Electrical Engineering 1
12026105

Chapter 2

Basic Laws

Learning Objectives

By using the information and exercises in this chapter you will be able to:

1. Know and understand the voltage current relationship of resistors (Ohm's law).
2. Understand the basic structure of electrical circuits, essentially nodes, loops, and branches.
3. Understand Kirchhoff's voltage and current laws and their importance in analyzing electrical circuits.
4. Understand series resistances and voltage division, and parallel resistances and current division.
5. Know how to convert delta-connected circuits to wye-connected circuits and how to convert wye-connected circuits to delta-connected circuits.

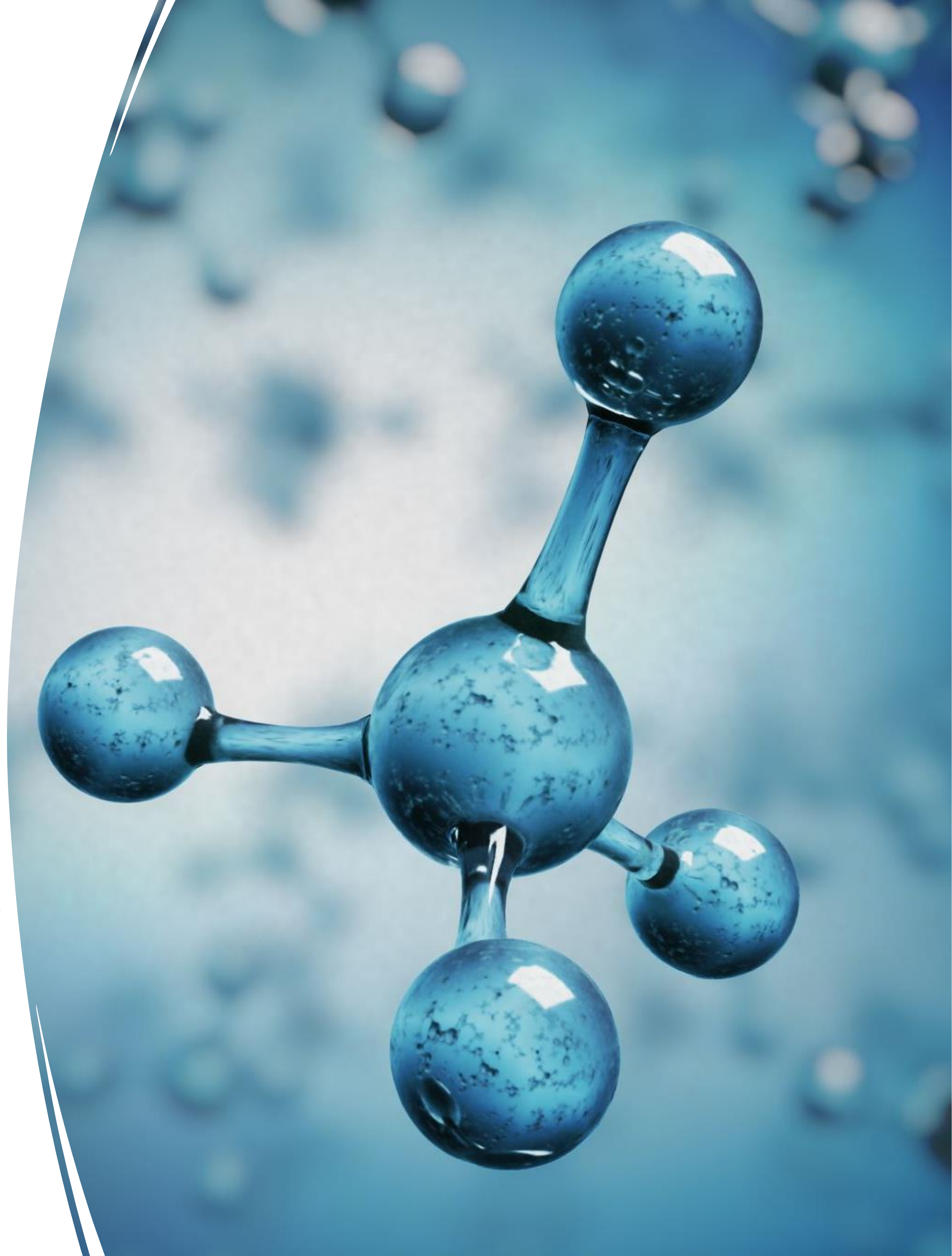
วัตถุประสงค์การเรียนรู้

โดยใช้ข้อมูลและแบบฝึกหัดในบทนี้ นักเรียนจะสามารถ:

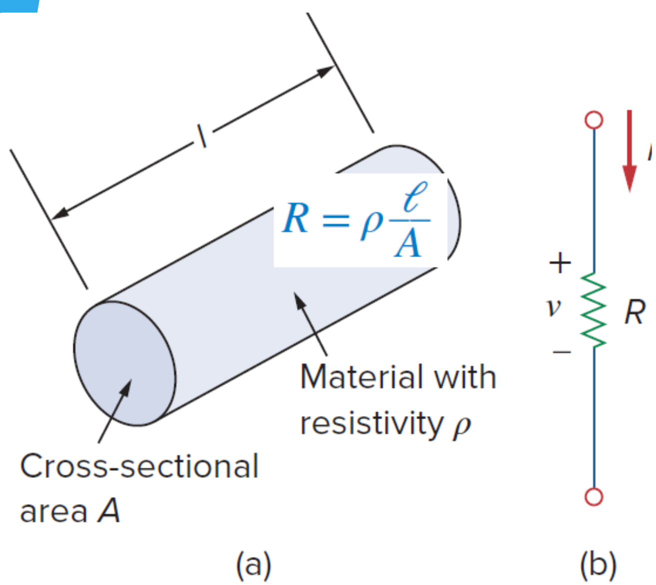
1. รู้และเข้าใจความสัมพันธะหว่างแรงดันไฟฟ้าและกระแสไฟฟ้าของตัวต้านทาน (กฎของโอห์ม)
2. เข้าใจโครงสร้างพื้นฐานของวงจรไฟฟ้าว่าประกอบด้วยโหนด ลูป และแขนง (nodes, loops, branches)
3. เข้าใจกฎแรงดันไฟฟ้าและกระแสไฟฟ้าของ Kirchhoff และความสำคัญในการวิเคราะห์วงจรไฟฟ้า
4. เข้าใจการต่ออนุกรมความต้านทานและการแบ่งแรงดัน และการต่อขนานความต้านทานและการแบ่งกระแส
5. รู้วิธีแปลงวงจรที่เชื่อมต่อเดลต้าเป็นไวย์ ($\nabla \rightarrow Y$)และวิธีการแปลงวงจรที่เชื่อมต่อไวย์เป็นเดลต้า ($Y \rightarrow \nabla$)

Basic Laws - Chapter 2

- Ohm’s Law.
- Nodes, Branches, and Loops.
- Kirchhoff’s Laws.
- Series Resistors and Voltage Division.
- Parallel Resistors and Current Division.
- Wye-Delta Transformations.



2.1 Ohms Law (1)

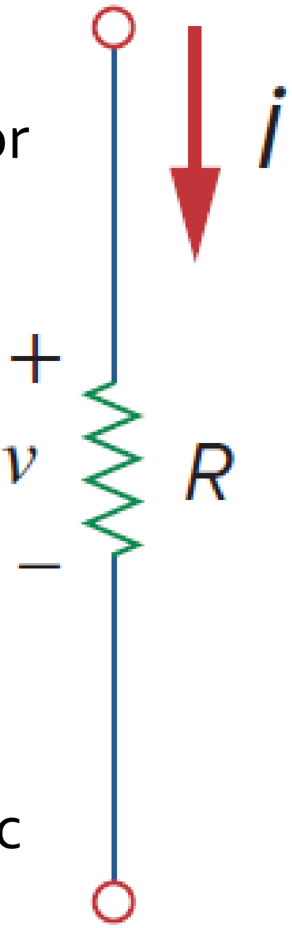


(a) Resistor, (b) Circuit symbol for resistance.

- The resistance R of any material with a uniform cross-sectional area A depends on A and its length ℓ.

- ρ is known as the resistivity of the material in ohm-meters.

2.1 Ohms Law (2)



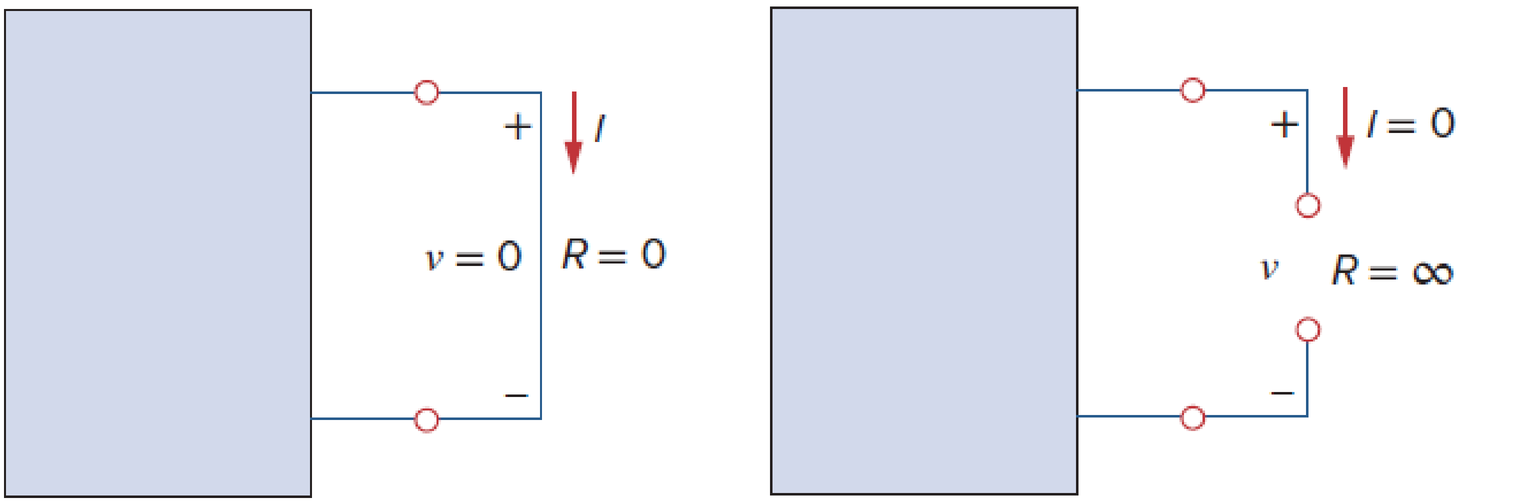
- Ohm's law states that "the voltage v across a resistor is directly proportional to the current i flowing through the resistor". ($v \propto i$)
- Mathematical expression for Ohm's Law is as follows:

$$v = i * R$$

- Two extreme possible values of

$v = 0 (sc)$, $R = 0$ and $v = \infty (oc)$, $R = \infty$ are related with two basic circuit concepts: *short circuit(sc)* and *open circuit(oc).*

2.1 Ohms Law (3)

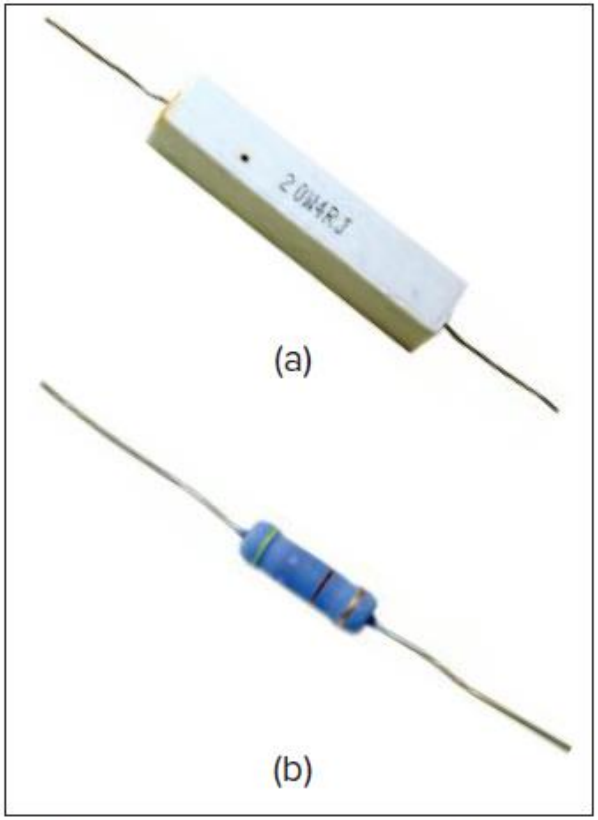


(a) Short circuit ($R = 0$) (b) Open circuit ($R = \infty$).

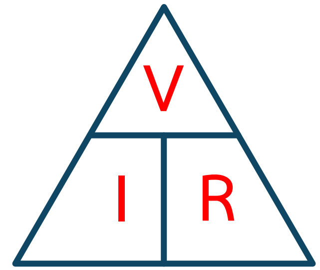
A short circuit is a circuit element with resistance approaching zero ($R = 0$).

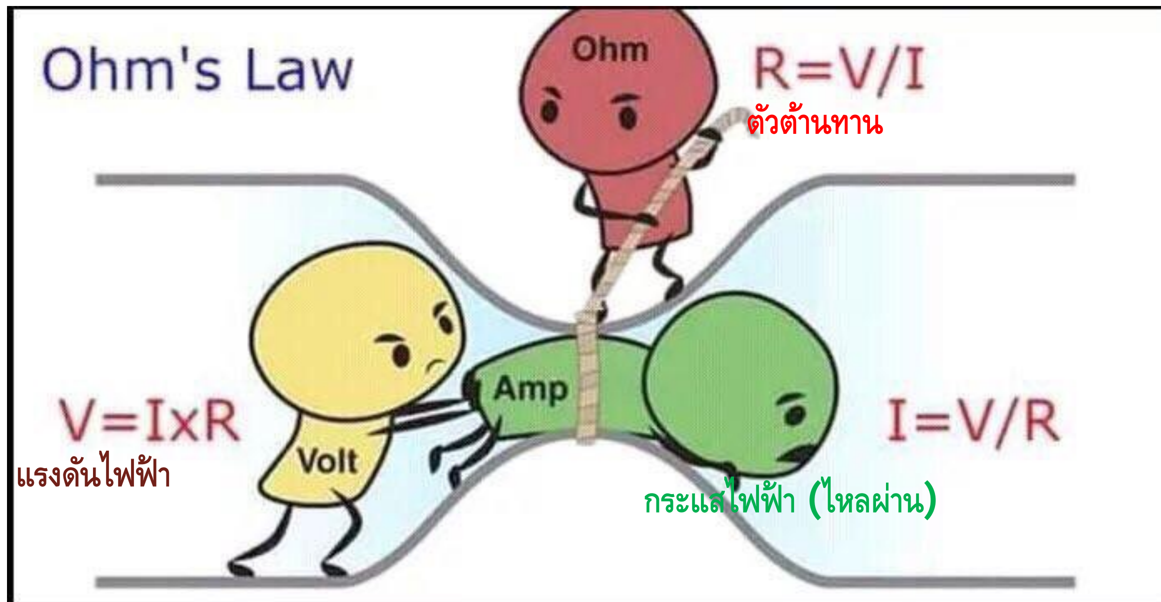
An open circuit is a circuit element with resistance approaching infinity ($R = \infty$).

