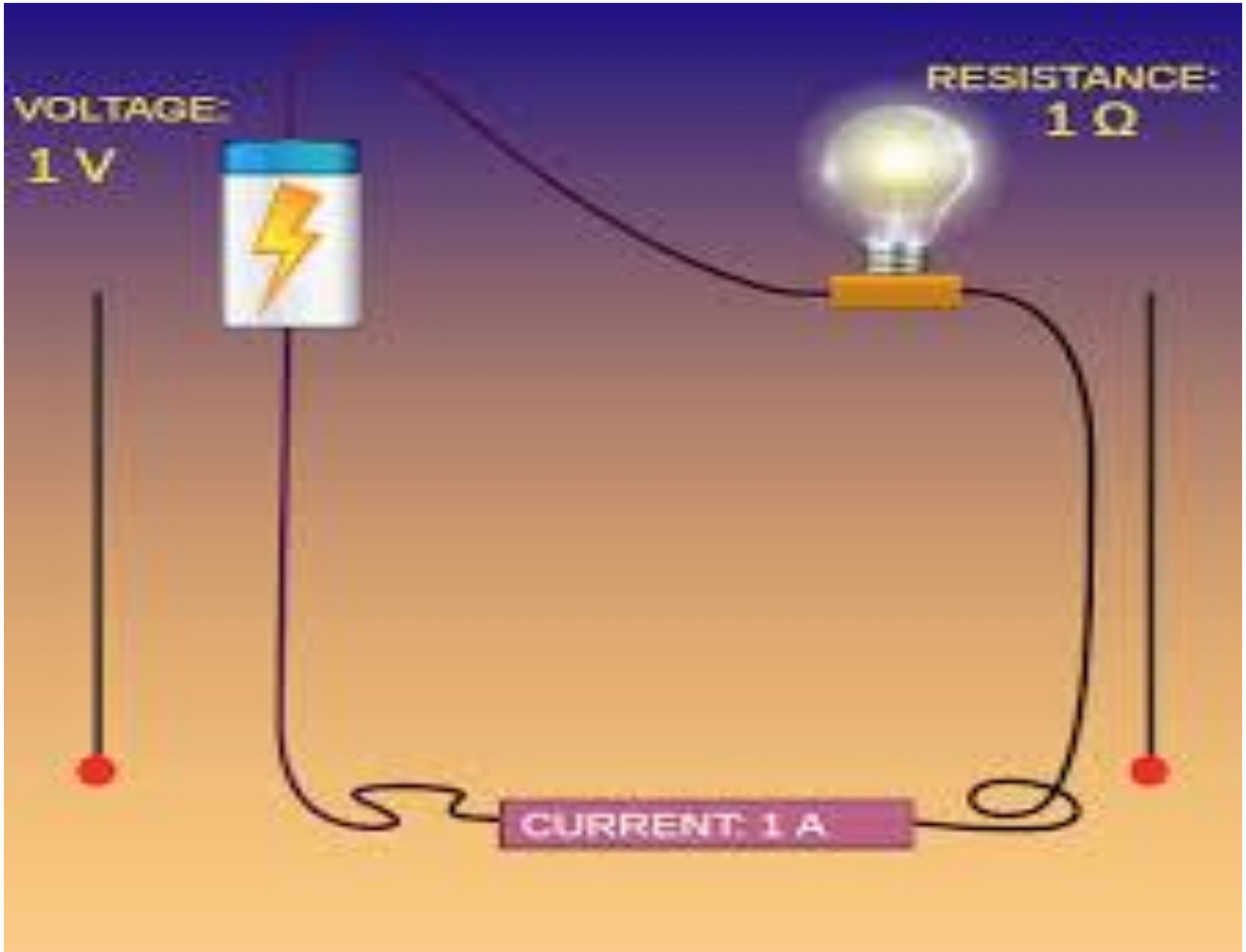
It is seen that $I \infty V$. Thus we can write

$$I = G\,V \qquad (1)$$

where G is called the conductance of the conductor.


