



UNIVERSITY OF HILLA
College of Engineering Technologies
Department of Medical Devices Technologies

Fundamental of Electrical Engineering(DC)

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First Stage

Lecture 2

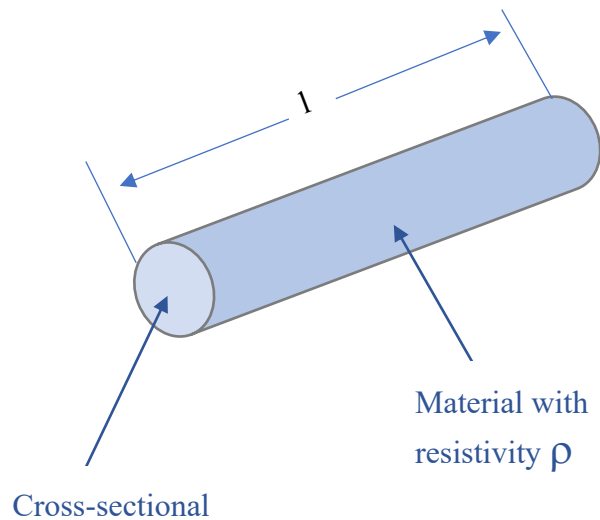
Ohm's law

states that the voltage v across a resistor is directly proportional to the current I flowing through the resistor.

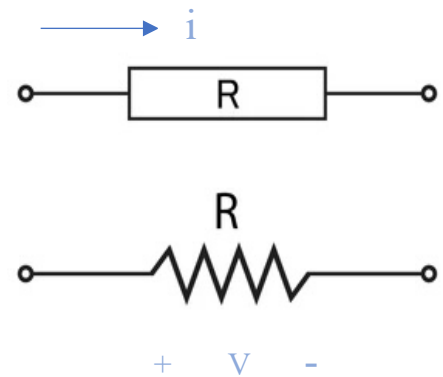
That is,

The **resistance** R of an element denotes its ability to resist the flow of electric current; it is measured in ohms (Ω).

Materials in general have a characteristic behavior of resisting the flow of electric charge. This physical property, or ability to resist current, is known as resistance and is represented by the symbol R . The resistance of any material with a uniform cross-sectional area A depends on A and its length, as shown in Fig. below.



(a) Resistor



(b) Circuit symbol for resistance

In mathematical from,

$$R = \rho \frac{l}{A}$$

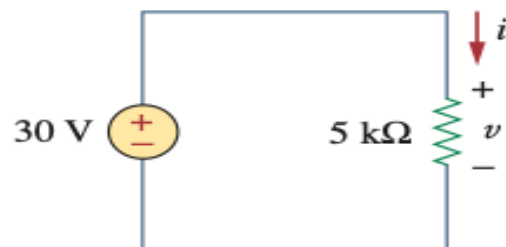
where ρ is known as the resistivity of the material in ohm-meters. Good conductors, such as copper and aluminum, have low resistivities, while insulators, such as mica and paper, have high resistivities. Table below presents the values of ρ for some common materials and shows which materials are used for conductors, insulators, and semiconductors.

Table – Resistivities of common materials

Material	Resistivity ($\Omega \cdot \text{m}$)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^2	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}	Insulator
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator

- Note:
- A **short circuit** is a circuit element with **resistance** approaching **zero**.
- An **open circuit** is a circuit element with **resistance** approaching **infinity**.

EXAMPLE : In the circuit shown in Fig. shown, calculate the current i , the conductance G , and the power p .



Solution:

The current is

$$i = \frac{v}{R} = \frac{30}{5 \times 10^3} = 6 \text{ mA}$$

The conductance is :

$$G = \frac{1}{R} = \frac{1}{5 \times 10^3} = 0.2 \text{ mS}$$

We can calculate the power in various ways :

$$p = vi = 30(6 \times 10^{-3}) = 180 \text{ mW}$$

or

$$p = i^2 R = (6 \times 10^{-3})^2 5 \times 10^3 = 180 \text{ mW}$$

or

$$p = v^2 G = (30)^2 0.2 \times 10^{-3} = 180 \text{ mW}$$

NODES, BRANCHES, AND LOOPS

- A **branch** represents a single element such as a voltage source or a resistor.
- A **node** is the point of connection between two or more branches.
- A **loop** is any closed path in a circuit.