2.1 Ohms Law (4)



Fixed resistors: (a) wirewound type, (b) carbon film type.
Mark Dierker/McGraw-Hill Education





Ability to resist current (*I*) is known as resistance (*R*) measured in ohms (Ω)

2.1 Ohms Law (5)

Conductance is the ability of an element to conduct electric current; it is the reciprocal of resistance R and is measured in mhos or siemens.

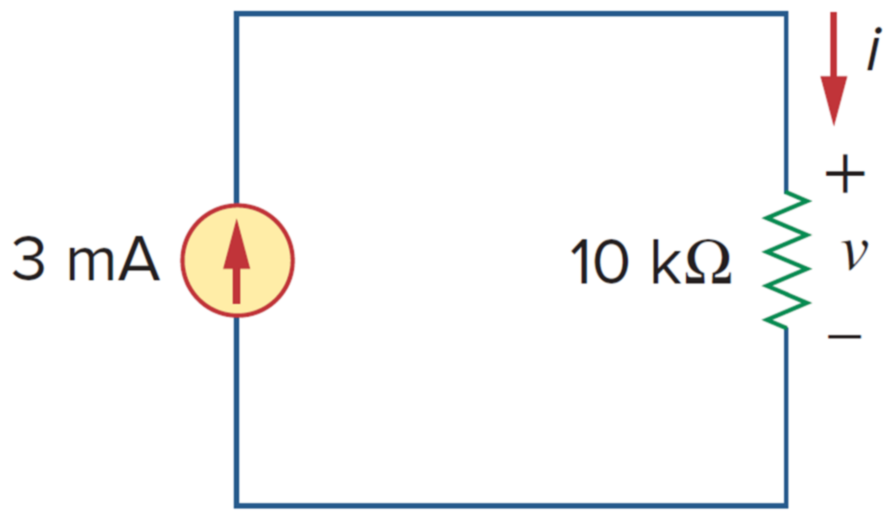
$$G = \frac{1}{R} = \frac{i}{v}$$

The power dissipated by a resistor: (*always positive*)

$$p = vi = i^2 R = \frac{v^2}{R}$$

2.1 Ohms Law (6)

Ex.1 Calculate the voltage v, the conductance G, and the power p.

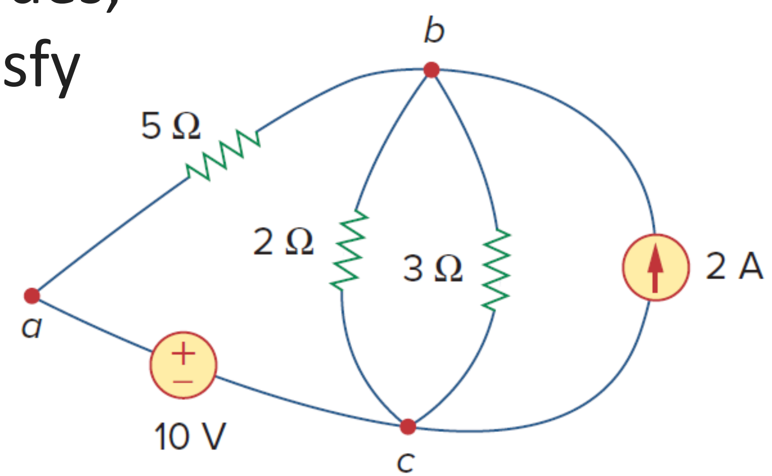


30 V, 100 μmho, 90 mW.

2.2 Nodes, Branches and Loops (1)

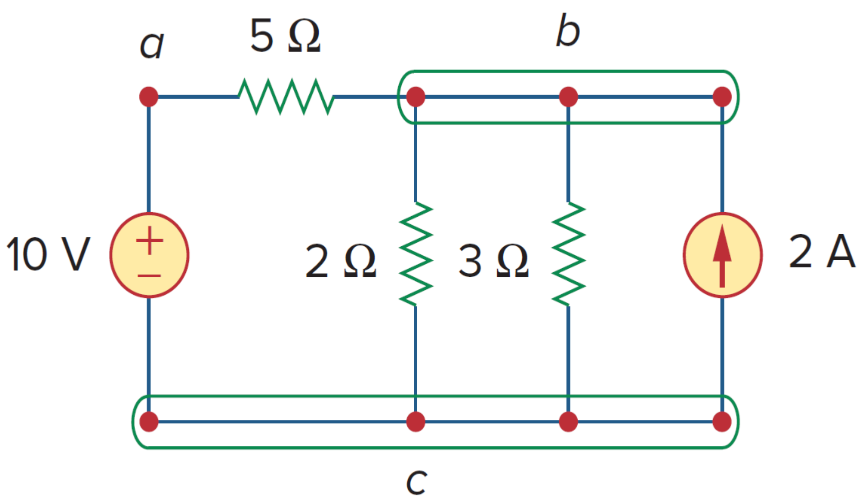
- A branch represents a single element such as a voltage source or a resistor.
- A node is the point of connection between two or more branches.
- A loop is any closed path in a circuit.
- A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology:

