18EES101J - BASIC ELECTRICAL & ELECTRONICS ENGINEERING

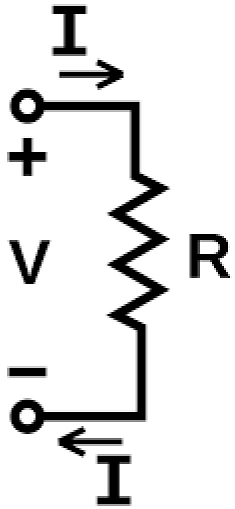
LECTURE-2

Overview

- Ohm’s law
- Kirchoff’s law
- Network topology
- Series and Parallel connection
- Verification of Ohm’s law and Kirchoff’s law
- Practice problems

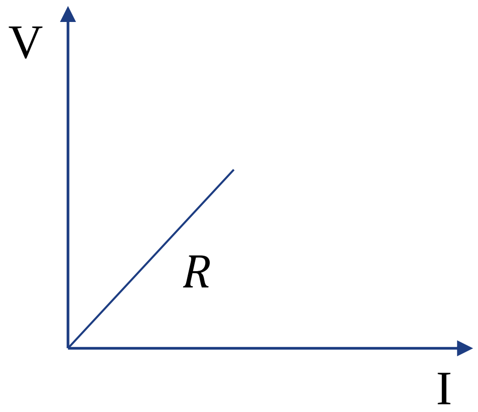
Ohm’s law

Ohm’s law states that “at constant temperature the voltage ‘V’ across a resistor is directly proportional to the current ‘I’ flowing through the resistor”.



$$V \propto I$$

$$V = I\,R$$



- Some expressions for power

$$P = VI \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

Basic Laws

Limitations of Ohm's law

- This law cannot be applied to unilateral networks.
    - A unilateral network has unilateral elements like diode, transistors, etc., which do not have same voltage current relation for both directions of current.
- This law is not applicable for non – linear elements.
    - Non- linear elements do not have current exactly proportional to the applied voltage

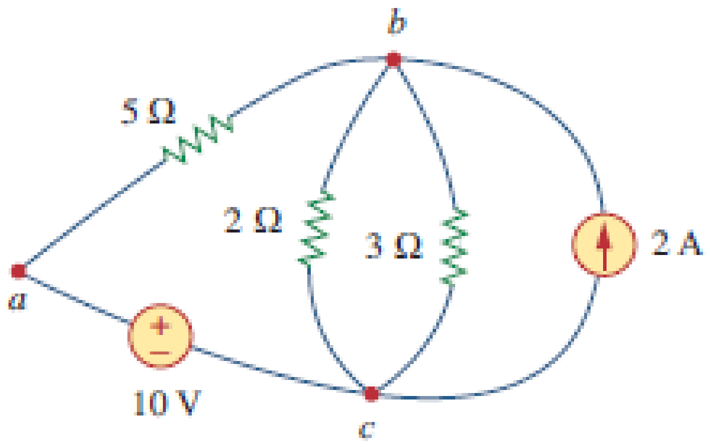
Network topology

Node

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

Branch

- A branch represents a single element such as a voltage source or a resistor.

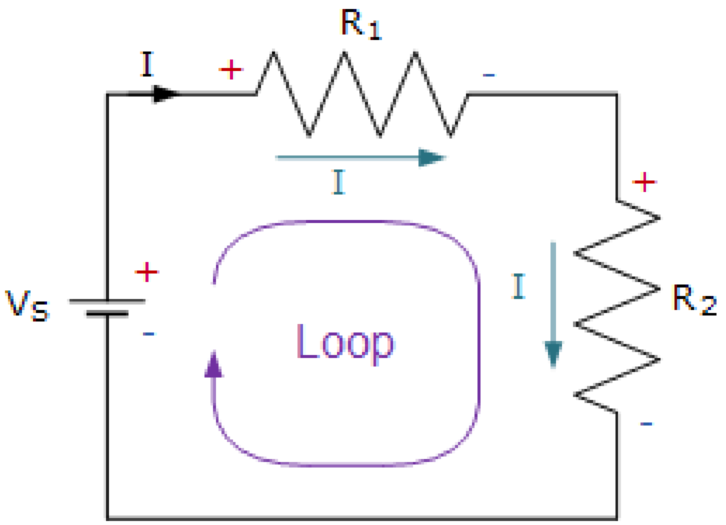


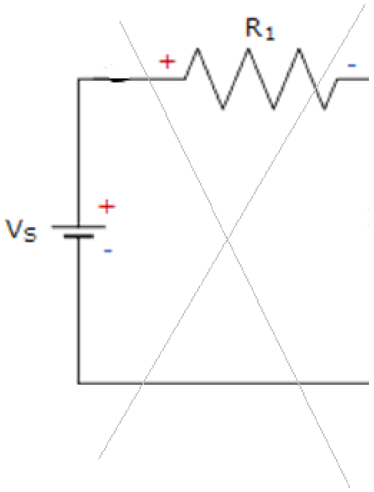
Loop

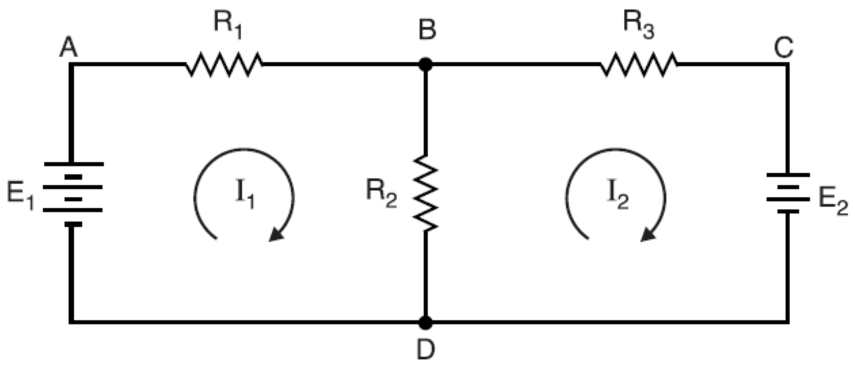
- A loop is any closed path in a circuit.

Mesh

- A mesh is the most elementary form of a loop and cannot be further divided into other loops.



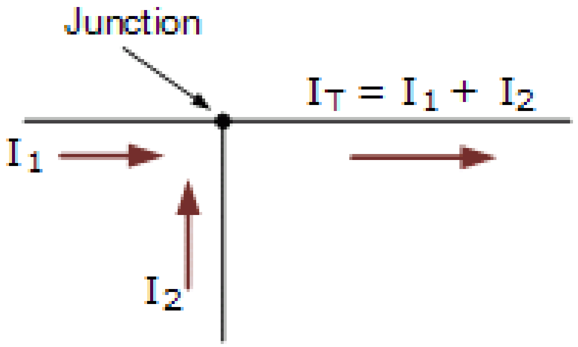




Kirchoff current law

Current law states that the “Algebraic sum of current in a node is zero”.

Total current entering a junction is exactly equal to the total current leaving the same junction.