A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology:

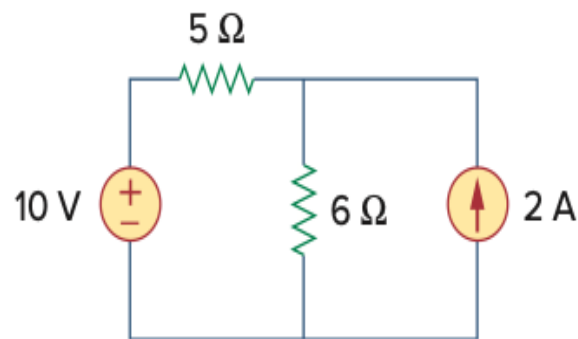
$$b = l + n - 1$$

*Two or more elements are in **series** if they are cascaded or connected sequentially and consequently carry the same current.

*Two or more elements are in **parallel** if they are connected to the same two nodes and consequently have the same voltage across them.

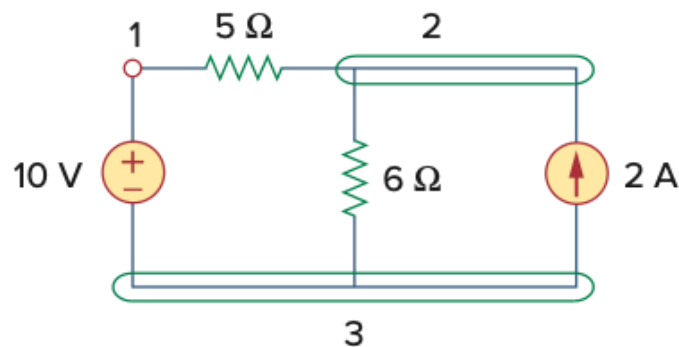
EXAMPLE :

Determine the number of branches and nodes in the circuit shown in Fig. below. Identify which elements are in series and which are in parallel.



Solution:

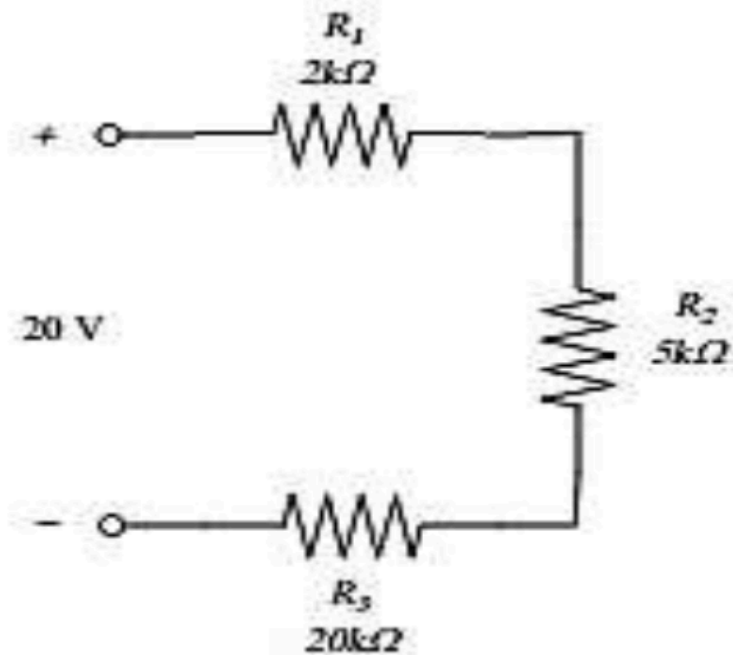
Since there are four elements in the circuit, the circuit has four branches: 10 V, 5, 6, and 2 A. The circuit has three nodes as identified in Fig. below. The 5- resistor is in series with the 10-V voltage source because the same current would flow in both. The 6- resistor is in parallel with the 2-A current source because both are connected to the same nodes 2 and 3.



Resistors in DC Circuits :

1- Series Resistors Circuits

Example 1: Calculate the total resistance R_T in the following circuit, then calculate the current flowing in the circuit.



Solution:

$$R_T = R_1 + R_2 + R_3$$

$$R_T = 2k\Omega + 5k\Omega + 20k\Omega, R_T = 27k\Omega$$

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

$$I = \frac{20}{27} = 0.47 \text{ mA}$$

Example 2: Three resistances are connected in series with 12 V supply, so that the current flow is (6 mA). If one of the resistance equal to (1kΩ), while the voltage across the second resistance is (3.6V), calculate the value of the third resistance.

Solution:

$$R_T = \frac{V}{I} = \frac{12}{6} = \frac{12}{6 \times 10^{-3}} = 2000 \Omega, R_T = 2 \text{ k}\Omega$$

If the voltage across the second resistance is (3.6 V) and the current is (6mA) then by using ohm's law.