Definition of Ohm's law
The current in an electrical circuit is directly proportional to the applied voltage and inversely proportional to the resistance.
V
R
www.ohmlaw.com


OHM'S LAW
Ohm
Amp
Volt


VOLTAGE:
1 V
RESISTANCE:
1 Ω
CURRENT: 1 A

Very often we are more interested on RESISTANCE, R of the conductor, than the conductance of the conductor. Resistance is the opposing property of the conductor and it is the reciprocal of the conductance, Thus

$$R = \frac{1}{G} \quad \text{or} \quad G = \frac{1}{R} \qquad (2)$$

Therefore

$$I = \frac{V}{R} \qquad (3)$$

The above relationship is known as OHM's law. Thus Ohm law can be stated as the current flows through a conductor is the ratio of the voltage across the conductor and its resistance. Ohm's law can also be written as

$$V = R\,I \qquad (4)$$

$$R = \frac{V}{I} \qquad (5)$$

The resistance of a conductor is directly proportional to its length, inversely proportional to its area of cross section. It also depends on the material of the conductor. Thus

$$\mathbf{R = \rho \frac{\ell}{A}} \qquad (6)$$

where ρ is called the specific resistance of the material by which the conductor is made of. The unit of the resistance is Ohm and is represented as Ω. Resistance of a conductor depends on the temperature also. The power consumed by the resistor is given by

$$\mathbf{P = V\,I} \qquad (7)$$

When the voltage is in volt and the current is in ampere, power will be in watt. Alternate expression for power consumed by the resistors are given below.

$$\mathbf{P = R\,I \times I = I^2 R} \qquad (8)$$

$$\mathbf{P = V \times \frac{V}{R} = \frac{V^2}{R}} \qquad (9)$$

Kirchhoff’s current law

Kirchhoff’s currents law states that the algebraic sum of element current meeting at a junction is zero.

Consider a junction P wherein four elements, carrying currents I_1, I_2, I_3 and I_4, are meeting as shown in Fig. 2.

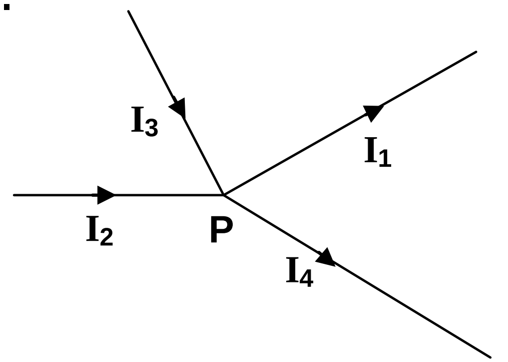


Fig. 2 Currents meeting at a junction

Note that currents I_1 and I_4 are flowing out from the junction while the currents I_2 and I_3 are flowing into the junction. According to KCL,

$$I_1 - I_2 - I_3 + I_4 = 0 \tag{10}$$

The above equation can be rearranged as

$$I_1 + I_4 = I_2 + I_3 \tag{11}$$

From equation (11), KCL can also stated as at a junction, the sum of element currents that flows out is equal to the sum of element currents that flows in.

Kirchhoff's voltage law

Kirchhoff's voltage law states that the algebraic sum of element voltages around a closed loop is zero.

Consider a closed loop in a circuit wherein four elements with voltages V_1, V_2, V_3 and V_4, are present as shown in Fig. 3.

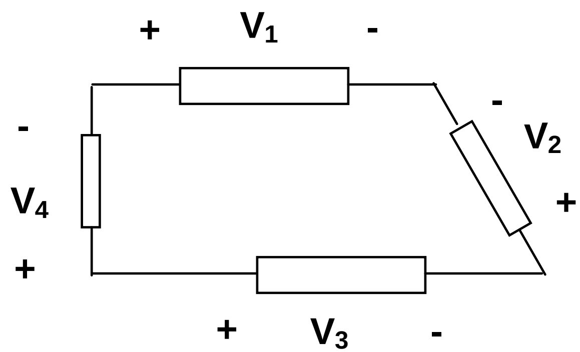


Fig. 3 Voltages in a closed loop

Assigning positive sign for voltage drop and negative sign for voltage rise, when the loop is traced in clockwise direction, according to KVL

$$V_1 - V_2 - V_3 + V_4 = 0 \qquad (12)$$

The above equation can be rearranged as

$$V_1 + V_4 = V_2 + V_3 \qquad (13)$$

From equation (13), KVL can also stated as, in a closed loop, the sum of voltage drops is equal to the sum of voltage rises in that loop.

Resistors connected in series

Two resistors are said to be connected in series when there is only one common point between them and no other element is connected in that common point. Resistors connected in series carry same current. Consider three resisters R_1, R_2 and R_3 connected in series as shown in Fig. 4. With the supply voltage of E, voltages across the three resistors are V_1, V_2 and V_3.