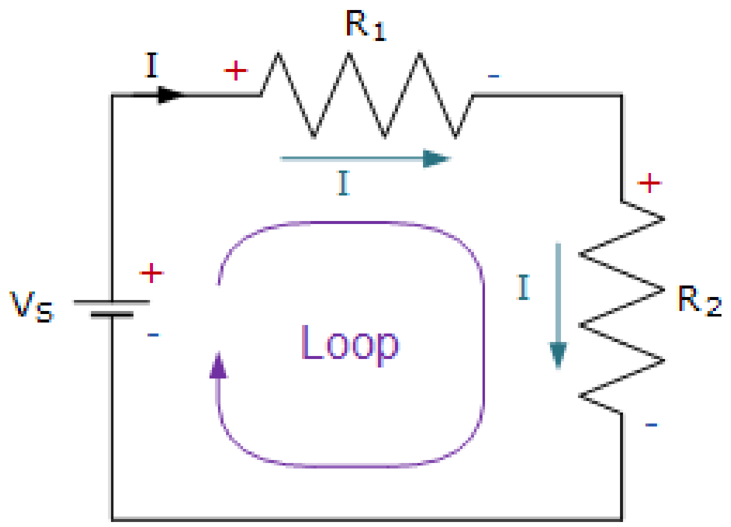
$$\Sigma I_{in} = \Sigma I_{out}$$

$$\Sigma I = 0$$

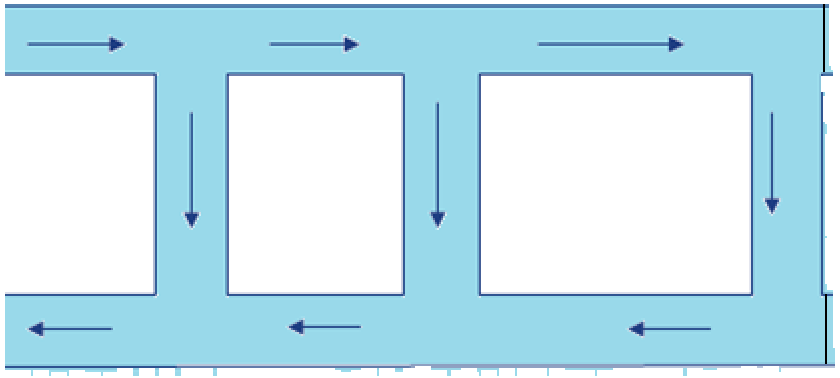
Kirchoff voltage law

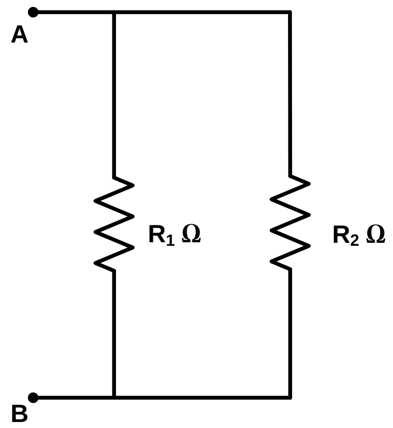
Voltage law states that for a closed loop, "Algebraic sum of all the voltages around any closed loop in a circuit is equal to zero".

