Electronic Circuits

ECEN 205/ECEN 202/MECH 227

Unit #2-2 DC Electrical Networks Analysis

SLIDES PREPARED BY Eng. Belaid Boukenna

PRESENTER Eng. Belaid Boukenna

COLLEGE / CENTRE Engineering

PROGRAM ICEN/COEN/MEN

SEMESTER Fall 2021-2022

جامعة البريمي
UNIVERSITY OF BURAIMI

Unit-2

DC Circuits and Networks Analysis

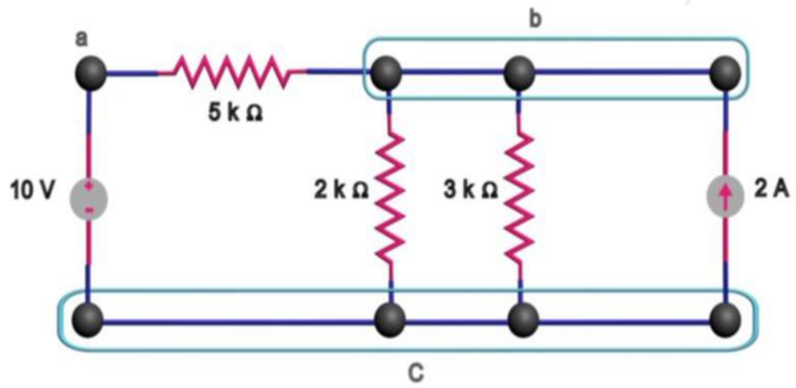
Section#2 Electric Networks Analysis

Introduction

- This section outlines the most commonly used laws and theorems that are required to analyze and solve electric Networks.
- Relationships between various laws and equation writing techniques are also provided.
- Several examples are shown demonstrating various aspects of the laws.

Definitions and terminologies

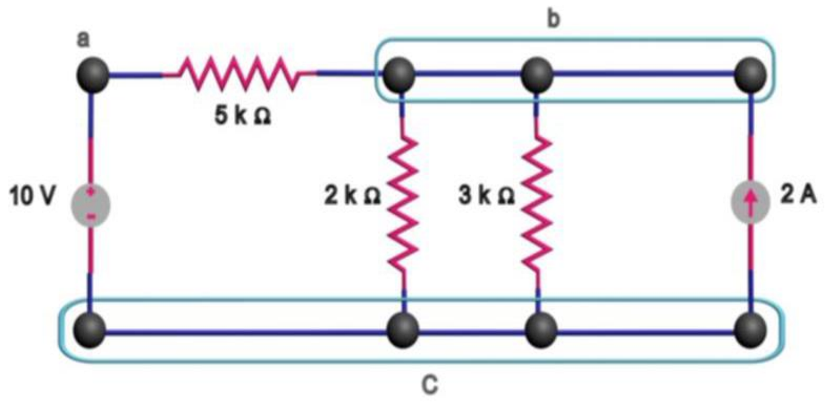
- **Electric Network**: connection of two ore more than two electrical circuits, the circuit diagram shown in Figure below is an electric network.



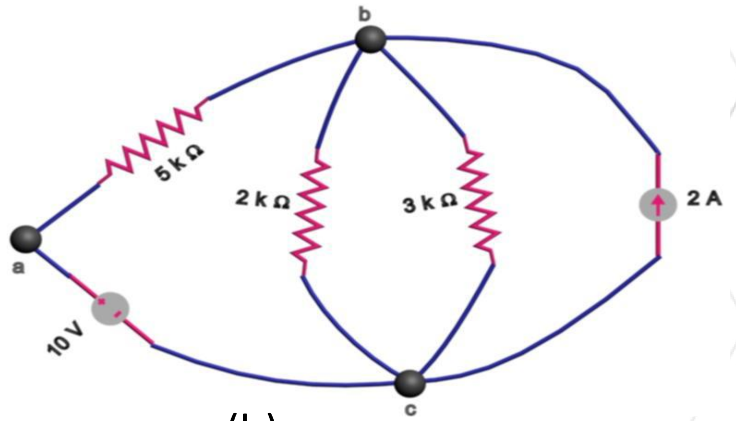
جامعة البريمي
UNIVERSITY OF BURAIMI

Definitions and terminologies

- **Branch:** a single element such as a voltage source or a resistor.
- **Node:** point of connection between two or more branches.
- **Loop:** any 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)



(b)

An electric network showing nodes, branches, elements and loop.