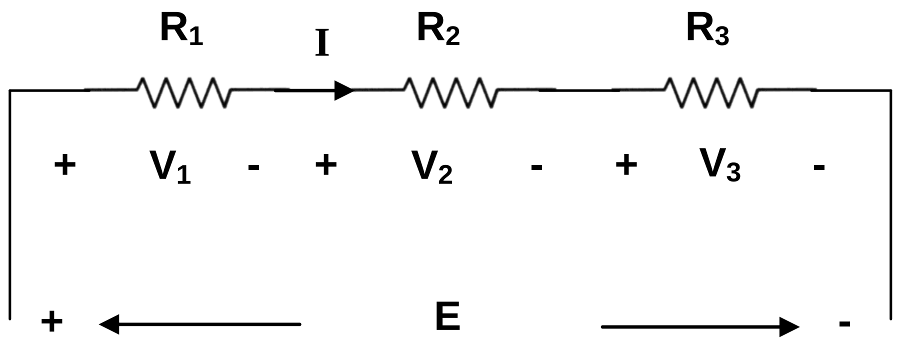


Fig. 4 Resistors connected in series

As per Ohm's law

$$\left.\begin{aligned} V_1 &= R_1 I \\ V_2 &= R_2 I \\ V_3 &= R_3 I \end{aligned}\right\} \qquad (14)$$

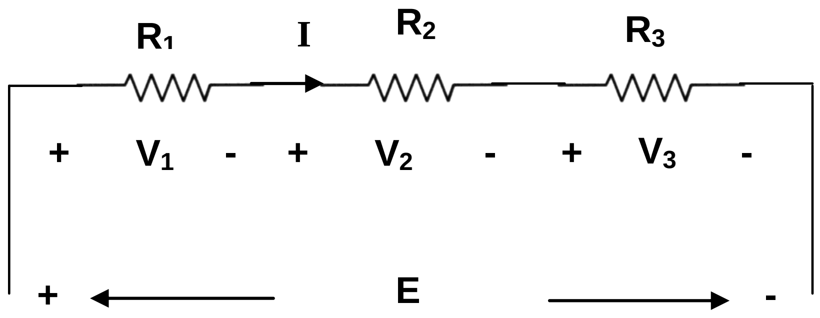


Fig. 4 Resistors connected in series

As per Ohm's law

$V_1 = R_1 I$

$V_2 = R_2 I$

$V_3 = R_3 I$

Applying KVL,

$$E = V_1 + V_2 + V_3 \tag{15}$$

$$= (R_1 + R_2 + R_3) I = R_{eq} I \tag{16}$$

Thus for the circuit shown in Fig. 4,

$$E = R_{eq} I \tag{17}$$

where E is the circuit voltage, I is the circuit current and R_{eq} is the equivalent resistance. Here

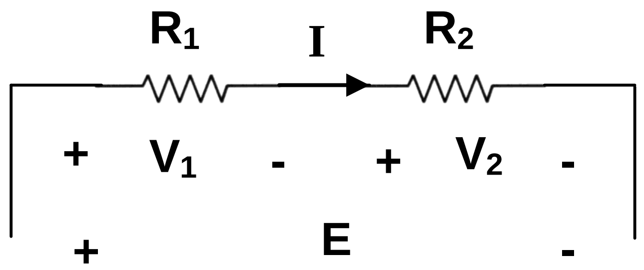
$$R_{eq} = R_1 + R_2 + R_3 \tag{18}$$

This is true when two are more resistors are connected in series. When n numbers of resistors are connected in series, the equivalent resistor is given by

$$R_{eq} = R_1 + R_2 + \ldots\ldots\ldots\ldots + R_n \tag{19}$$

Voltage division rule

Consider two resistors connected in series. Then



$V_1 = R_1 I$

$V_2 = R_2 I$

$E = (R_1 + R_2) I$ and hence $I = E / (R_1 + R_2)$

Total voltage of E is dropped in two resistors. Voltage across the resistors are given by

$$V_1 = \frac{R_1}{R_1 + R_2} E \quad \text{and} \tag{20}$$

$$V_2 = \frac{R_2}{R_1 + R_2} E \tag{21}$$

Resistors connected in parallel

Two resistors are said to be connected in parallel when both are connected across same pair of nodes. Voltages across resistors connected in parallel will be equal.

Consider two resistors R_1 and R_2 connected in parallel as shown in Fig. 5.