$$\Sigma v = 0.$$

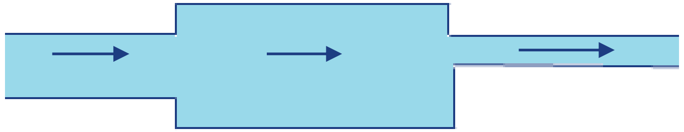


- Parallel connection

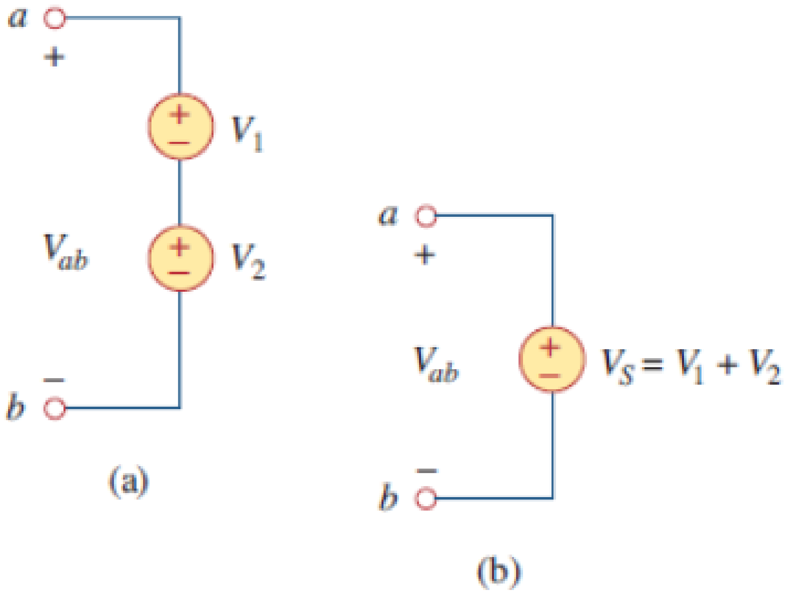


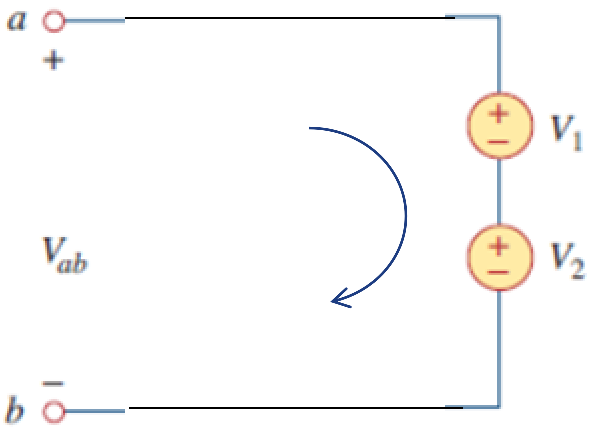


- Series connection



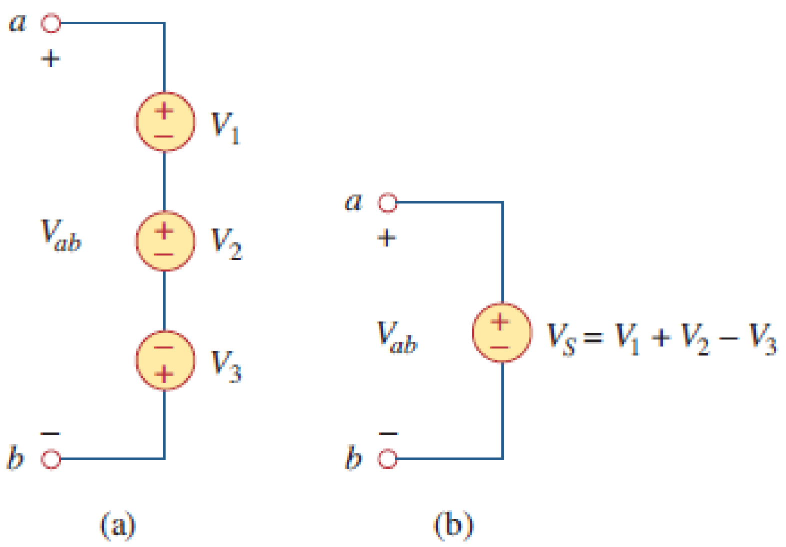
Voltage sources in series





$$-V_{ab} + V_1 + V_2 = 0$$

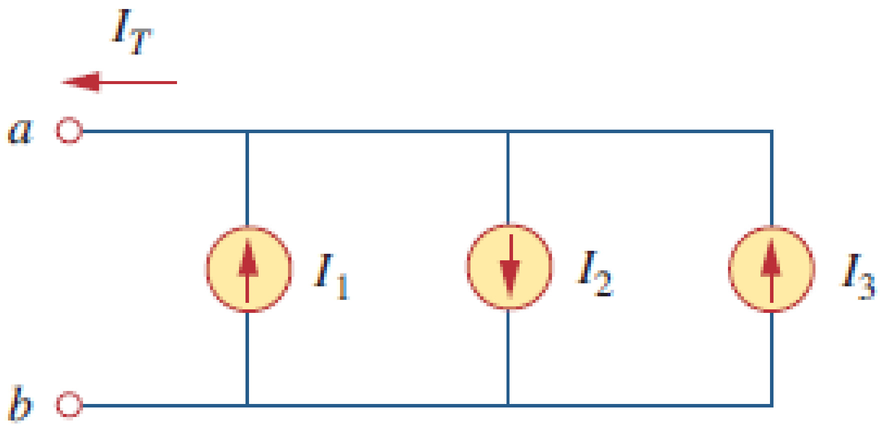
$$V_{ab} = V_1 + V_2$$

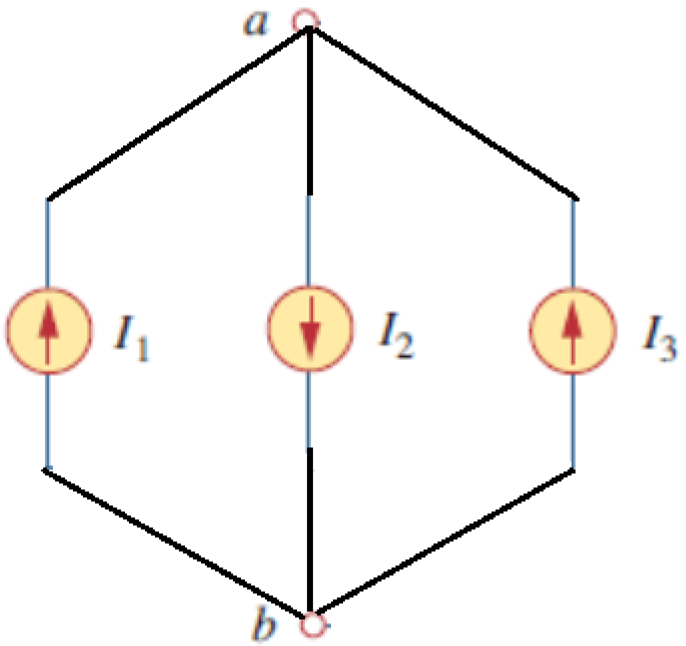


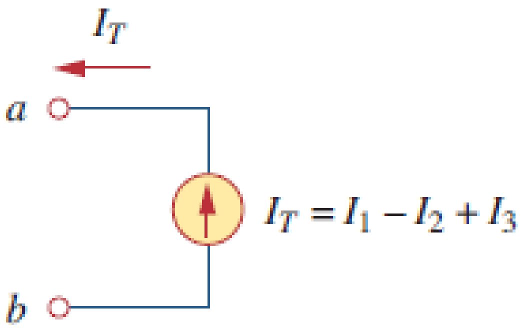
$$-V_{ab} + V_1 + V_2 - V_3 = 0$$

$$V_{ab} = V_1 + V_2 - V_3$$

Current sources in parallel

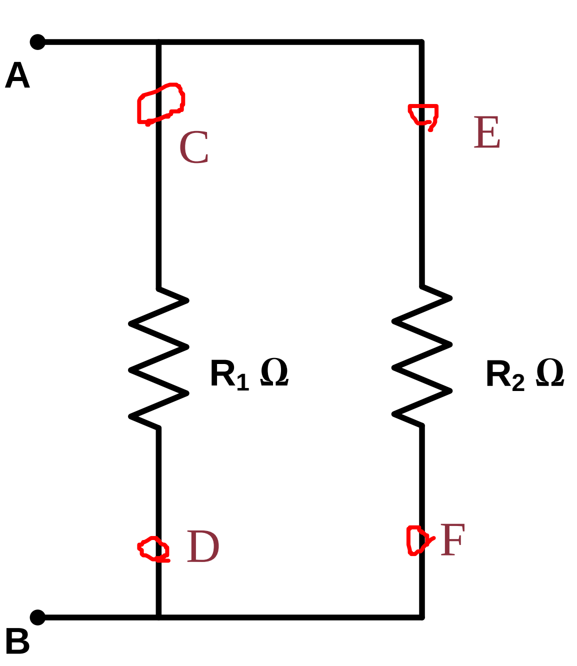


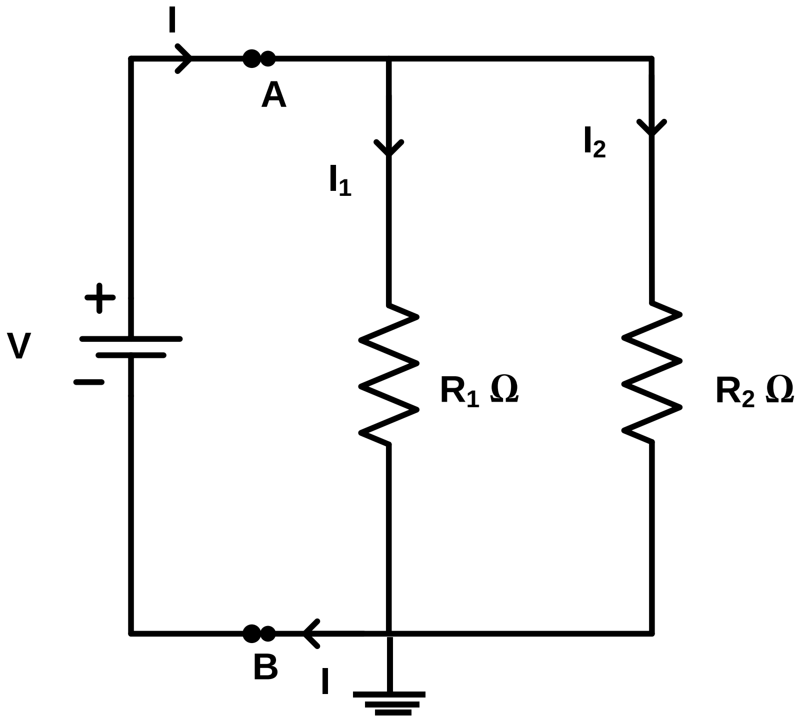




$$I_T = I_1 - I_2 + I_3$$

Resistance in parallel





$$V_1 = I_1 R_1 \qquad V_2 = I_2 R_2$$

$$I_1 = \frac{V_1}{R_1} \qquad I_2 = \frac{V_2}{R_2} \qquad V_1 = V_2 = V$$

Voltage across the elements in parallel is same

Basic Laws

$$I = I_1 + I_2$$

$$I = \frac{V}{R_1} + \frac{V}{R_2}$$

$$I = V\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$\frac{I}{V} = \left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

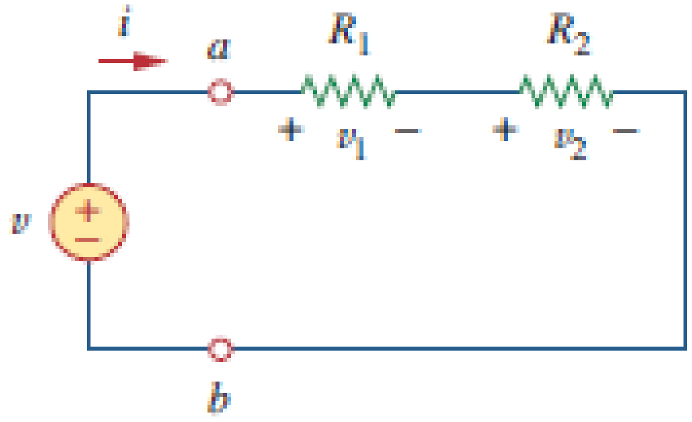
$$R = \frac{V}{I}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R} = \frac{R_2 + R_1}{R_1 R_2}$$

$$\boxed{R_{eq} = \frac{R_1 R_2}{R_1 + R_2}}$$

Resistance in Series



$$v_1 = iR_1, \qquad v_2 = iR_2$$

$$\frac{i}{v} = \frac{1}{R_1 + R_2}$$

$$-v + v_1 + v_2 = 0$$

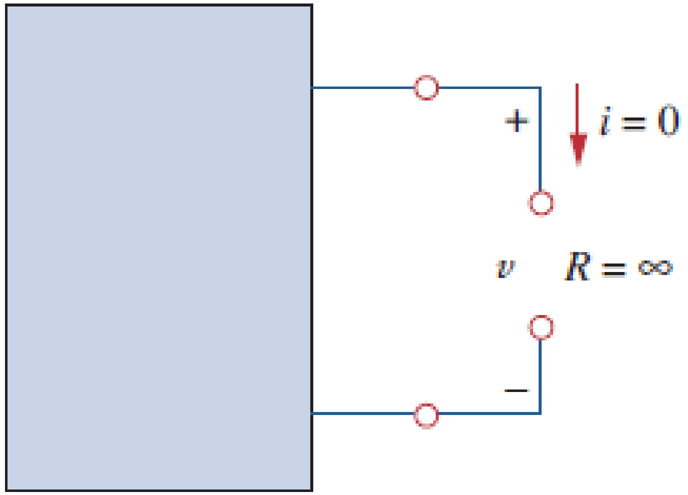
$$\frac{1}{R} = \frac{1}{R_1 + R_2}$$

$$v = v_1 + v_2 = i(R_1 + R_2)$$

$$i = \frac{v}{R_1 + R_2}$$

$$R_{eq} = R_1 + R_2$$

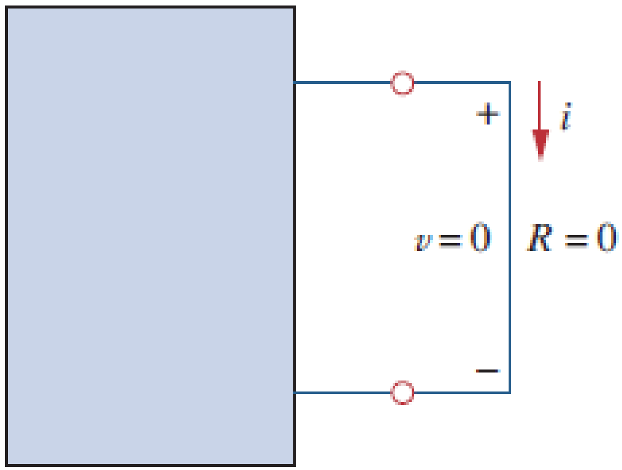
- Open circuit



An **open circuit** is a circuit element with resistance approaching infinity.