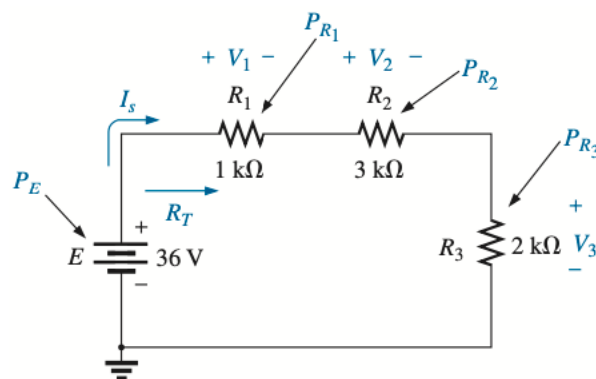
$$R_2 = \frac{V}{I} = \frac{3.6}{6 \times 10^{-3}} = 600 \Omega$$

$$R_T = R_1 + R_2 + R_3$$

$$2000 = 1000 + 600 + R_3 \Rightarrow 2000 = 1600 + R_3$$

$$R_3 = 2000 - 1600 = 400 \Omega$$

Example 3 : For the series circuit in Fig. (all standard values):



- Determine the total resistance R_T .
- Calculate the current I_s .
- Determine the voltage across each resistor.
- Find the power supplied by the battery.

Solutions:

a.

$$R_T = R_1 + R_2 + R_3 = 1\ \Omega\text{ k} + 3\ \Omega\text{ k} + 2\ \Omega\text{ k}$$

$$R_T = 6\ \Omega\text{ k}$$

b.

$$I_s = \frac{E}{R_T} = \frac{36}{6} = 6\text{ mA}$$

c.

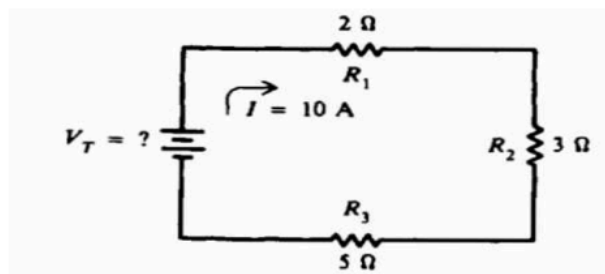
$$V_1 = I_1 R_1 = I_s R_1 = (6\text{ mA})(1\text{ k}) = \mathbf{6\text{ V}}$$

$$V_2 = I_2 R_2 = I_s R_2 = (6\text{ mA})(3\text{ k}) = \mathbf{18\text{ V}}$$

$$V_3 = I_3 R_3 = I_s R_3 = (6\text{ mA})(2\text{ k}) = \mathbf{12\text{ V}}$$

d. $PE = EI_s = (36\text{ V})(6\text{ mA}) = \mathbf{216\text{ mW}}$

Example 4: find the voltage needed so that a current of 10 A will flow through the series circuit shown below



Sol:

Step 1. Find total resistance.

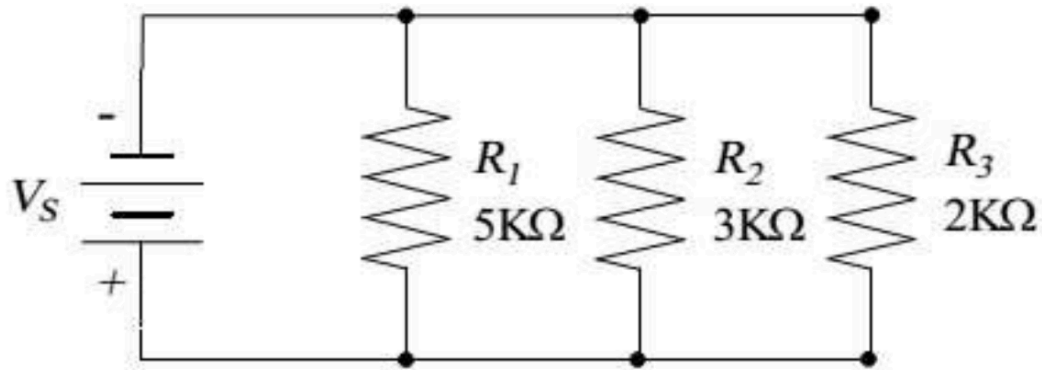
$$\begin{aligned} R_T &= R_1 + R_2 + R_3 \\ &= 2 + 3 + 5 = 10\ \Omega \end{aligned}$$

Step 2. Find the voltage

$$\begin{aligned} V_T &= IR_T \\ &= 10(10) = 100\text{ V} \end{aligned}$$

2-Parallel Resistors Circuits:

Example 1: Calculate the total resistance of this circuit



Solution:

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

$$\frac{1}{R_T} = \frac{1}{5\text{ k}\Omega} + \frac{1}{3\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega}$$

$$(0.2 \times 10^{-3}) + (0.33 \times 10^{-3}) + (0.5 \times 10^{-3}) \frac{1}{R_T} =$$

$$(1.03 \times 10^{-3}) \frac{1}{R_T} =$$

$$R_T = 971\ \Omega$$

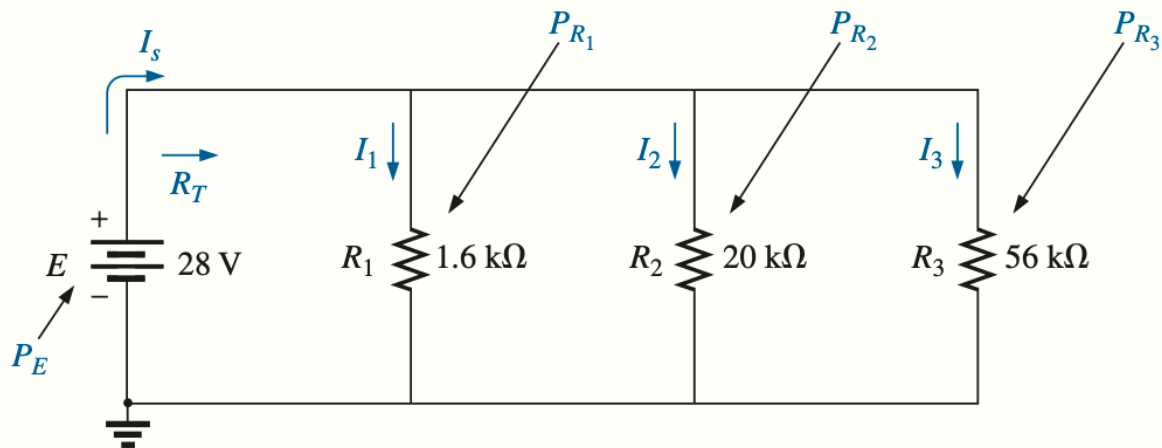
Note:

In general, if we have two resistors in parallel, their total resistance is:

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

Example 2: For the parallel network in Fig. 6.30 (all standard values):

- Determine the total resistance R_T .
- Find the source current and the current through each resistor.
- Calculate the power delivered by the source.



Solution:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{1.6 \text{ k}\Omega} + \frac{1}{20 \text{ k}\Omega} + \frac{1}{56 \text{ k}\Omega}}$$

$$a. R_T = \frac{1}{0.625 + 0.05 + 0.17} = 1.44 \text{ k}\Omega$$

b. applying Ohm's law:

$$I_S = \frac{E}{R_T} = \frac{28}{1.44} = 19.44 \text{ mA}$$

Recalling that current always seeks the path of least resistance immediately tells us that the current through the 1.6 k resistor will be the largest and the current through the 56 k resistor the smallest.

Applying Ohm's law again:

$$I_1 = \frac{V_1}{R_1} = \frac{E}{R_1} = \frac{28 \text{ V}}{1.6 \text{ k}\Omega} = \mathbf{17.5 \text{ mA}}$$

$$I_2 = \frac{V_2}{R_2} = \frac{E}{R_2} = \frac{28 \text{ V}}{20 \text{ k}\Omega} = \mathbf{1.4 \text{ mA}}$$

$$I_3 = \frac{V_3}{R_3} = \frac{E}{R_3} = \frac{28 \text{ V}}{56 \text{ k}\Omega} = \mathbf{0.5 \text{ mA}}$$

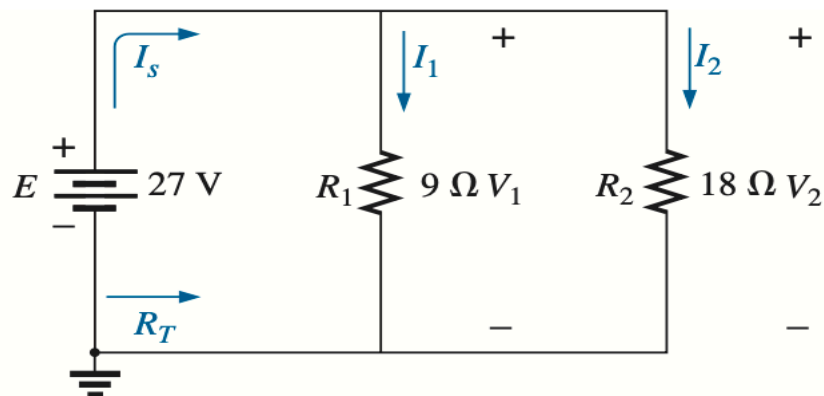
C. Applying Eq.

$$P_E = EI_s = (28 \text{ V}) \times (19.4 \text{ mA}) = 543.2 \text{ mW}$$

Example 3 :

For the parallel network in Fig

- Find the total resistance.
- Calculate the source current.
- Determine the current through each parallel branch.