- A node is usually indicated by a dot in a circuit.
- If a short circuit (connecting wire) connects two or more nodes, the nodes constitute a single node.

The circuit in Figure above has three nodes a, b, and c.

جامعة البريمي
UNIVERSITY OF BURAIMI

Definitions and terminology

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

For example, the closed path abca containing 10v, 5kΩ, and 2kΩ in Figure below is a loop.

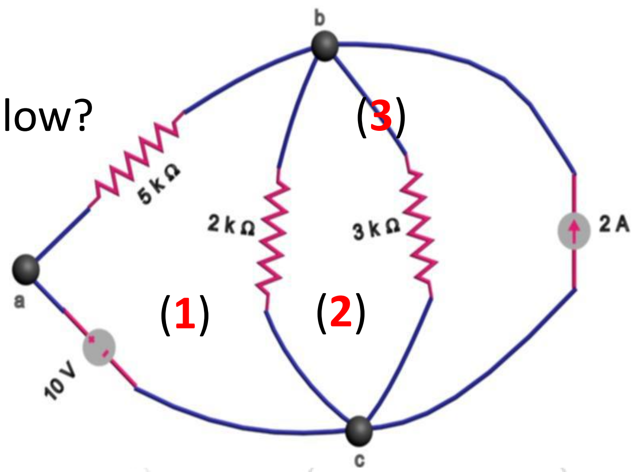
Another loop is the closed path bcb containing the 3kΩ resistor and the current source 2A.

Although one can identify six loops in Figure below, only three of them are independent.

- A circuit with **B** branches, **N** nodes, and **L** independent loops will satisfy the fundamental theorem of circuit topology:

$$L = (B+1) - N$$

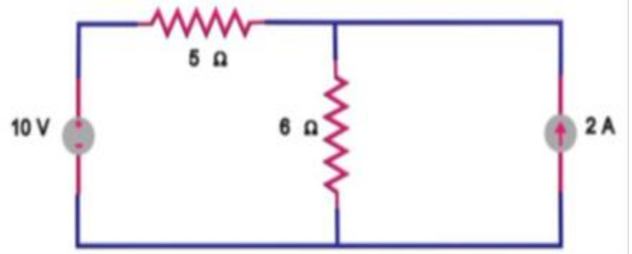
Question:
How many independent loops are there in the circuit below?
Answer:
B = 5; N = 3; therefore: L = (5+1) – 3 = **3**
(1): 10v, 5kΩ, and 2kΩ
(2): 2kΩ, and **3kΩ**
(3): **2A**, and 2kΩ



➢ Definitions (cont.)

Example1

1. Determine the number of branches and nodes in the next shown circuit.
2. Identify which elements are in series and which are in parallel.
3. Find the number of independent loops



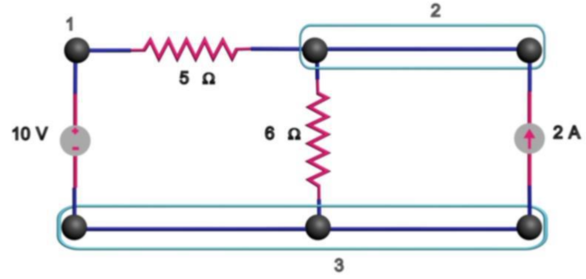
Solution:

1. Since there are 4 elements in the circuit, there are 4 branches: 10 V, 5Ω, 6Ω, and 2 A.

   3 nodes as identified in Figure: 1, 2, and 3

2. The 5Ω resistor is in series with the 10V voltage source because the same current would flow in both.

- The 6Ω resistor is in parallel with the 2A current source because both are connected to the same nodes 2 and 3.