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

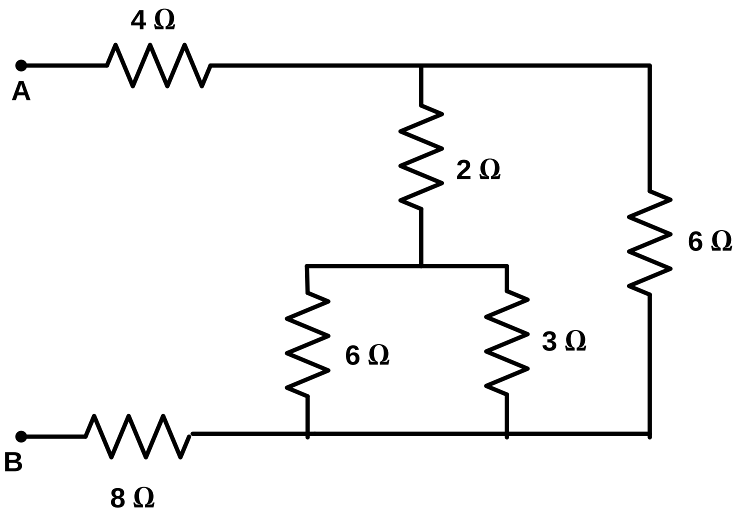
- Short circuit

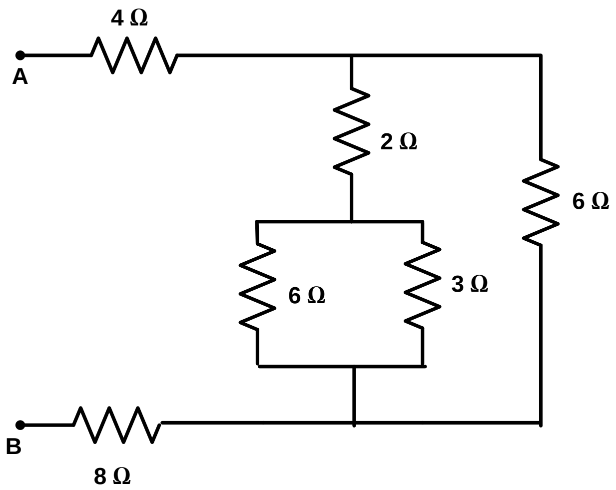


A **short circuit** is a circuit element with resistance approaching zero.

Circuit reduction technique

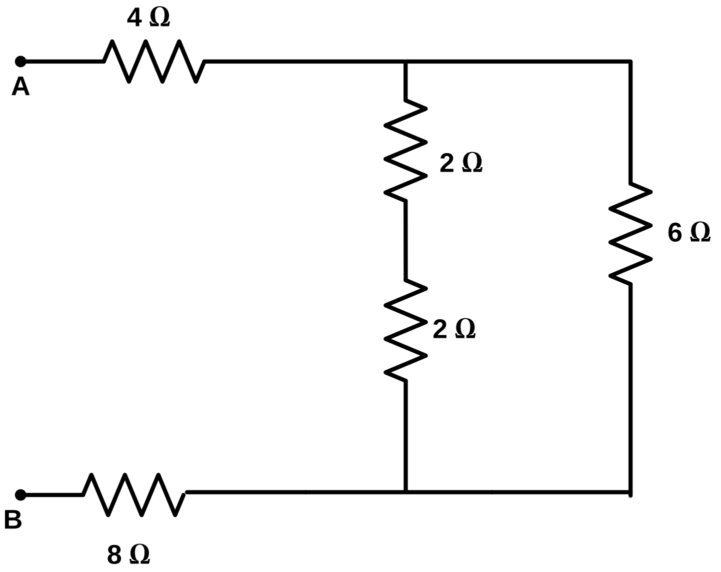
- Find the equivalent resistance across the terminals AB