$$b = l + n - 1$$

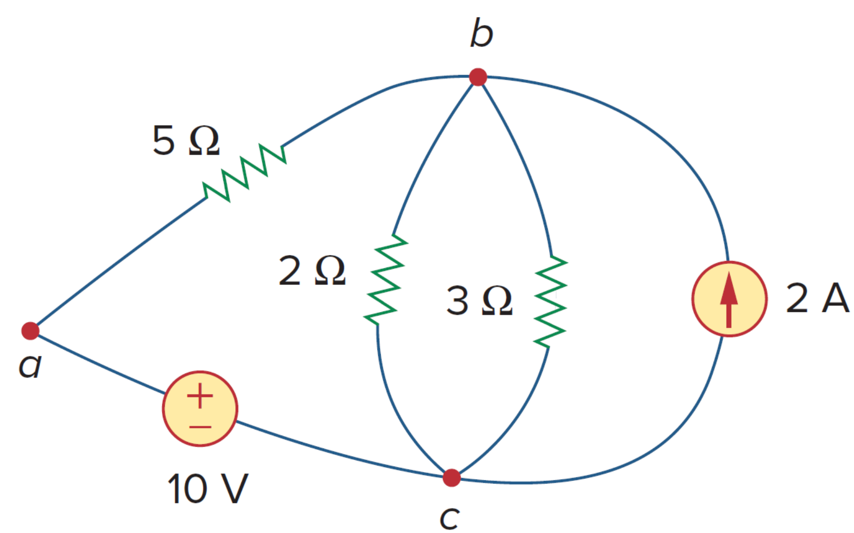


2.2 Nodes, Branches and Loops (2)

Ex.2 How many branches, nodes and loops are there?



Original circuit



Equivalent circuit

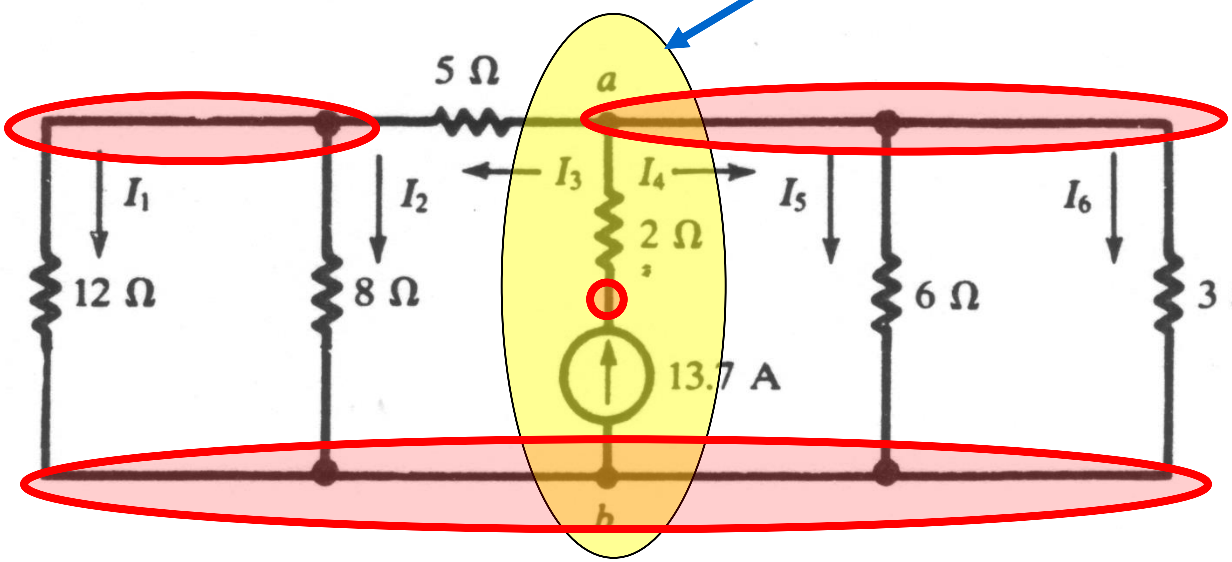
$$b = l + n - 1$$

$$5 = 3 + 3 - 1$$

2.2 Nodes, Branches and Loops (3)

Ex.3 How many branches, nodes and loops are there?

Should we consider it as one branch or two branches?