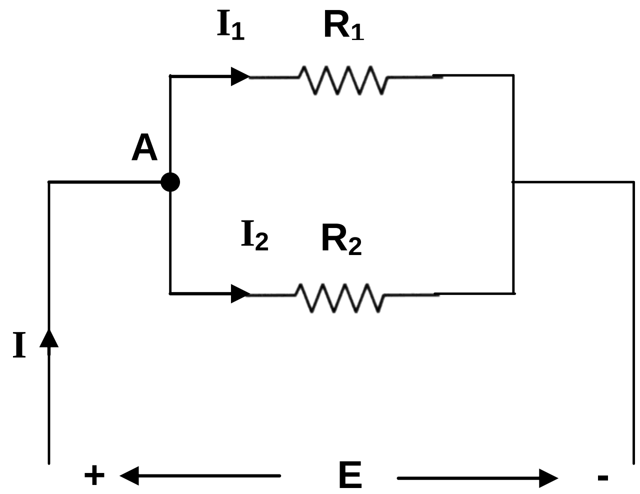
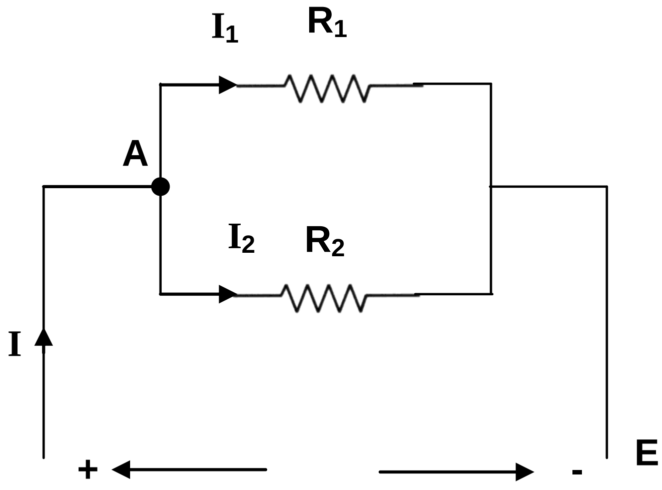


Fig. 5 Resistors connected in parallel

As per Ohm's law,

$$\left.\begin{aligned} I_1 &= \frac{E}{R_1} \\ I_2 &= \frac{E}{R_2} \end{aligned}\right\} \qquad (22)$$



As per Ohm's law

$$I_1 = \frac{E}{R_1}$$

$$I_2 = \frac{E}{R_2}$$

Applying KCL at node A

$$I = I_1 + I_2 = E\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{E}{R_{eq}} \qquad (23)$$

Thus for the circuit shown in Fig. 5

$$I = \frac{E}{R_{eq}} \qquad (24)$$

where E is the circuit voltage, I is the circuit current and R_{eq} is the equivalent resistance. Here

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad (25)$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad (25)$$

From the above $\frac{1}{R_{eq}} = \frac{R_1 + R_2}{R_1 R_2}$

Thus $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$ **(26)**

When n numbers of resistors are connected in parallel, generalizing eq. (25), R_{eq} can be obtained from

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\ldots\ldots\ldots + \frac{1}{R_n} \qquad (27)$$

Current division rule

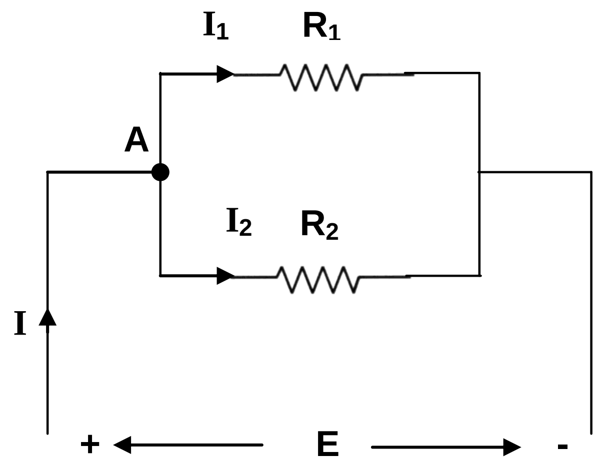


Fig. 5 Resistors connected in parallel

Referring to Fig. 5, it is noticed the total current gets divided as I_1 and I_2. The branch currents are obtained as follows.