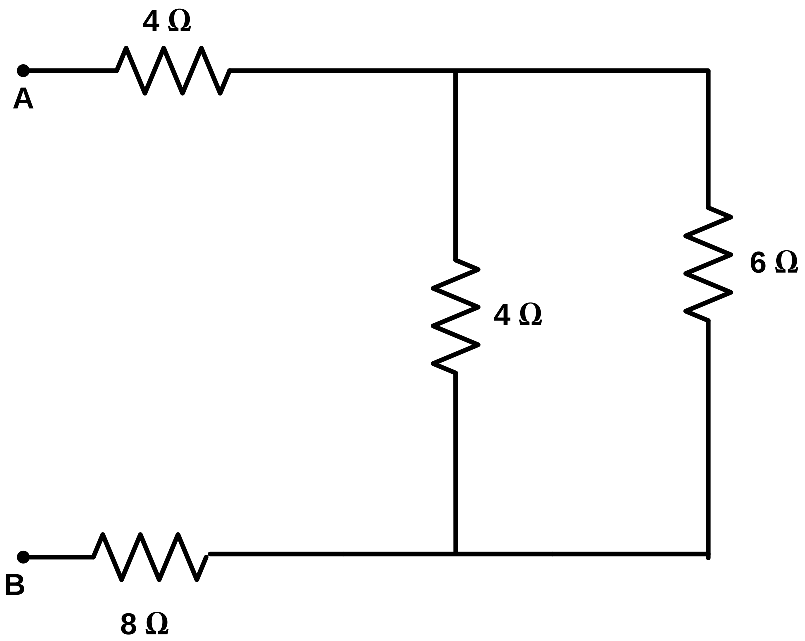


$$6 \,||\, 3 \Rrightarrow \frac{6 \times 3}{6 + 3} = 2\Omega$$

Basic Laws

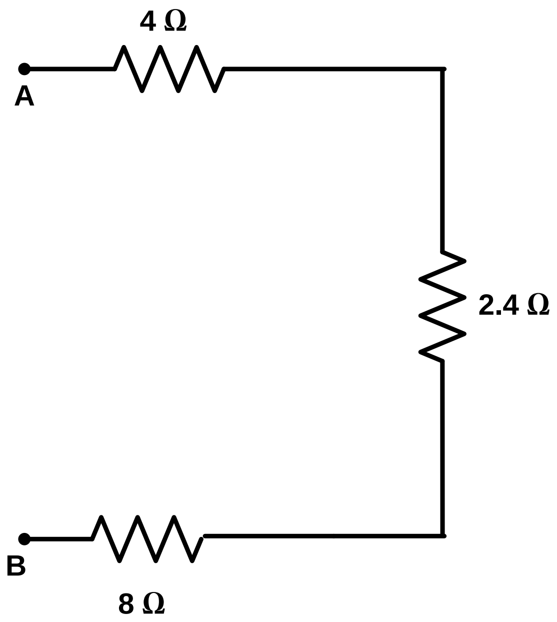


$$2 + 2 = 4\Omega$$

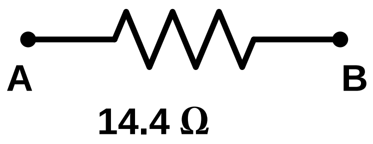


$$4||\,6 \Rrightarrow \frac{4 \times 6}{4 + 6} = 2.4\Omega$$

Basic Laws

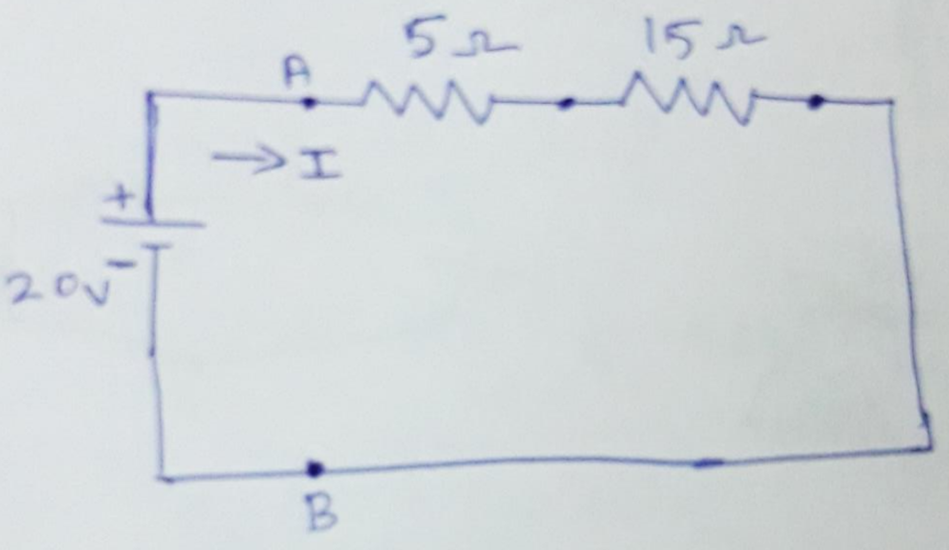


$$4 + 2.4 + 8 = 14.4\Omega$$



Problems

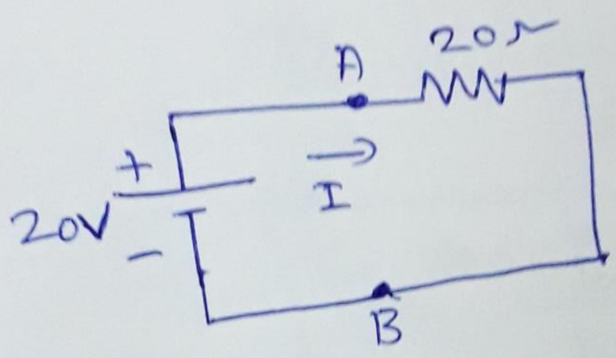
Find the current I in the given circuit



$$R_1 = 5\Omega, \quad R_2 = 15\Omega$$

$$R_{eq} = R_1 + R_2$$

$$R_{eq} = 5 + 15 = 20\Omega$$

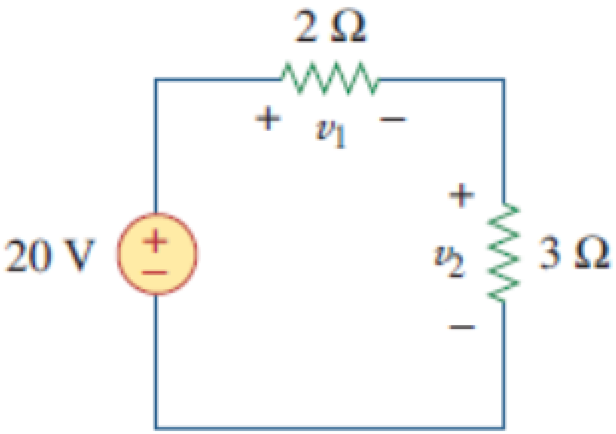


$$I = \frac{V}{R_{eq}}$$

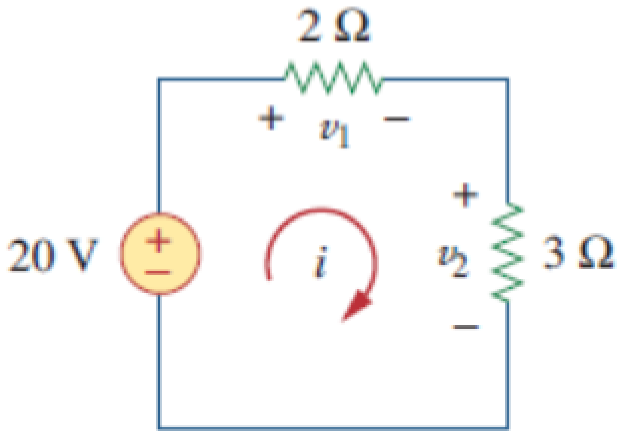
$$= \frac{20}{20}$$

$$\boxed{I = 1A}$$

For the circuit find voltages v_1 and v_2.



Soln:



$$v_1 = 2i, \quad v_2 = \quad 3i$$

$$-20 + v_1 + v_2 = 0$$

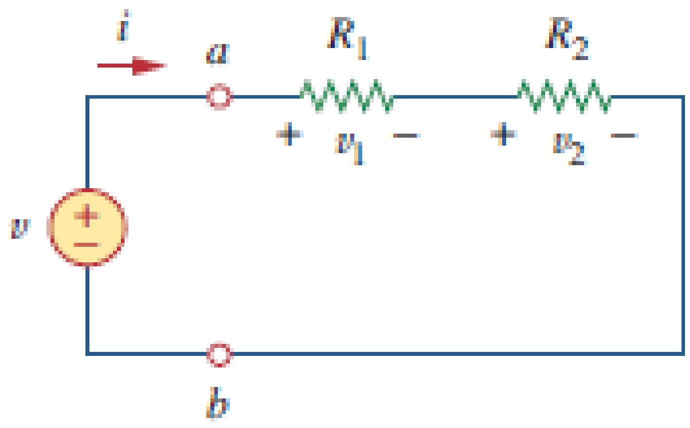
$$-20 + 2i + 3i = 0$$

$$5i = 20$$

$$i = 4 \text{ A}$$

$$v_1 = 8 \text{ V}, \quad v_2 = \quad 12 \text{ V}$$

Voltage division rule



$$i = \frac{v}{R_1 + R_2}$$

$v_1 = iR_1,$ $\quad V_1 = \dfrac{R_1}{R_1 + R_2}V$ $\quad v_2 = iR_2$ $\quad V_2 = \dfrac{R_2}{R_1 + R_2}V$

Current division rule

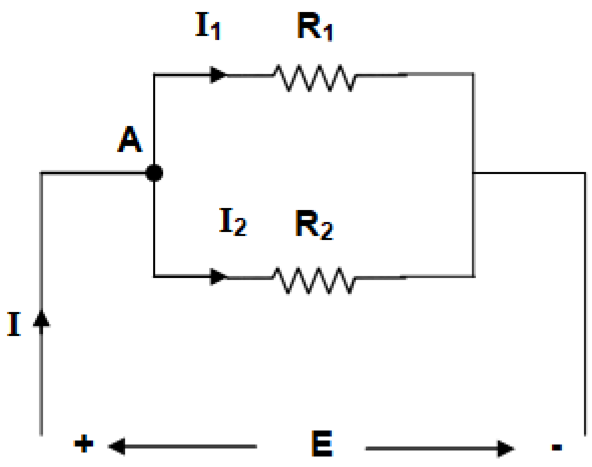


Fig. Resistors connected in parallel

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

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

$$I_1 = \frac{E}{R_1} \qquad I_1 = \frac{R_2}{R_1 + R_2} I$$

$$I_2 = \frac{E}{R_2} \qquad I_2 = \frac{R_1}{R_1 + R_2} I$$

Example 1.34. *A 100 V lamp has a hot resistance of 250 Ω. Find the current taken by the lamp and its power rating in watts. Calculate also the energy it will consume in 24 hours.*

Current taken by lamp, $I = V/R = 100/250 = \mathbf{0.4\ A}$

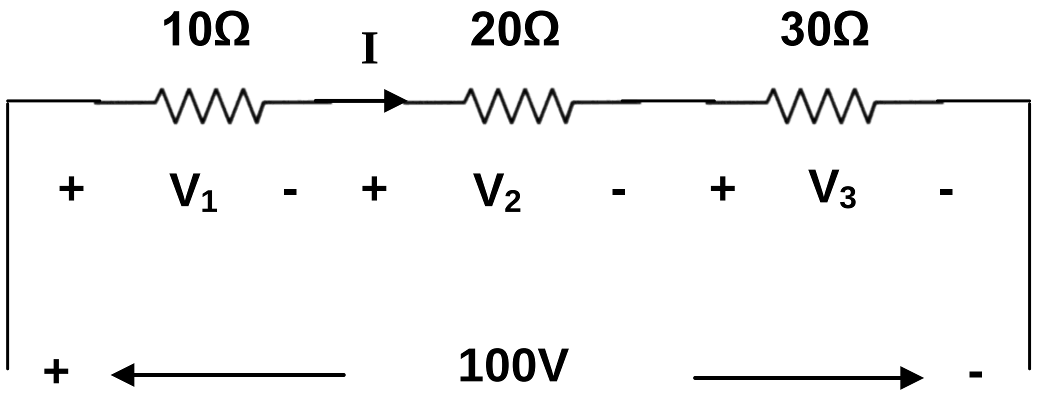
Power rating of lamp, $P = VI = 100 \times 0.4 = \mathbf{40\ W}$

Energy consumption in 24 hrs. $=$ Power $\times$ time $= 40 \times 24 =$ **960 watt-hours**

Example 1

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

Solution



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

Voltage across 10Ω = 10 x 1.6667 = 16.67 V

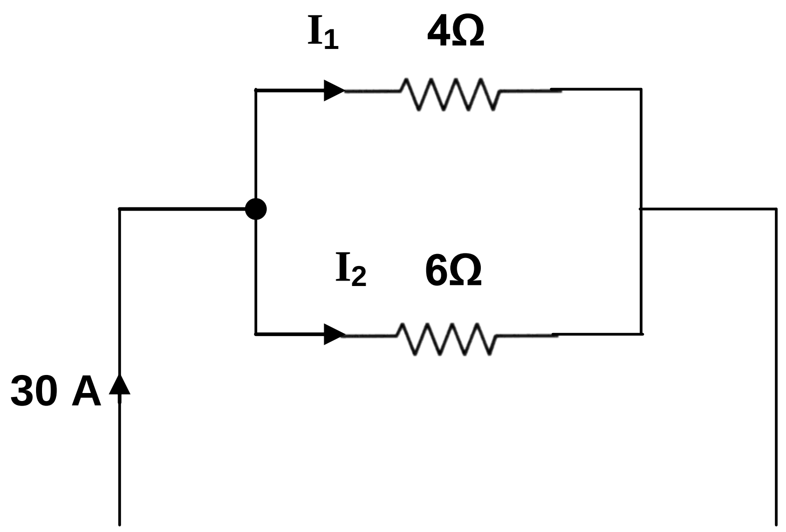
Voltage across 20Ω = 20 x 1.6667 = 33.33 V