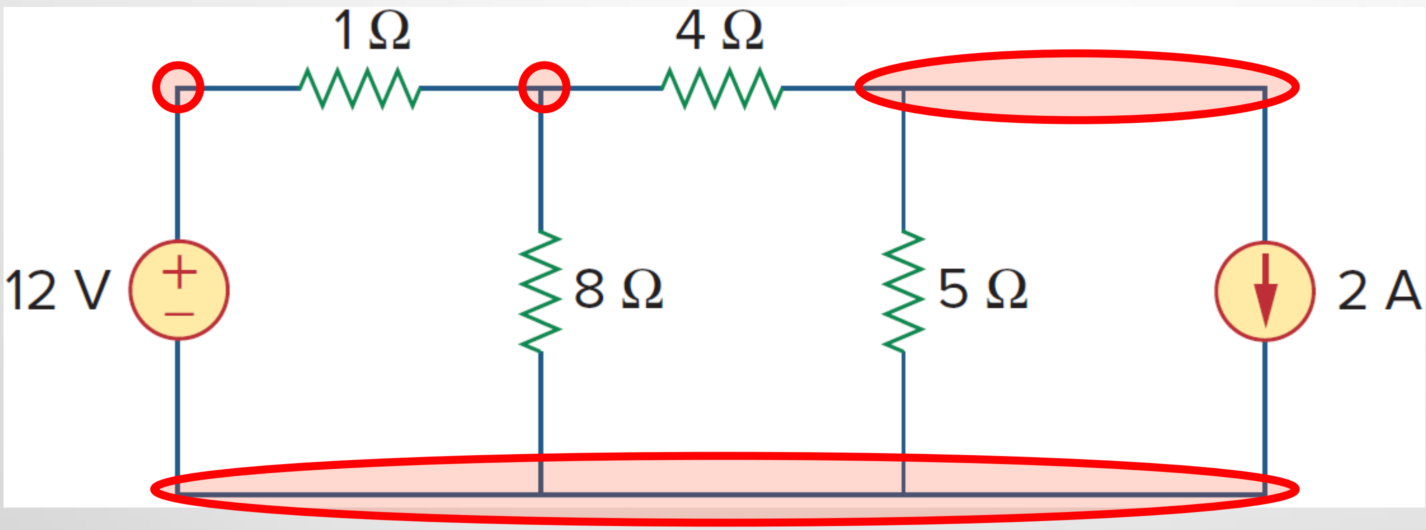


$$b = l + n - 1$$

$$7 = 4 + 4 - 1$$

2.2 Nodes, Branches and Loops (4)

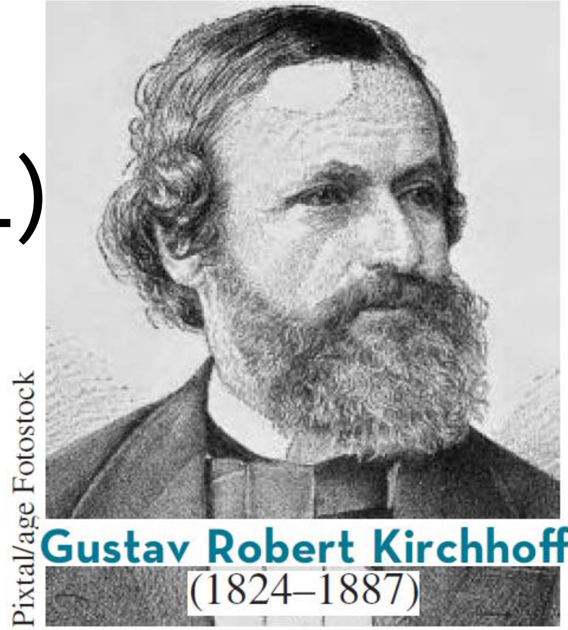
<u>Ex.4</u> How many branches, nodes and loops are there?

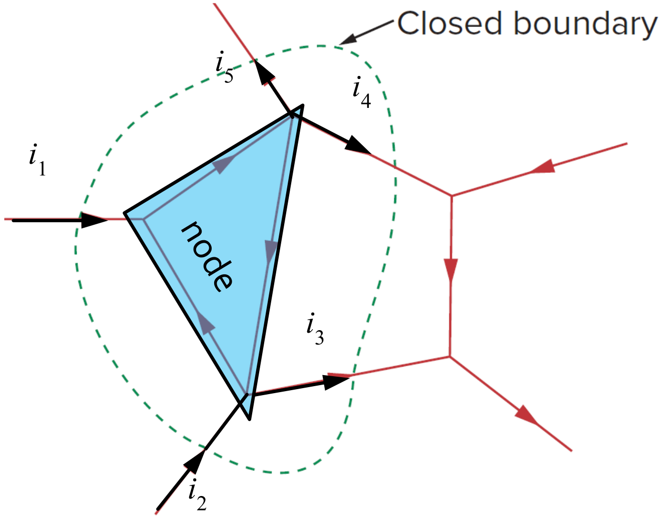


$$b = l + n - 1$$

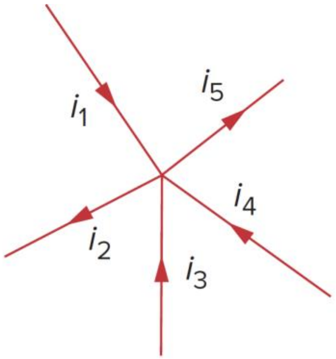
$$6 = 3 + 4 - 1$$

2.3 Kirchhoff's Laws (KCL)





Applying KCL to a closed boundary.