From eq. (23)

$$E = \frac{R_1 R_2}{R_1 + R_2} I \tag{29}$$

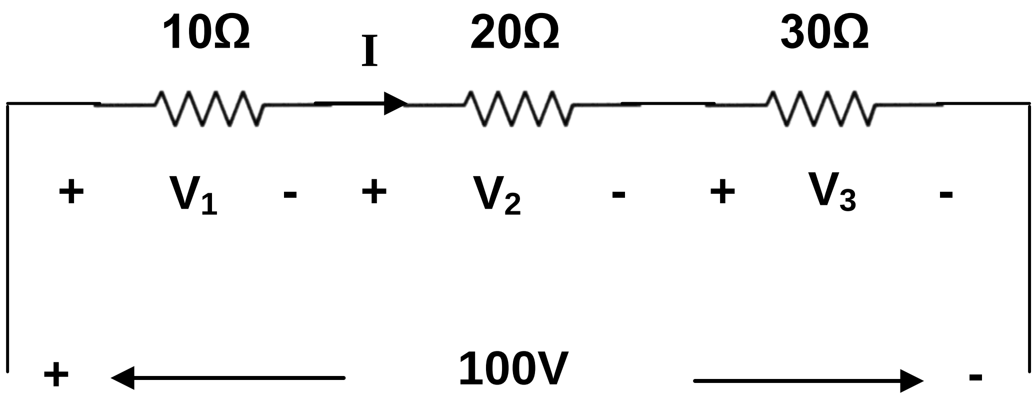
Substituting the above in eq. (22)

$$\left.\begin{aligned} I_1 &= \frac{R_2}{R_1 + R_2} I \\ I_2 &= \frac{R_1}{R_1 + R_2} I \end{aligned}\right\} \tag{30}$$

<u>Example</u>

Three resistors 10Ω, 20Ω and 30Ω are connected in series across 100 V supply. Find the voltage across each resistor.

<u>Solution</u>



Current I = 100 / (10 + 20 + 30) = 1.6667 A

Voltage across 10Ω = 10 x 1.6667 = 16.67 V

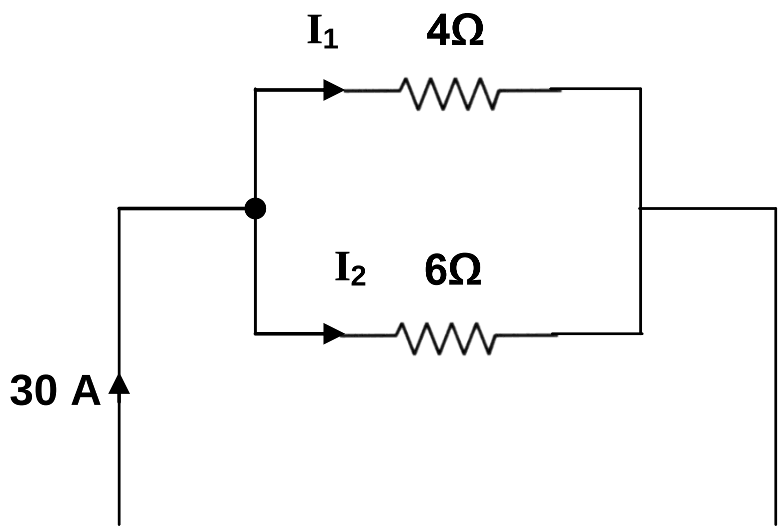
Voltage across 20Ω = 20 x 1.6667 = 33.33 V

Voltage across 30Ω = 30 x 1.6667 = 50 V

Example

Two resistors of 4Ω and 6Ω are connected in parallel. If the supply current is 30 A, find the current in each resistor.

Solution



Using the current division rule

Current through 4Ω = $\dfrac{6}{4+6} \times 30 = 18\text{ A}$

Current through 6Ω = $\dfrac{4}{4+6} \times 30 = 12\text{ A}$

Example

Four resistors of 2 ohms, 3 ohms, 4 ohms and 5 ohms respectively are connected in parallel. What voltage must be applied to the group in order that the total power of 100 W is absorbed?