Solutions:

a.

$$R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{(9 \, \Omega)(18 \, \Omega)}{9 \, \Omega + 18 \, \Omega} = \frac{162}{27} \, \Omega = \mathbf{6 \, \Omega}$$

b. Applying Ohm's law:

$$I_s = \frac{E}{R_T} = \frac{27 \, \text{V}}{6 \, \Omega} = \mathbf{4.5 \, \text{A}}$$

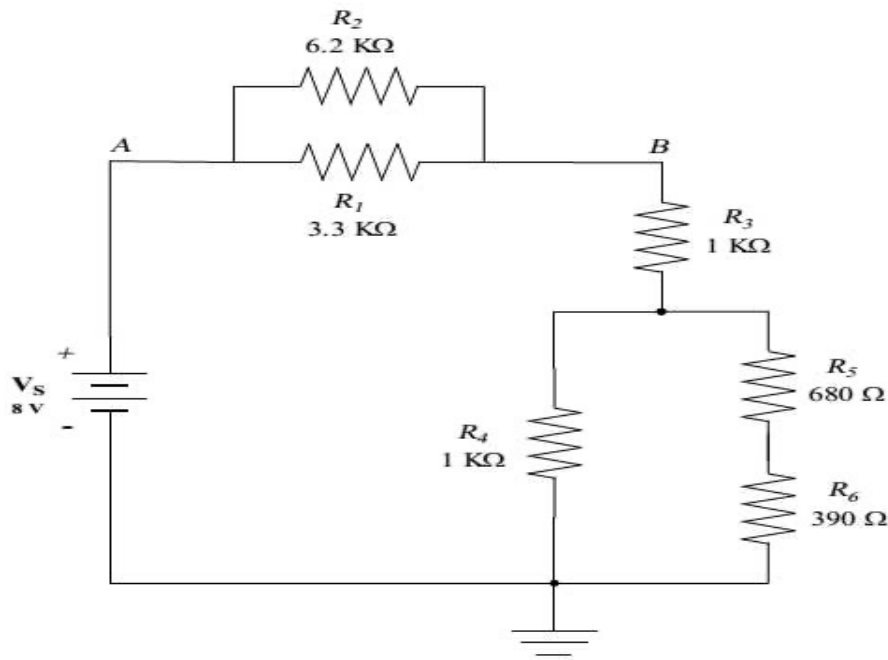
c. Applying Ohm's law:

$$I_1 = \frac{V_1}{R_1} = \frac{E}{R_1} = \frac{27 \, \text{V}}{9 \, \Omega} = \mathbf{3 \, \text{A}}$$

$$I_2 = \frac{V_2}{R_2} = \frac{E}{R_2} = \frac{27 \, \text{V}}{18 \, \Omega} = \mathbf{1.5 \, \text{A}}$$

Series-Parallel Circuits

Example 1: Calculate the total resistance in this circuit.



Solution:

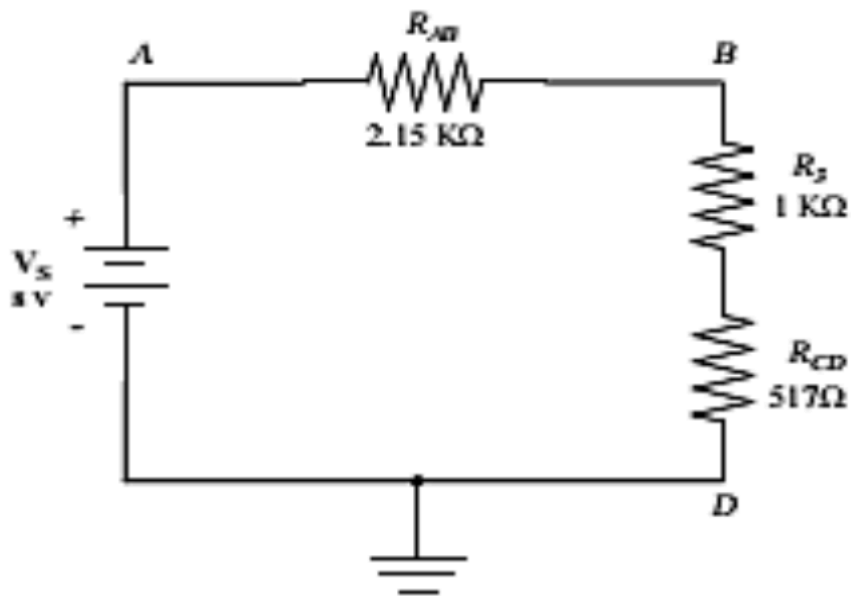
$$R_{AB} = \frac{R_1 R_2}{R_1 + R_2}$$

$$R_{AB} = \frac{(3.3 \text{ k}\Omega)(6.2 \text{ k}\Omega)}{(3.3 \text{ k}\Omega) + (6.2 \text{ k}\Omega)} = 2.15 \text{ k}\Omega$$

$$R_{CD} = \frac{R_4(R_5 + R_6)}{R_4 + R_5 + R_6}$$

$$R_{CD} = \frac{1 \text{ k}\Omega(1.07 \text{ k}\Omega)}{1 \text{ k}\Omega + 1.07 \text{ k}\Omega} = 517 \Omega$$

So the circuit will be

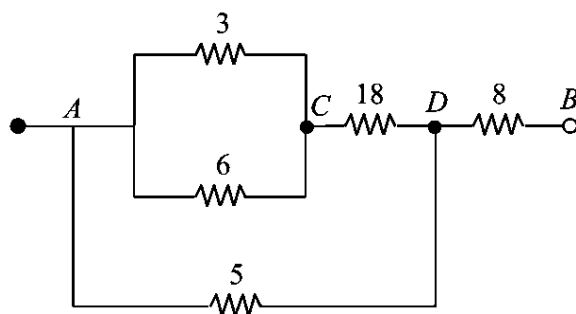


$$R_T = R_{AB} + R_3 + R_{CD}$$

$$R_T = 2.15 \text{ k}\Omega + 1 \text{ k}\Omega + 517\Omega$$

$$R_T = 3.6 \text{ k}\Omega$$

Example 2 : Calculate the effective resistance of the following combination of resistances between points A and B and the total current.



Solution: Resistance between A and C

$$= 6 \parallel 3 = 2 \Omega$$

$$\text{Resistance of branch } ACD = 18 + 2 = 20 \Omega$$

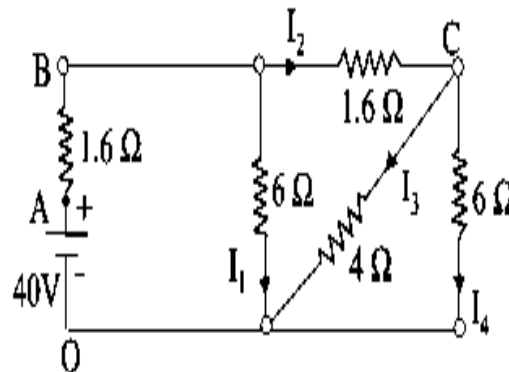
Now, there are two parallel paths between points A and D of resistances 20Ω and 5Ω

$$\text{Hence, resistance between } A \text{ and } D = 20 \parallel 5 = 4 \Omega$$

$$\therefore \text{Resistance between } A \text{ and } B = 4 + 8 = 12 \Omega$$

$$\text{Total circuit current} = 60/12 = 5 \text{ A}$$

Example 3: Find current through 4Ω resistance.



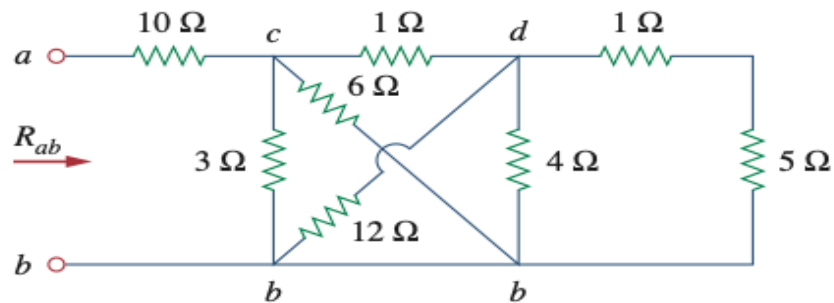
Solution. Simplifying the series-parallel combinations, and solving the circuit, the source current is 10 amp. With respect to 0, $V_A = 40$, $V_B = 40 - 16 = 24$ volts.

$$I_1 = 4 \text{ amp, hence } I_2 = 6 \text{ amp}$$

$$V_C = V_B - I_2 \times 1.6 = 24 - 9.6 = 14.4 \text{ volts}$$

$$I_3 = 14.4/4 = 3.6 \text{ amp, which is the required answer. Further } I_4 = 24 \text{ amp.}$$

Example 4: Calculate the equivalent resistance R_{ab} in the circuit in Fig.