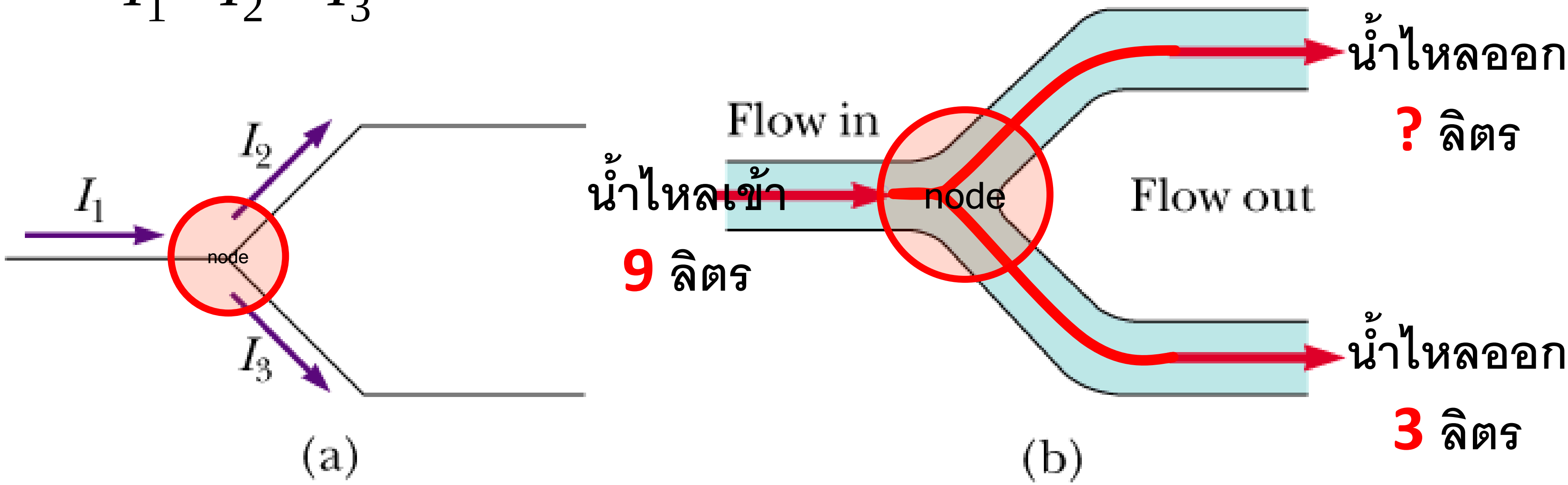
Currents at a node illustrating KCL

- Kirchhoff's current law (KCL): algebraic sum of currents entering a node (or a closed boundary) is zero.

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

2.3 Kirchhoff's Laws (KCL)

$$I_1 = I_2 + I_3$$



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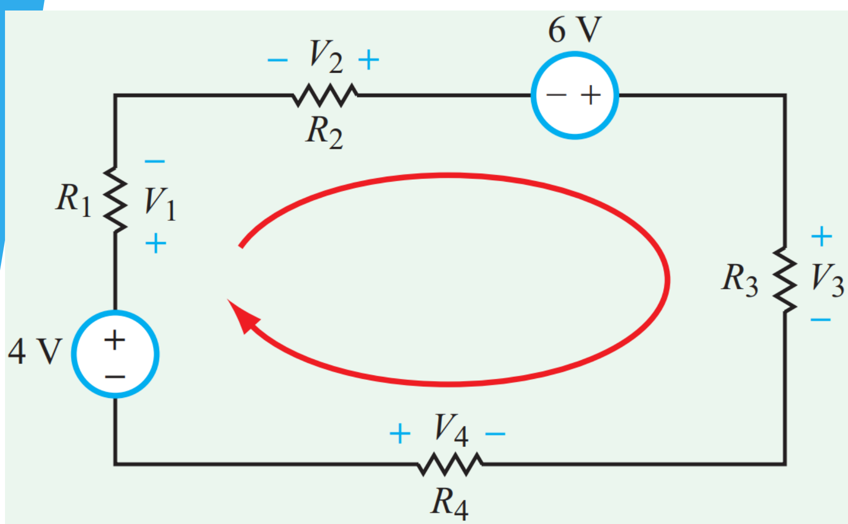
2.3 Kirchhoff's Laws (KVL)



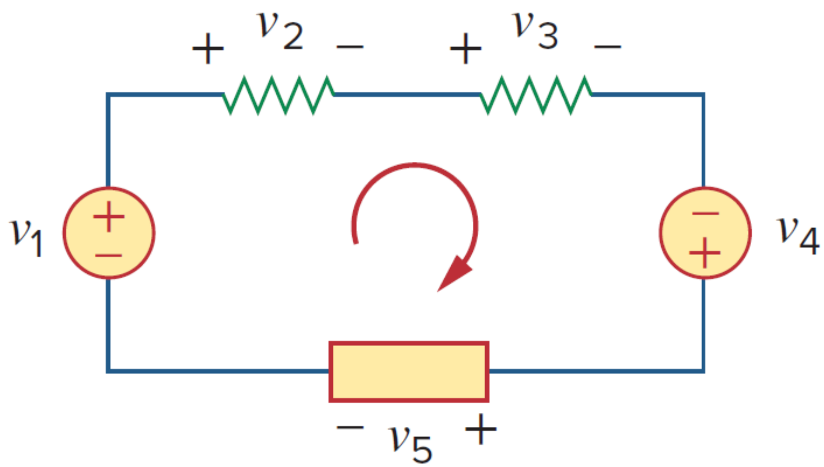
$$V_1 - V_2 - 6 + V_3 - V_4 - 4 = 0$$

- Kirchhoff's voltage law (KVL): algebraic sum of all voltages around a closed path(or loop) is ***ZERO***.

$$\sum_{m=1}^{M} v_m = 0$$

2.3 Kirchhoff's Laws (KVL)

Ex.5 Applying the KVL equation for the circuit of the figure below.