Solution

Let R_T be the total equivalent resistor. Then

$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} = \frac{60 + 40 + 30 + 24}{120} = \frac{154}{120}$$

Resistance $R_T = \frac{120}{154} = 0.7792\ \Omega$

Let E be the supply voltage. Then total current taken = E / 0.7792 A

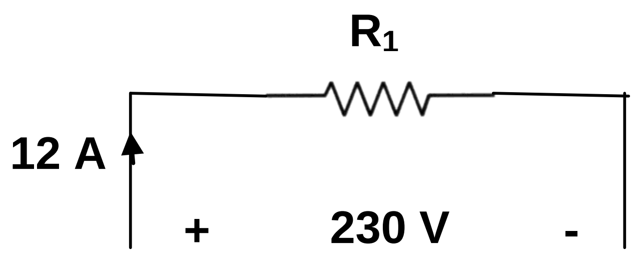
Thus $\left(\frac{E}{0.7792}\right)^2 \times 0.7792 = 100$ and hence $E^2 = 100 \times 0.7792 = 77.92$

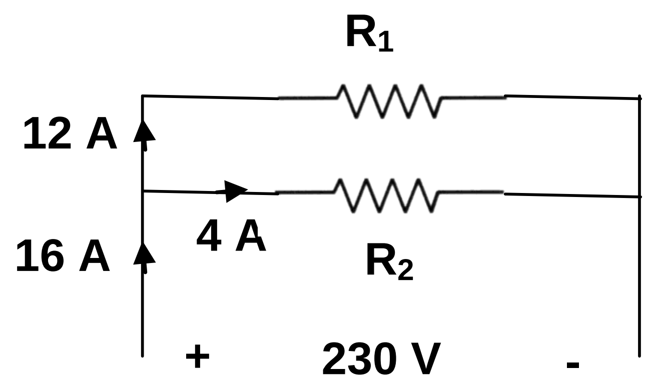
Required voltage = $\sqrt{77.92} = 8.8272$ V

Example

When a resistor is placed across a 230 V supply, the current is 12 A. What is the value of the resistor that must be placed in parallel, to increase the load to 16 A

Solution





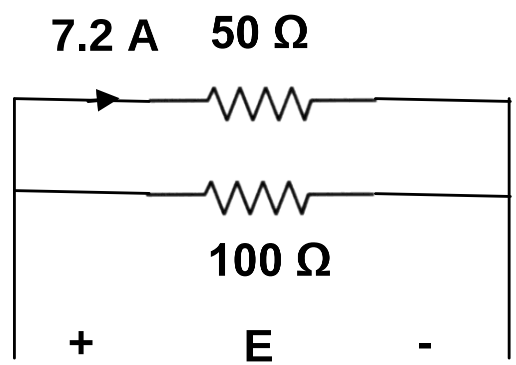
To make the load current 16 A, current through the second resistor = 16 –12 = 4 A

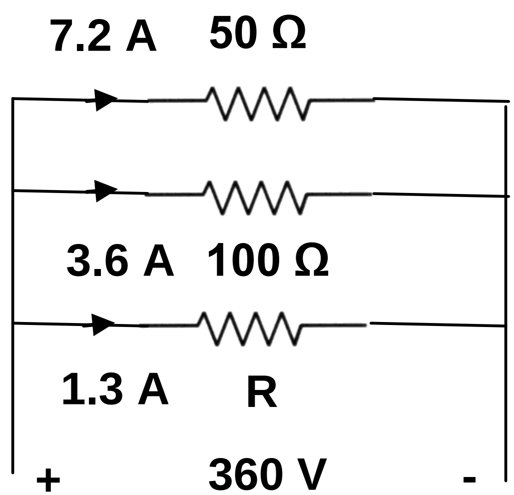
Value of second resistor R_2 = 230/4 = 57.5 Ω

Example

A 50 Ω resistor is in parallel with a 100 Ω resistor. The current in 50 Ω resistor is 7.2 A. What is the value of third resistor to be added in parallel to make the line current as 12.1A?

Solution





Supply voltage E = 50 x 7.2 = 360 V

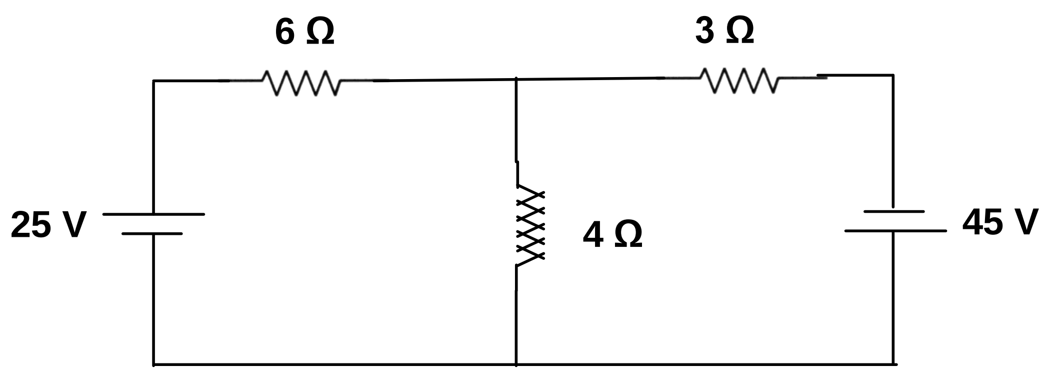
Current through 100 Ω = 360/100 = 3.6 A

When the line current is 12.1 A, current through third resistor = 12.1 – (7.2 + 3.6)