Voltage across 30Ω = 30 x 1.6667 = 50 V

Example 2

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 = $\frac{6}{4+6} \times 30 = 18\ A$

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

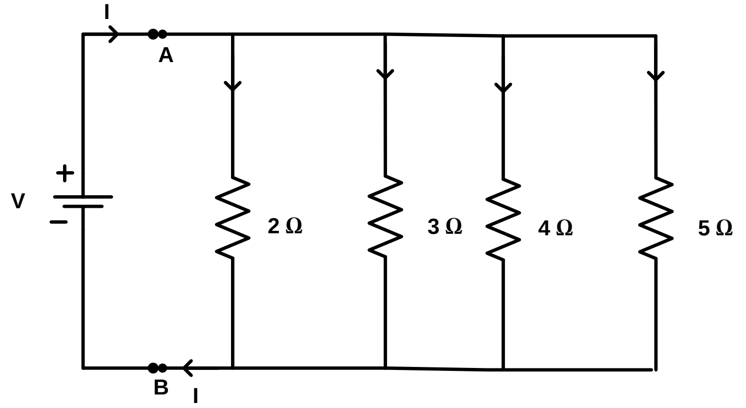
Example 3

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?

$$P = VI \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

Solution

Let R_T be the total equivalent resistor.



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

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

Let V be the supply voltage.

$$\frac{V^2}{0.7792} = 100$$

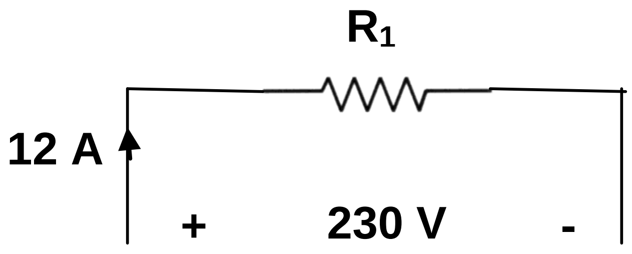
$V^2 = 100 \times 0.7792 = 77.92$

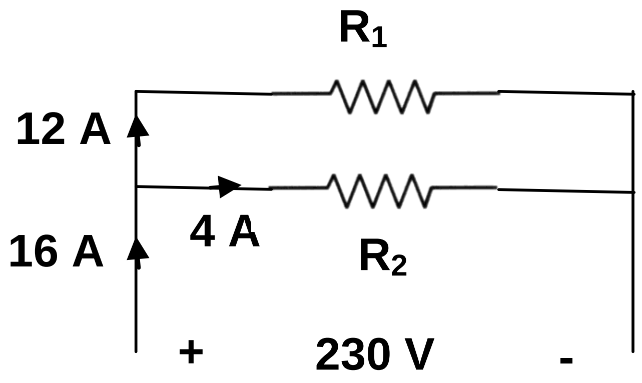
Required voltage $= \sqrt{77.92} = 8.8272\ \text{V}$

<u>Example 4</u>

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

<u>Solution</u>





$$R_1 = \frac{230}{12} = 19.17\Omega$$

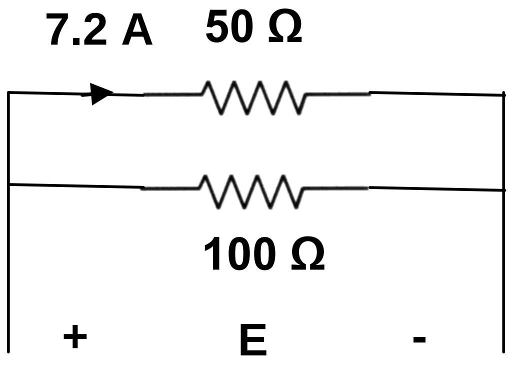
To make the load current 16 A, current through the second resistor = 16 –12 = 4 A

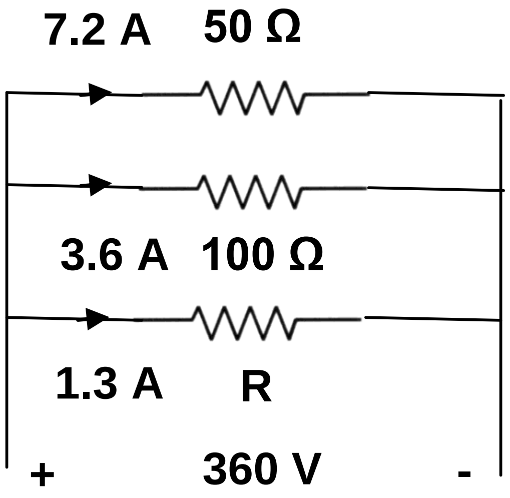
Value of second resistor R_2 = 230/4 = 57.5 Ω

Example 5

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)

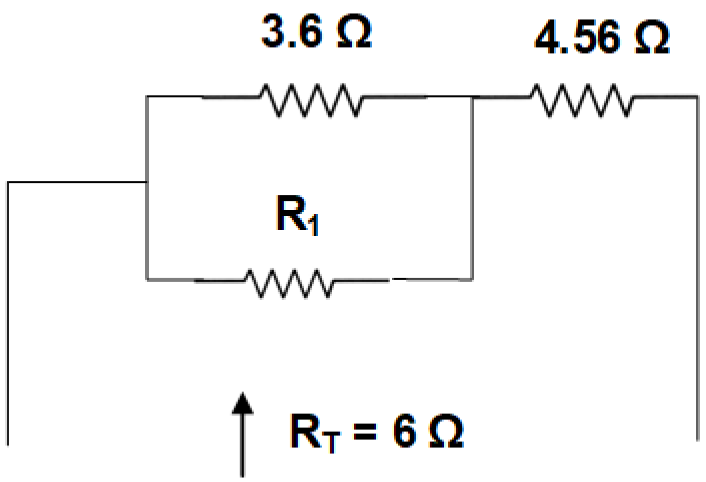
= 1.3 A

Value of third resistor = 360/1.3 = 276.9230 Ω

Example 6

A resistor of 3.6 ohms is connected in series with another of 4.56 ohms. What resistance must be placed across 3.6 ohms, so that the total resistance of the circuit shall be 6 ohms?

Solution



$$(3.6 \parallel R_1) + 4.56 = R_T$$

$$(3.6 \parallel R_1) = 6 - 4.56 = 1.44$$

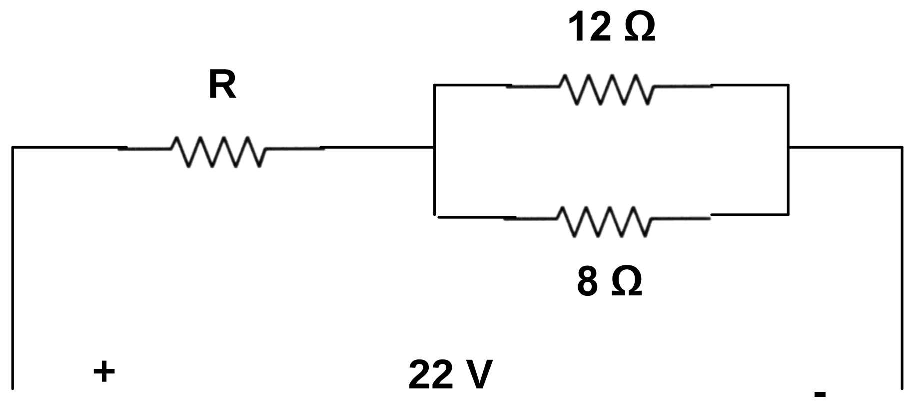
$$\frac{3.6 \times R_1}{3.6 + R_1} = 1.44$$

$$R_1 = 2.4\ \Omega$$

Example 7

A resistance R is connected in series with a parallel circuit comprising two resistors 12 Ω and 8 Ω respectively. Total power dissipated in the circuit is 70 W when the applied voltage is 22 V. Calculate the value of the resistor R.