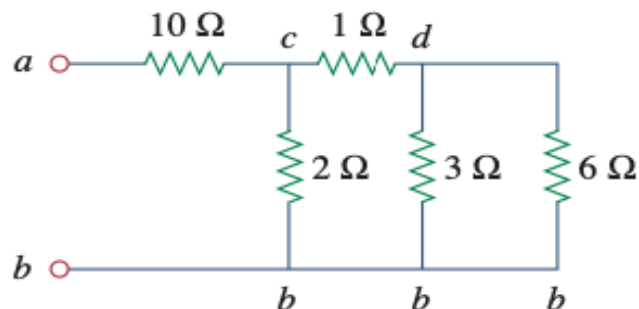


Solution:

$$3\Omega \parallel 6\Omega = \frac{3 \times 6}{3 + 6} = 2\Omega$$

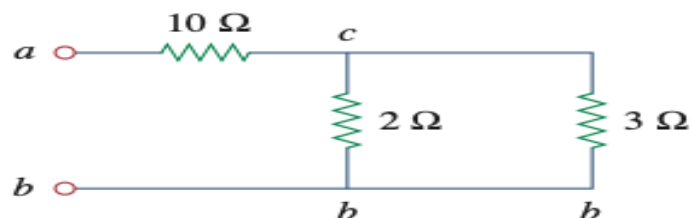
$$12\Omega \parallel 4\Omega = \frac{12 \times 4}{12 + 4} = 3\Omega$$