= 1.3 A

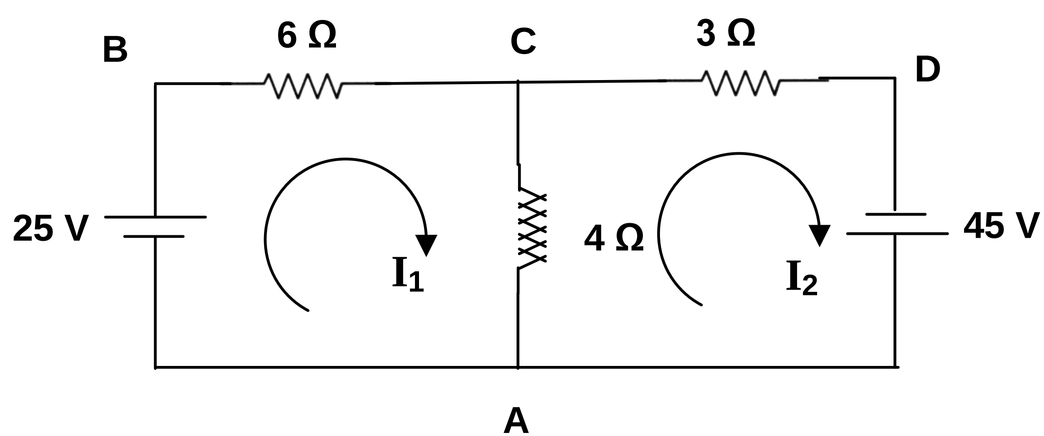
Value of third resistor = 360/1.3 = 276.9230 Ω

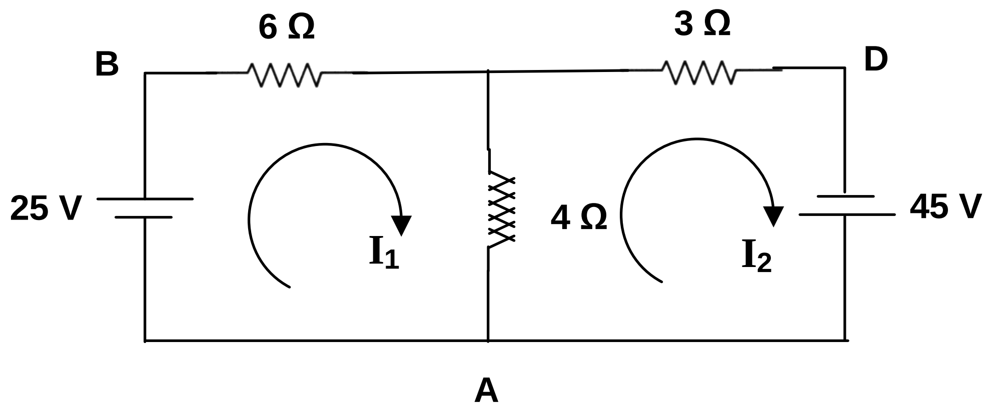
Using Kirchhoff's laws, find the current in various resistors in the circuit shown.