3. B =4, N=3, then L = (B+1) – N= 5-3=2

   (1): <u>10V</u>, 5Ω, 6Ω

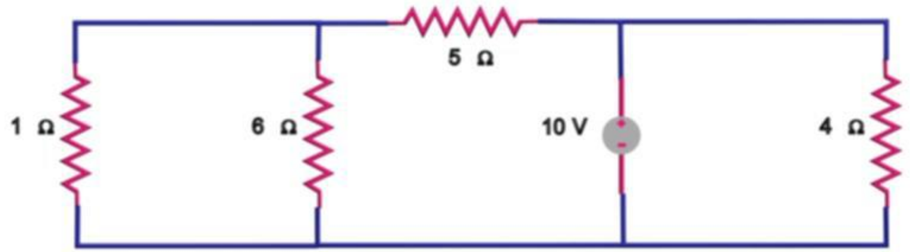
   (2): <u>2A</u>, 6 Ω

Example 2

1. How many branches and nodes does the circuit below have?

2. Identify the elements that are in series and in parallel.

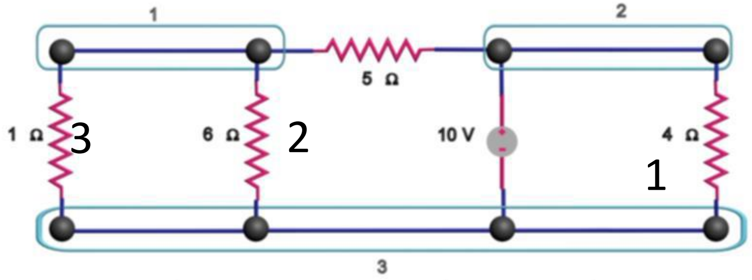
3. Find the number of independent loops



Solution:

1. 5 branches and 3 nodes are identified in Fig below.
2. The 1 Ω and 6 Ω resistors are in parallel.
   The 4 Ω resistor and 10-V source are also in parallel.

3. B=5, N=3, then L=6-3 = 3
   (1): 10V and **4Ω**
   (2): 10V, **5Ω**, and **6Ω**
   (3): 10V, 5Ω, **and 1Ω**



OHM'S LAW

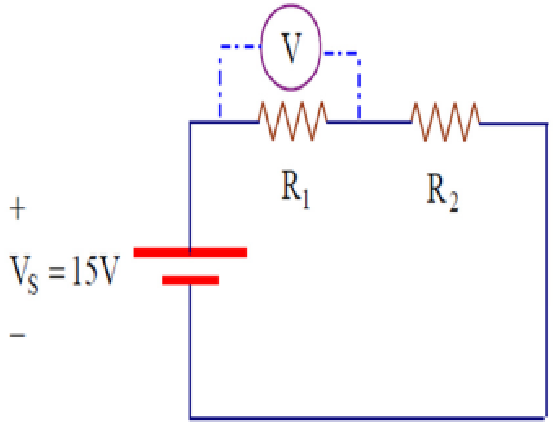
Ohm's law states that the voltage v across a resistor is directly proportional to the current i flowing through the resistor.

$$V = RI$$

Ohm's law application:

In the circuit below, R_1=1.5KΩ and the current through R_1 is 3 mA.

1. Find the voltage drop (**V_1**) across R_1
2. Find the value of R_2



Answer:

1. $V_1 = R_1 I_1$ = $1.5 \times 10^3 \times 3 \times 10^{-3}$ = **4.5V**
2. $V_2 = V_S - V_1 = 15 - 4.5 = 10.5V$

   $V_2 = R_2\, I_2$ then $R_2 = V_2 / I_2$

Since, R_1 and R_2 are in series then $I_2 = I_1$ = **3mA**

Then, $R_2 = 10.5 / 3 \times 10^{-3} = 3.5 \times 10^3\, \Omega$ = **3.5 KΩ**

➢ KIRCHHOFF'S LAWS

- Arguably the most common and useful set of laws for solving electric circuits are the **Ohm's law and Kirchhoff's voltage and current laws.**

- Several other useful relationships are derived based on these laws.