Solution



Total current taken = 70 / 22 = 3.1818 A

Equivalent of 12 Ω ‖ 8 Ω = 96/20 = 4.8 Ω

Voltage across parallel combination = 4.8 x 3.1818 = 15.2726 V

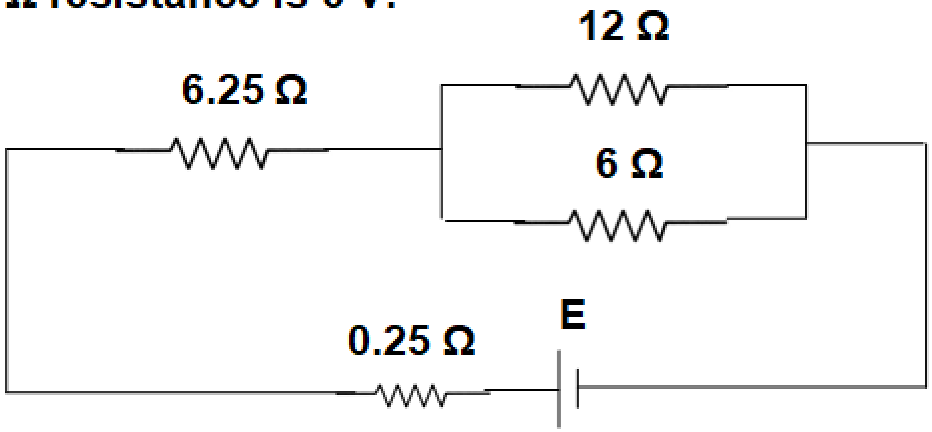
Voltage across resistor R = 22 – 15.2726 = 6.7274 V

Value of resistor R = 6.7274/3.1818 = 2.1143 Ω

Problems

Example 8

The resistors 12 Ω and 6 Ω are connected in parallel and this combination is connected in series with a 6.25 Ω resistance and a battery which has an internal resistance of 0.25 Ω. Determine the emf of the battery if the potential difference across 6 Ω resistance is 6 V.



Voltage across 6 Ω = 6 V

Solution

Current in 6 Ω = 6/6 = 1 A

Current in 12 Ω = 6/12 = 0.5 A

Therefore current in .25 Ω = 1.0 + 0.5 = 1.5 A

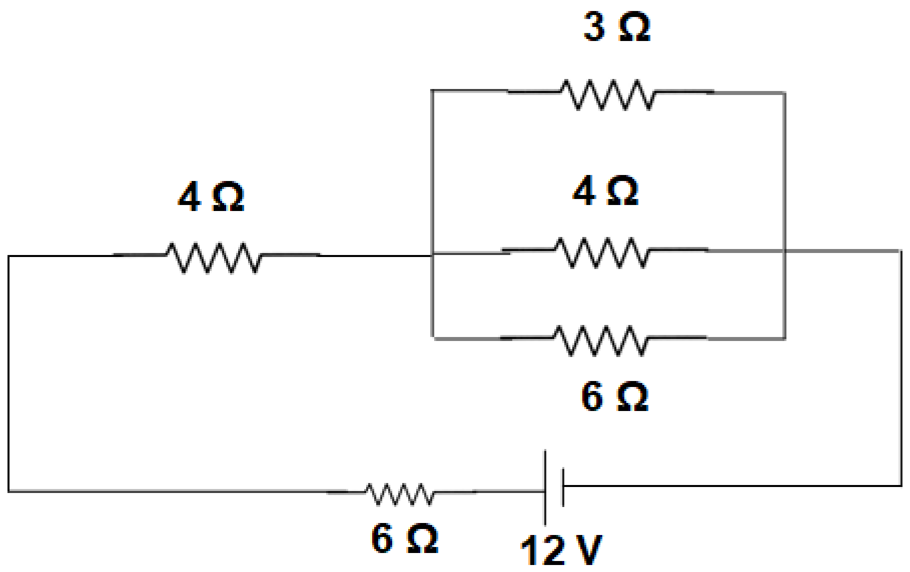
Using KVL E = (0.25 x 1.5) + (6.25 x 1.5) + 6 = 15.75 V

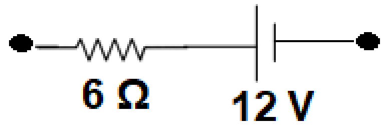
Therefore battery emf E = 15.75 V

Example 9

A circuit consist of three resistors 3 Ω, 4 Ω and 6 Ω in parallel and a fourth resistor of 4 Ω in series. A battery of 12 V and an internal resistance of 6 Ω is connected across the circuit. Find the total current in the circuit and the terminal voltage across the battery.

Solution





$$3||4||6\,,\qquad \frac{1}{R_p}=\left(\frac{1}{3}+\frac{1}{4}+\frac{1}{6}\right)\qquad R_p=1.33\ \Omega$$

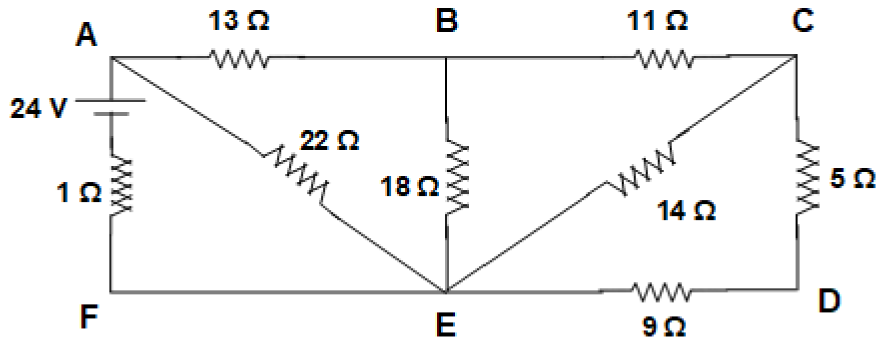
Total circuit resistance = 4 + 6 + 1.3333 = 11.3333 Ω

Circuit current = 12/11.3333 = 1.0588 A

Terminal voltage across the battery = 12 – (6 x 1.0588) = 5.6472 V

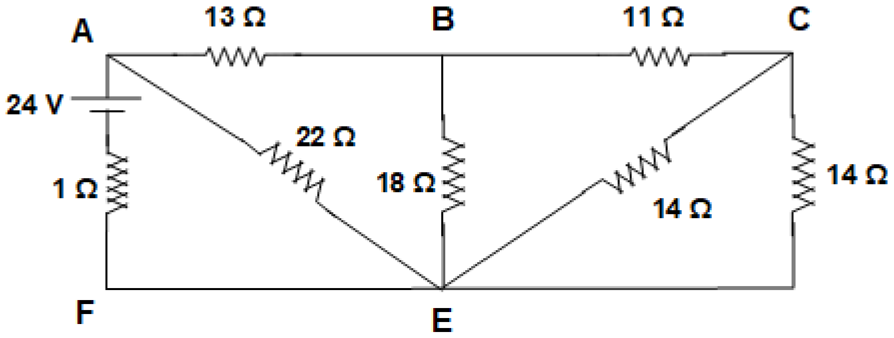
Example 10

An electrical network is arranged as shown. Find (i) the current in branch AF (ii) the power absorbed in branch BE and (iii) potential difference across the branch CD.



Solution

Various stages of reduction are shown.



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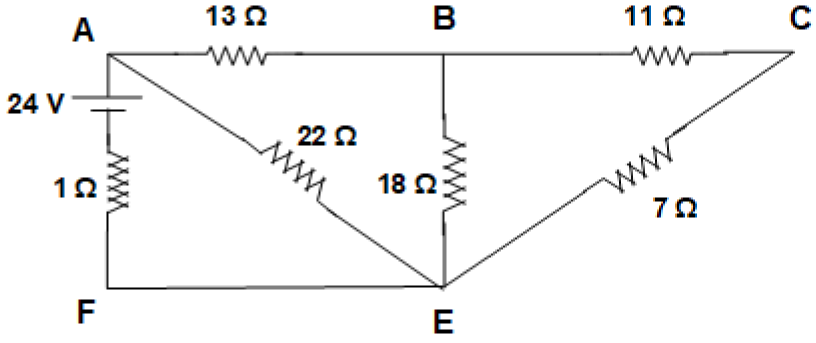
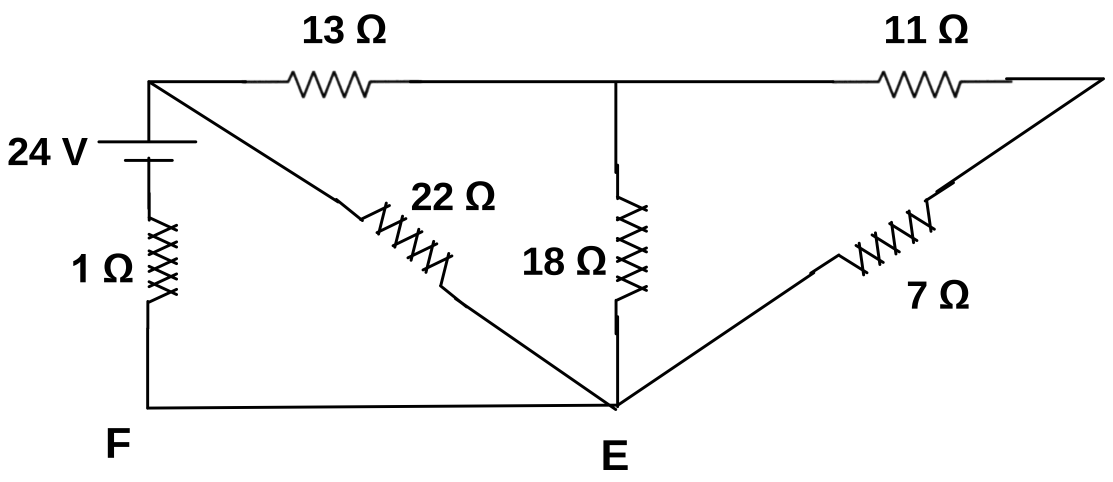