Solution

Let the loop current be I_1 and I_2





Considering the loop ABCA, KVL yields

$6\ I_1 + 4\ (I_1 – I_2) – 25 = 0$

For the loop CDAC, KVL yields

$3\ I_2 – 45 + 4\ (I_2 – I_1) = 0$

Thus $10\ I_1 - 4\ I_2 = 25$

$- 4\ I_1 + 7\ I_2 = 45$

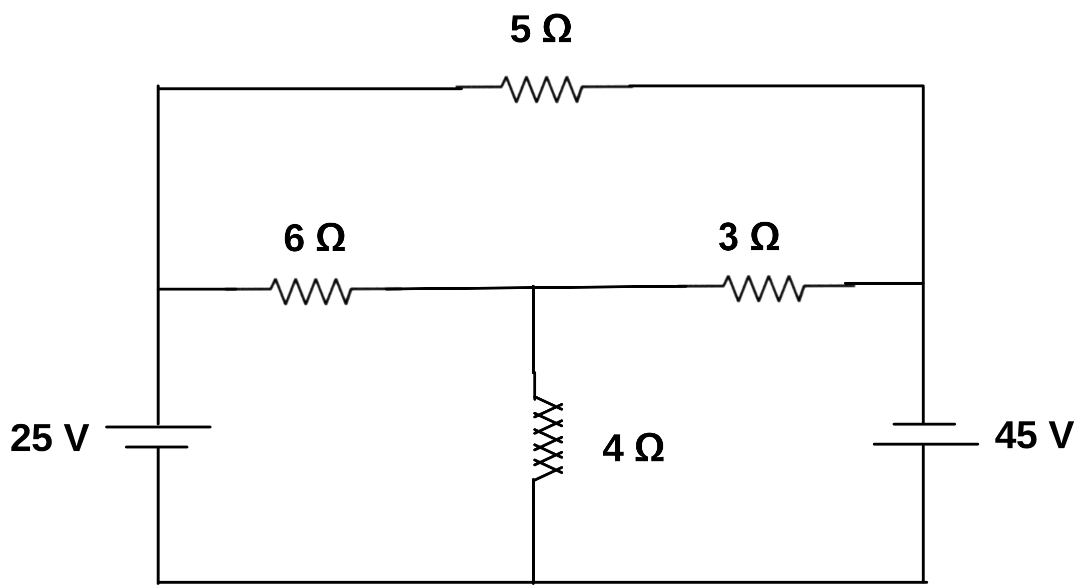
On solving the above $I_1 = 6.574$ A; $I_2 = 10.1852$ A

Current in 4Ω resistor = $I_1 – I_2 = 6.574 – 10.1852 = - 3.6112$ A

Thus the current in 4Ω resistor is 3.6112 A from A to C

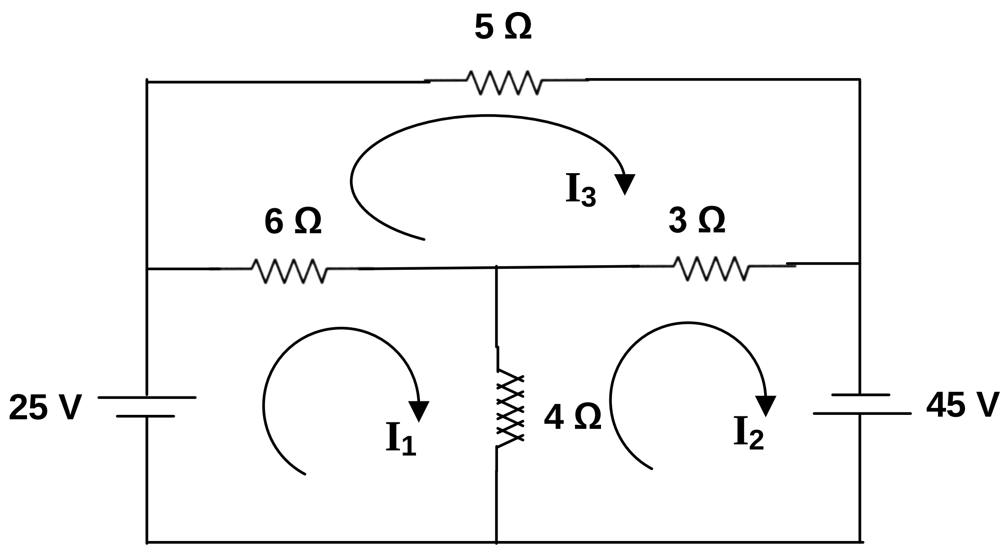
Current in 6 Ω resistor = 6.574 A; Current in 3 Ω resistor = 10.1852 A

Find the current in 5 Ω resistor in the circuit shown.



Solution

Let the loop current be I_1, I_2 and I_3.



Three loops equations are:

$6\,(I_1 - I_3) + 4\,(I_1 - I_2) - 25 = 0$

$4\,(I_2 - I_1) + 3\,(I_2 - I_3) - 45 = 0$

$5\,I_3 + 3\,(I_3 - I_2) + 6\,(I_3 - I_1) = 0$

On solving

Current in 5 Ω resistor, $I_3 = 14$ A