- Kirchhoff's laws are formally known as Kirchhoff's voltage law **(KVL)** and Kirchhoff's current law **(KCL).**

  - **Kirchhoff's voltage law (KVL):**

    Algebraic sum of all voltages around a loop is zero.

    In other words: sum of voltage drops equal sum of voltage rises

$$\sum_{1}^{M} V_m = 0$$

Where M is the number of voltages in the loop (or number of branches in the loop) and

V_m is the mth voltage.

Electric Networks Analysis

- To illustrate KVL, consider the circuit in Figure below.
- The sign on each voltage is the polarity of the terminal encountered first as we travel around the loop.
- We can start with any branch and go around the loop either clockwise or counter clockwise.

Thus, KVL yields:

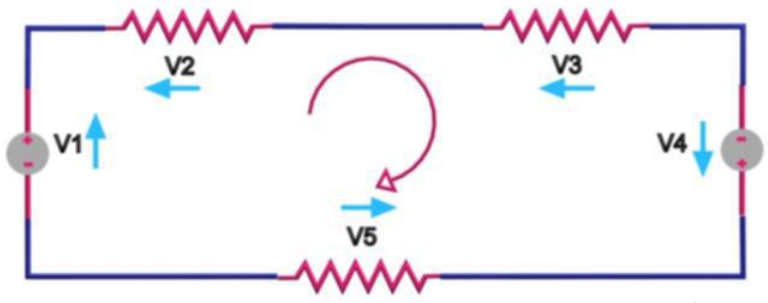
$$-V1+V2+V3-V4+V5=0$$

Rearranging terms gives:

$$V1+V4=V2+V3+V5$$

(V1 + V4) are sum of voltage rises

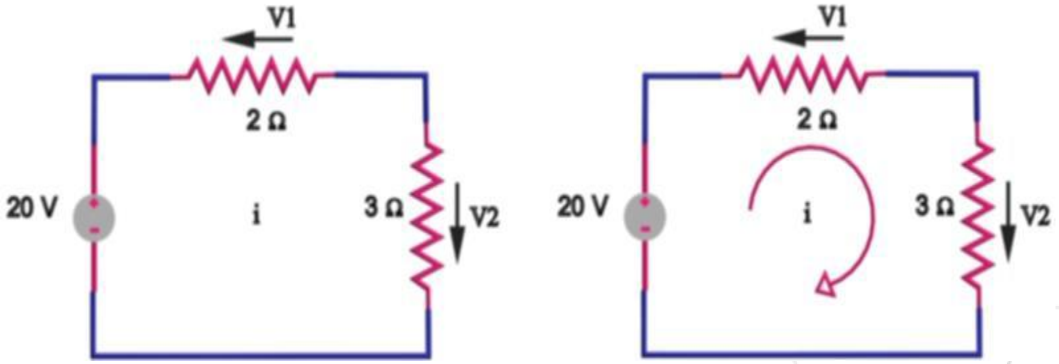
(V2 + V3 + V5) are sum of voltage drops



A single-loop circuit illustrating KVL.

Example1:

For the circuit in Figure below, find the current I, the voltages V1 and V2.



a b

Solution:

To find V1 and V2, we apply Ohm's law and Kirchhoff's voltage law.
Assume that current **I** flows through the loop as shown in Fig. (b) above.

From Ohm's law:

$V1=2I$ **(1)**
$V2=-3I$ **(2)**

$-20+V1-V2=0$ **(3)** **or** $20 + V2 = V1$ (Applying KVL around the loop)

Solving the three equations we can easily obtain I, V1, and V2:

$-20 + 2I + 3I = 0 \rightarrow$ $5I = 20$ $\rightarrow$ $\mathbf{I = 4A}$ $\rightarrow$ $\mathbf{V1 = 8\,V}$ **and** $\mathbf{V2 = -12\,V}$

➢ KIRCHHOFF'S LAWS

▪ Kirchhoff's current law (KCL):

Algebraic sum of currents entering a node is zero.
In other words: the sum of the currents entering a node is equal to the sum of the currents leaving the node.