2

Problems



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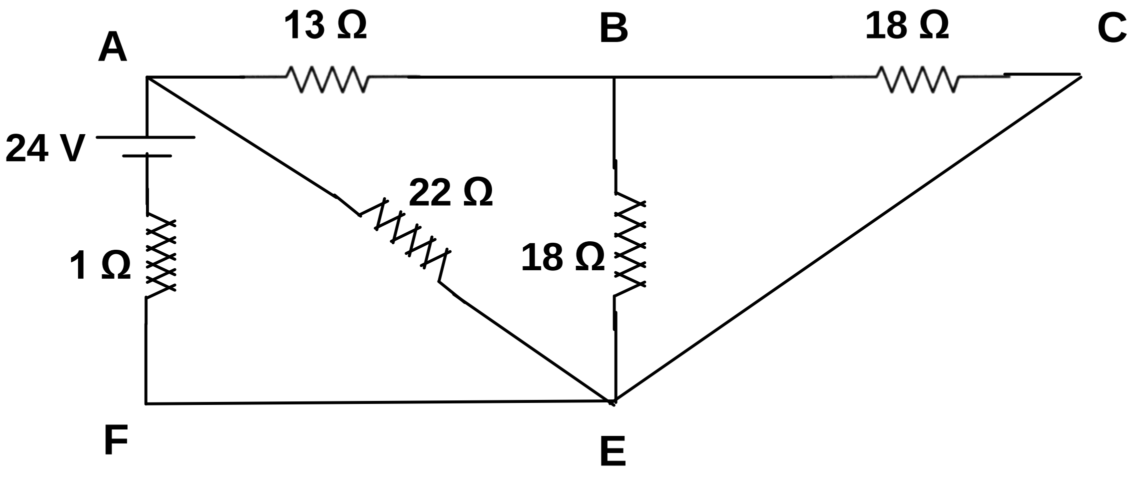

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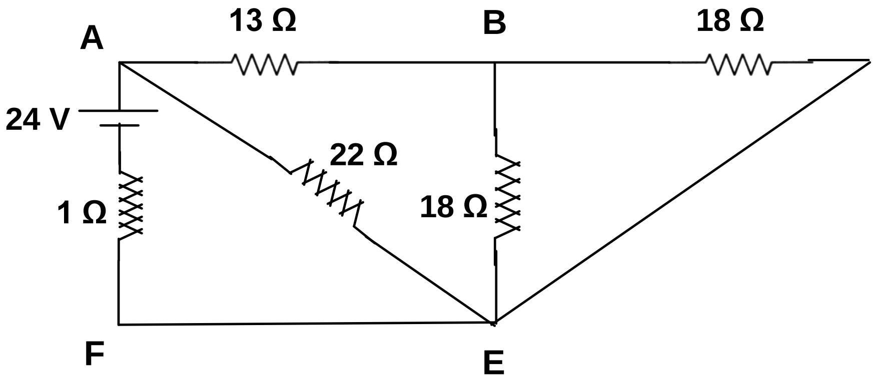
Problems



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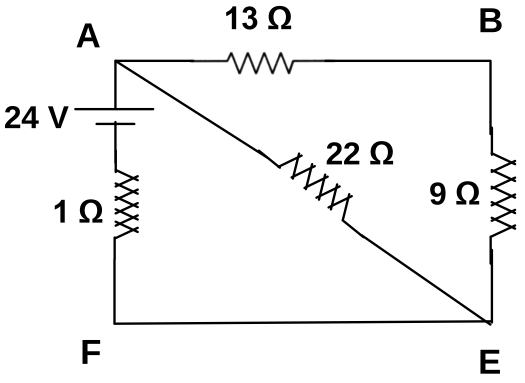

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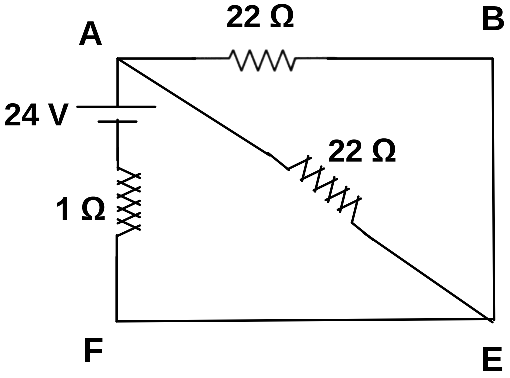

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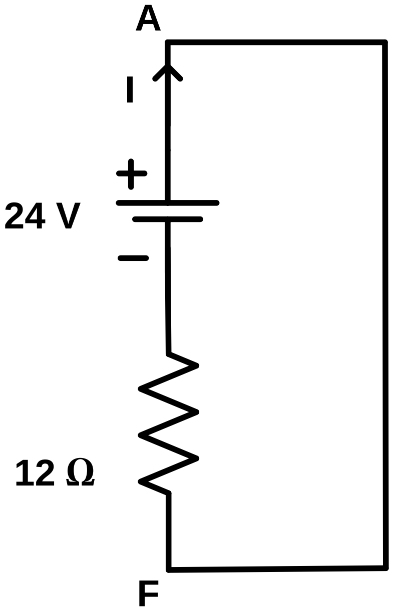
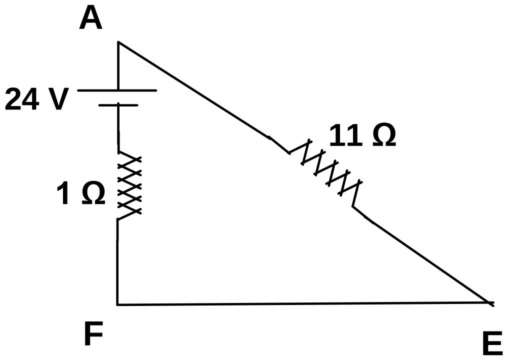




6

Problems

Current in branch AF = 24/12 = 2 A from F to A

Using current division rule current in 13 Ω = 1 A

Referring Fig. 3, current in branch BE = 0.5 A

Power absorbed in branch BE = 0.5^2 x 18 = 4.5 W

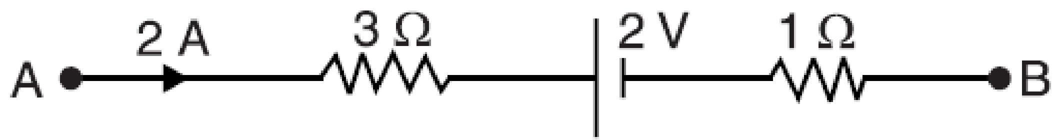
Voltage across BE = 0.5 x 18 = 9 V

Voltage across CE in Fig. 1 = $\frac{7}{18} \times 9 = 3.5$ V

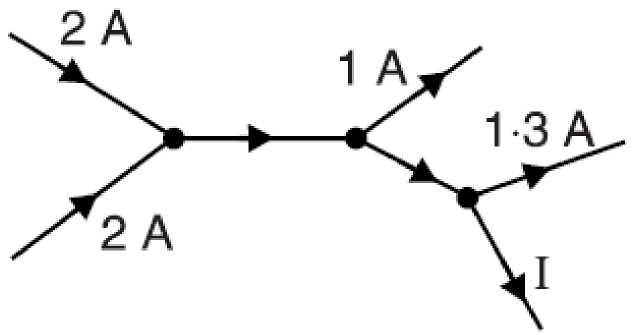
Referring Fig. given in the problem, using voltage division rule, voltage across branch CD = $\frac{5}{14} \times 3.5 = 1.25$ V

Practice problems

- Find the voltage V_{AB}



- Find the current I



Practice problems

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

2. Four resistors are in parallel. The currents in the first three resistors are 4 mA, 5 mA and 6 mA respectively. The voltage drop across the fourth resistor is 200 volts. The total power dissipated is 5 watts. Determine the values of the resistances of the branches and the total resistance.

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

Practice Problems

- Find the equivalent circuit across the terminals AB