$$1\Omega + 5\Omega = 6\Omega$$



$$3\Omega \parallel 6\Omega = \frac{3 \times 6}{3 + 6} = 2\Omega$$

$$1\Omega + 2\Omega = 3\Omega$$

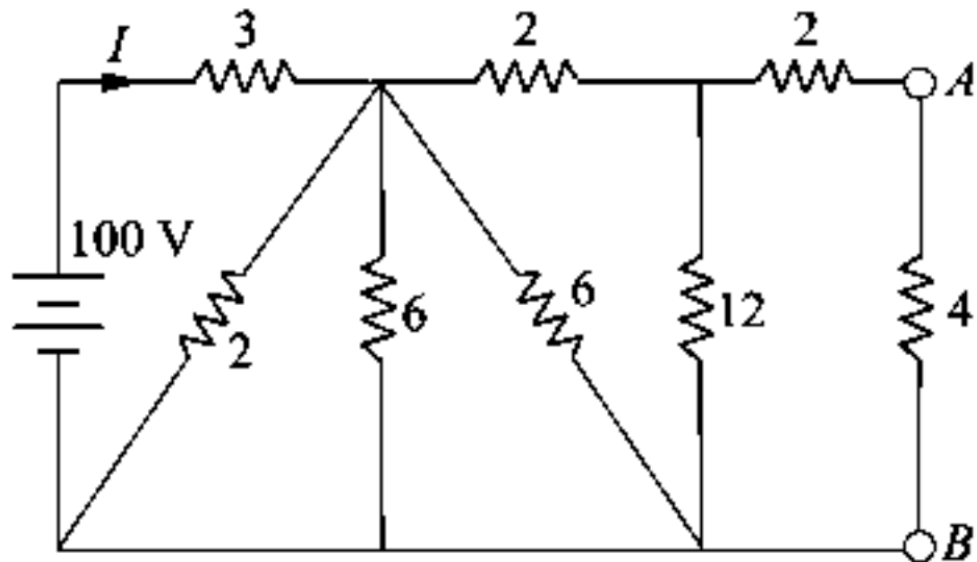


$$2\Omega \parallel 3\Omega = \frac{2 \times 3}{2 + 3} = 1.2\Omega$$

$$R_{ab} = 10\Omega + 1.2\Omega = 11.2\Omega$$

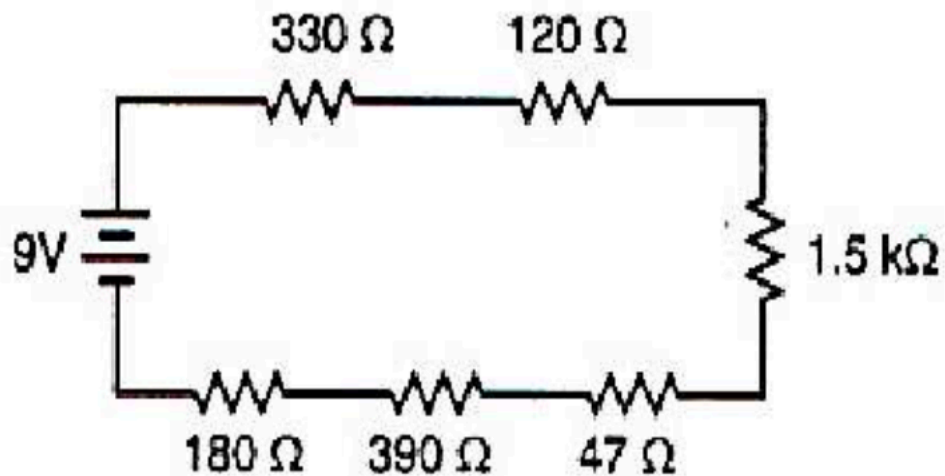
Homework:

Q1: Calculate the total resistance :

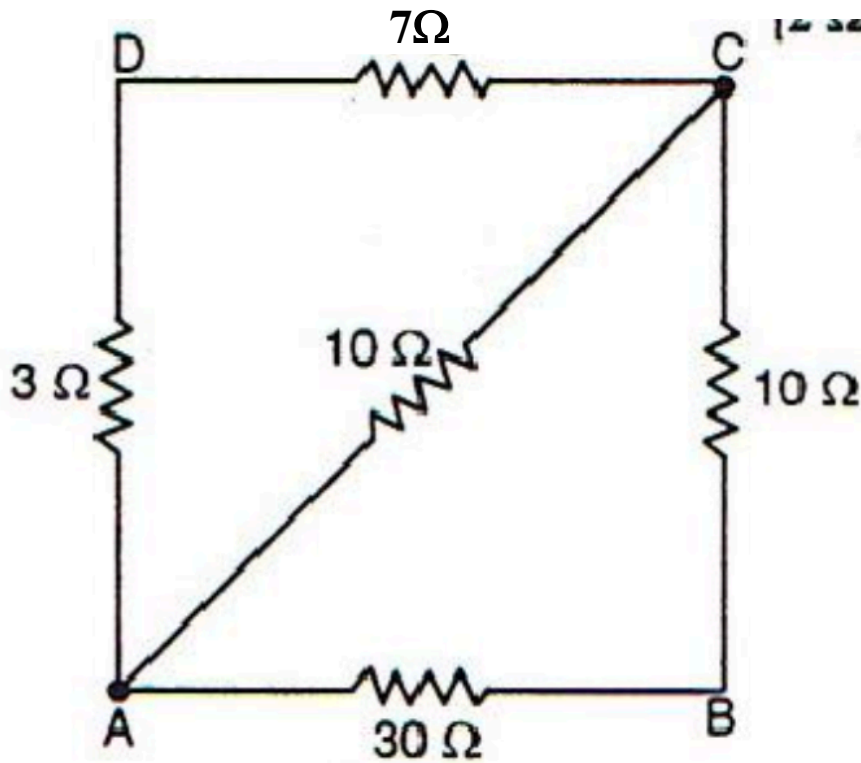


$$R_t = 25 \Omega$$

Q2: Calculate the current flow for below figure:

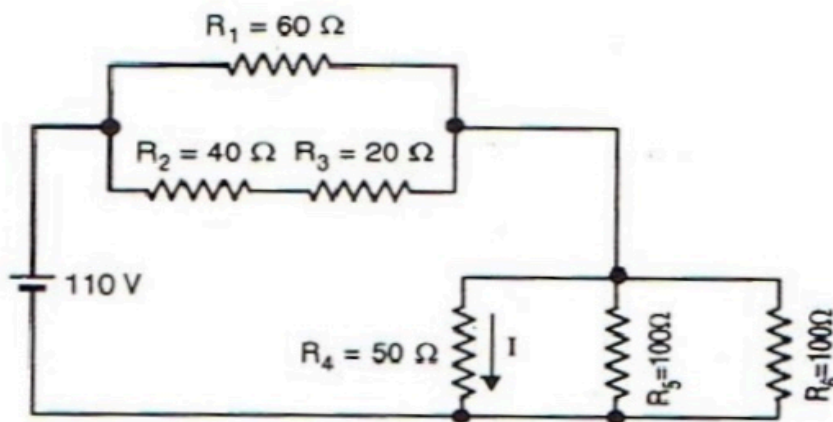


Q3: Find the equivalent resistance between points A and B in the circuit shown below.



[10 Ω]

Q4: find the current I in the 50 resistor in the circuit below figure.



[1 A]