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

where N is the number of branches connected to the node and *in* 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.

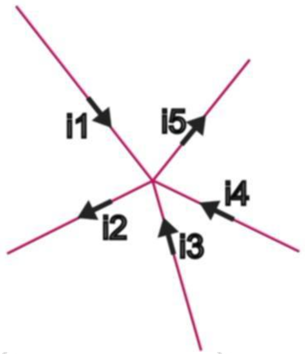
$$\sum i_{\,entering} = \sum i_{\,living}$$

For example consider the node in Fig. below. Applying KCL gives:

$I_1 - I_2 + I_3 + I_4 - I_5 = 0$; Thus: $I_1 + I_3 + I_4 = I_2 + I_5$

$(I_1 + I_3 + I_4)$ are the sum of entering currents to the node

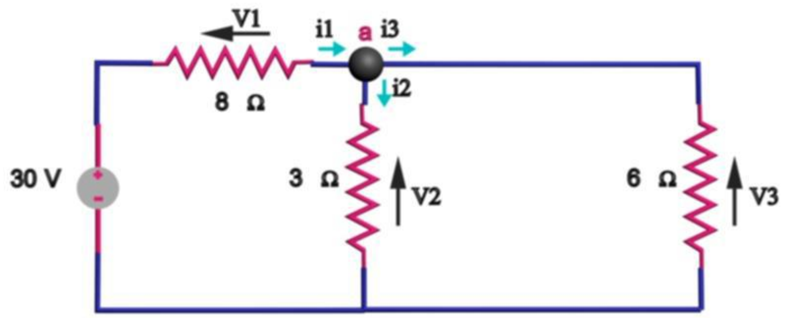
$(I_2 + I_5)$ are sum of leaving currents to the node



Electric Networks Analysis

Example 2:

Find the currents and voltages in the circuit shown below.



Solution:

We apply Ohm's law and Kirchhoff's laws.

By Ohm's law:

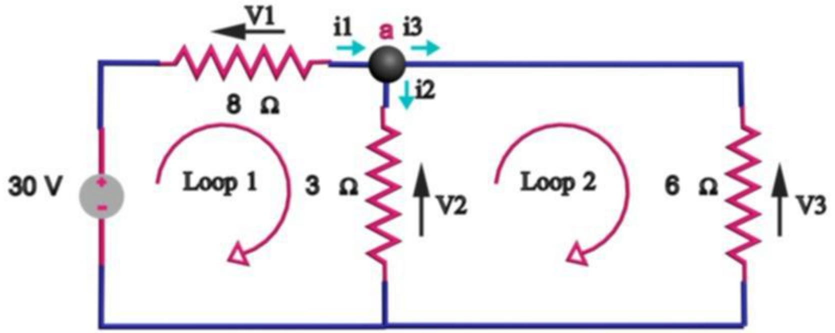
V1=8I1 **(1)**

V2=3I2 **(2)**

V3=6I3 **(3)**

At nod a, **KCL** gives:

I1−I2−I3=0 **(4)**



Applying KVL to loop 1 as in Figure:

30 = V1 + V2 **(5)**

Applying KVL to loop 2:

V2 = V3 **(6)**

Solving the six equations gives: I1 = 3A; I2 = 2A; I3 = 1A; and V1 = 24V; V2=6V; V3=6V

Exercise1

Find the currents I_1, I_2, and I_3 in the circuit shown in Figure below

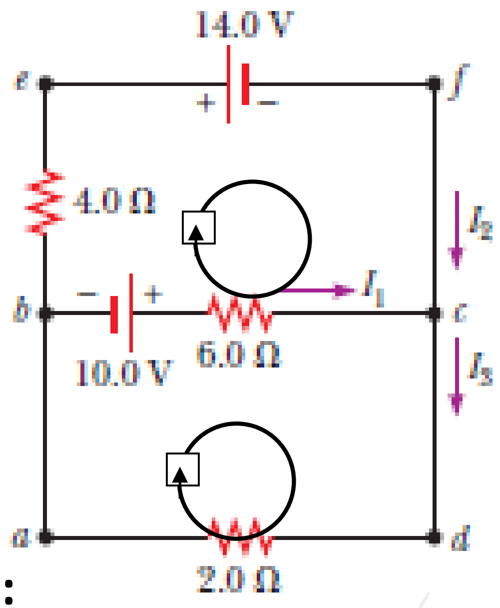
Apply KCL to node *c*: $I_1 + I_2 = I_3$ (1)

From the lower loop we can find:

$10V = 6I_1 + 2I_3$ (2)

From the upper loop we can find:

$24V = 4I_2 - 6I_1$ (3)



Figure

Solve Equation (1) for I_3 and substitute into Equation(2):

$I_1 = 2A$

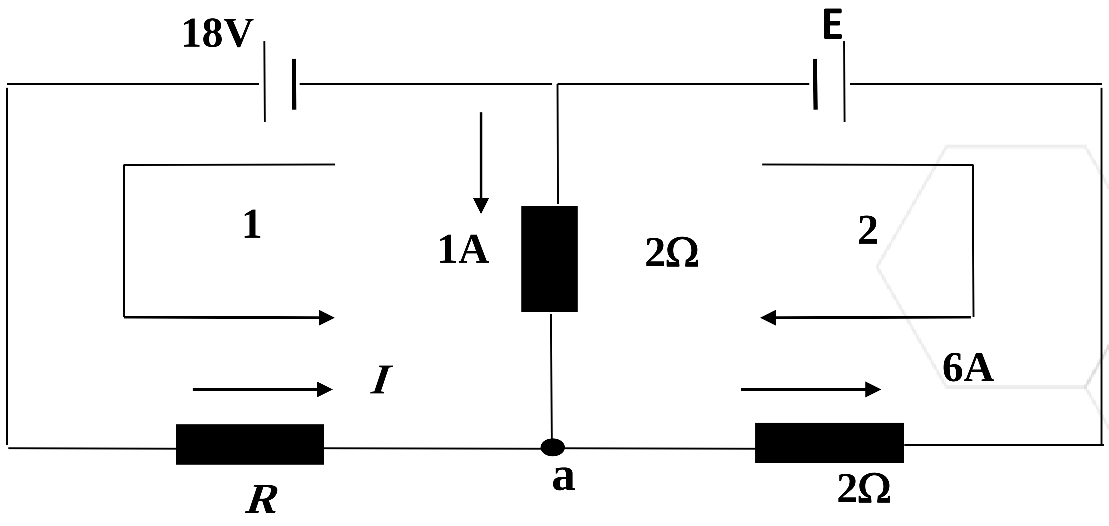
$I_2 = -3A$ (so change direction of I_2)

$I_3 = -1$ A (so change direction of I_3)

جامعة البريمي
UNIVERSITY OF BURAIMI

Exercise2:

Find the values of *R*, *I*, and *E* in the circuit below



Answer

We can take *a* as a junction point, thus the value of I is

$$I + 1A = 6A \qquad \Rightarrow I = 5A$$

From the loop (1), we can find R:

$$18V - (5A)(R) + (1A)(2\Omega) = 0$$

$$18V + 2V = (5A)(R) \qquad \Rightarrow R = \frac{20V}{5A} = 4\Omega$$

To determine the value of *ε, use the loop (2)*

$$E + (6A)(2\Omega) + (1A)(2\Omega) = 0$$

$$E + 12V + 2V = 0 \qquad \Rightarrow \quad E = -14V$$

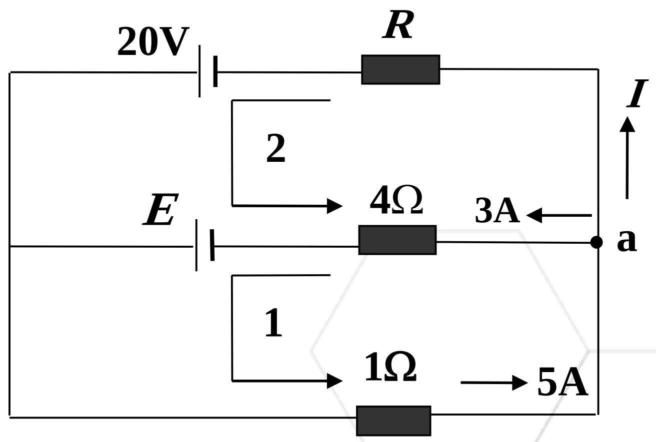
$$\varepsilon + 12V + 2V = 0 \qquad \Rightarrow \quad \varepsilon = -14V$$

The negative of E indicates that the direction is opposite of that assumed

UNIVERSITY OF BURAIMI جامعة البريمي

Exercise3:

Find the values of I, E, *and* R in the circuit shown in the figure below.



Answer

At node a :

$$5A = 3A + I \Rightarrow I = 2A$$

Use loop (1) to find E:

$$E - (1\Omega)(5A) - (4\Omega)(3A) = 0 \quad \Rightarrow \quad E = 17V$$

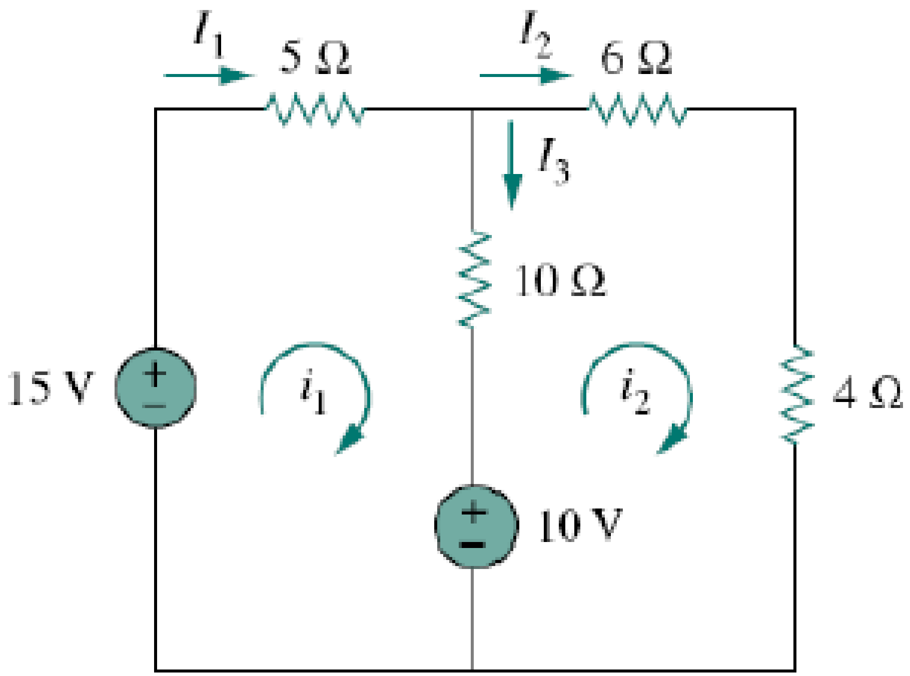
By Using the loop (2) to find the value of R:

$$20V - 17V + (3A)(4\Omega) - (2A)(R) = 0 \quad \Rightarrow \quad R = \frac{15V}{2A} = 7.5\Omega$$

Answer: 2A, 17V, 7.5Ω

Homework1

For the circuit below, find I_1, I_2, and I_3 using Ohm and Kirchhoff Laws.



Electric Networks Theorems

The most common electric Networks theorems are the following:

- **SUPERPOSITION THEOREM**
- **THVENIN'S THEOREM**
- **NORTON'S THEOREM**
- **SOURCE TRANSFORMATION**
- **MAXIMUM POWER TRANSFER THEOREM**
- **MESH AND NODAL ANALYSIS BY INSPECTION**

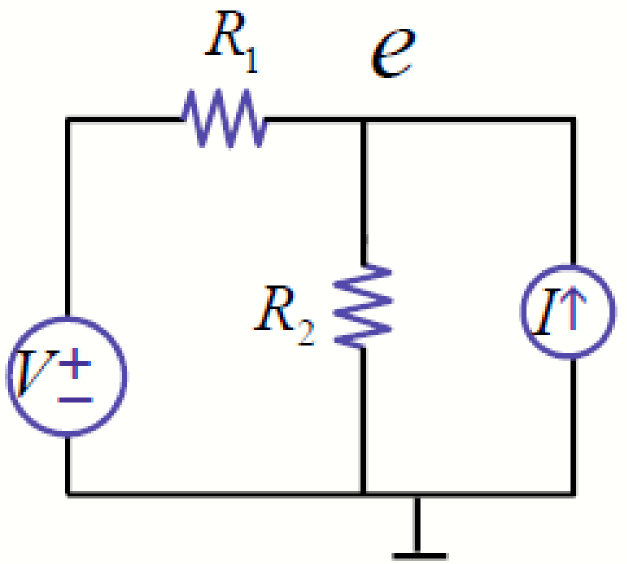
Superposition Theorem

Consider the circuit below

Find the current flowing through R2

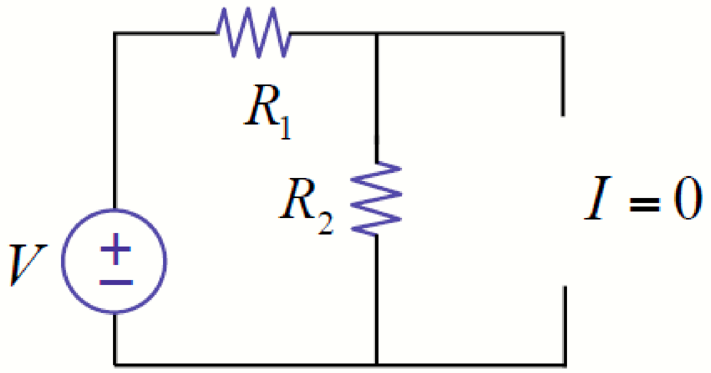
1.Find the responses of the circuit to each source acting alc

2. Sum the individual responses



1. Source voltage acting alone (open current source)

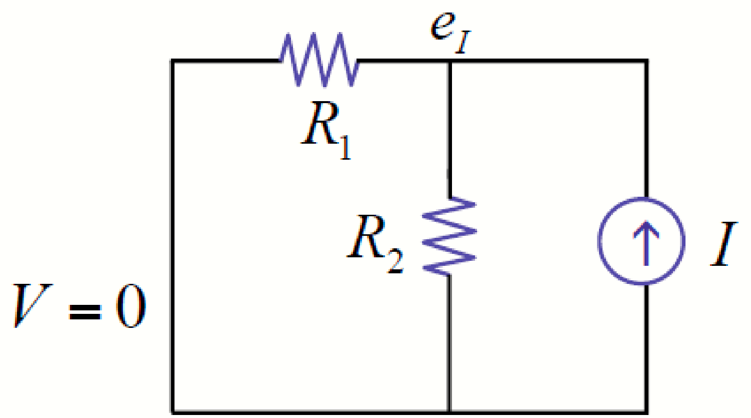
$$I_V = \frac{V}{R_1 + R_2}$$



Superposition Method

2. Current source acting alone
   (Short-circuit voltage source)

R_1 and R_2 are parallel, hence: $I_I = \frac{R_1}{R_1+R_2} I$



By superposition, sum the two partial voltages

$$I_{R2} = I_V + I_I = \frac{V}{R_1+R_2} + \frac{R_1}{R_1+R_2} I$$

جامعة البريمي
UNIVERSITY OF BURAIMI

Thank *You*