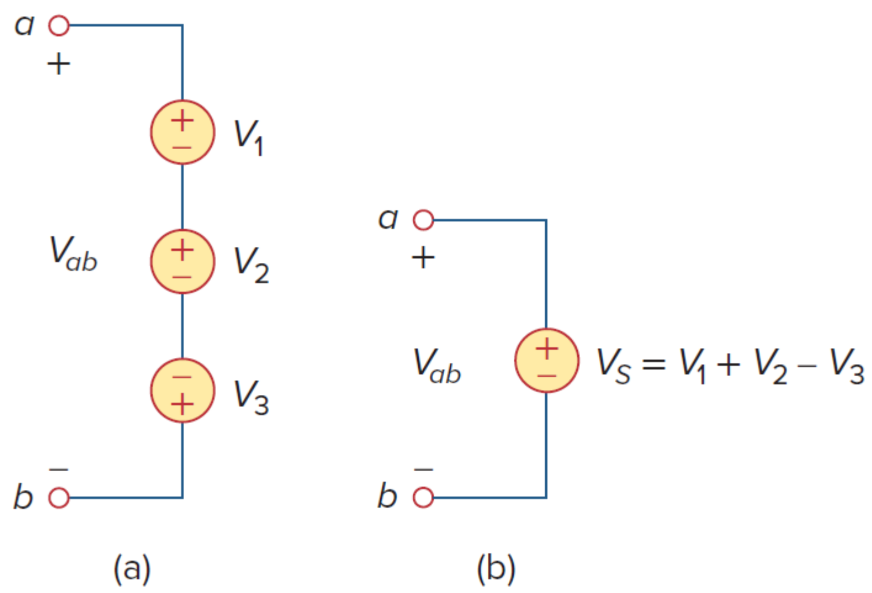


$$-v_1+v_2+v_3-v_4+v_5=0$$

$$v_1+v_4=v_2+v_3+v_5$$

2.3 Kirchhoff's Laws (KVL)

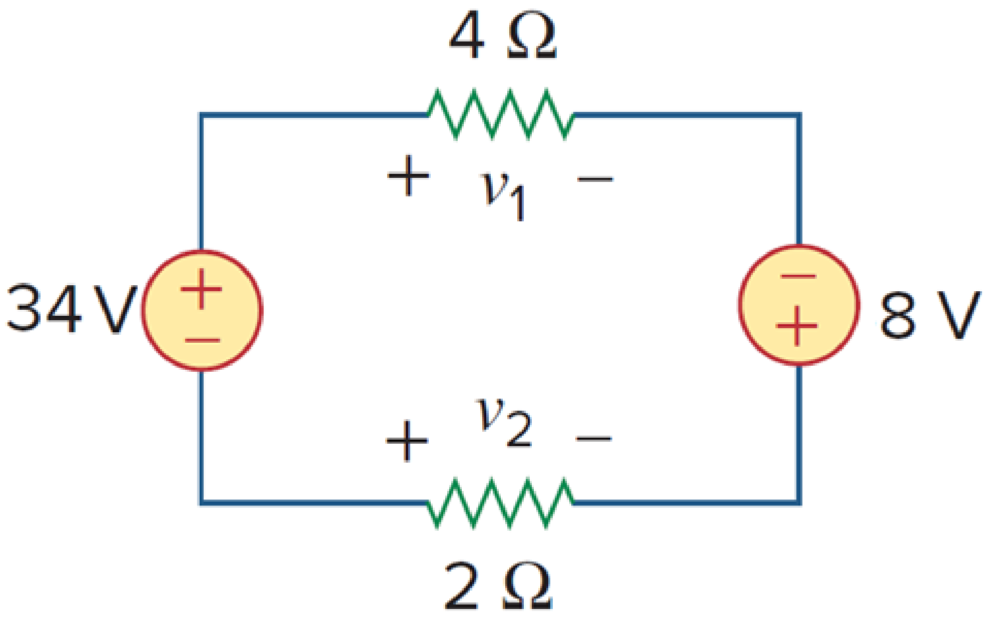
Ex.6 Applying the KVL equation for the circuit of the figure below.



$$v_a - v_b = v_{ab} = V_1 + V_2 - V_3$$

2.3 Kirchhoff's Laws (KVL)

Ex.7 Find v_1 and v_2 in the circuit



v_1-8-v_2-34= 0

v_1-v_2= 42

v_1= 4i, v_2= -2i

i=7A, v_1= 28V, v_2= -14V

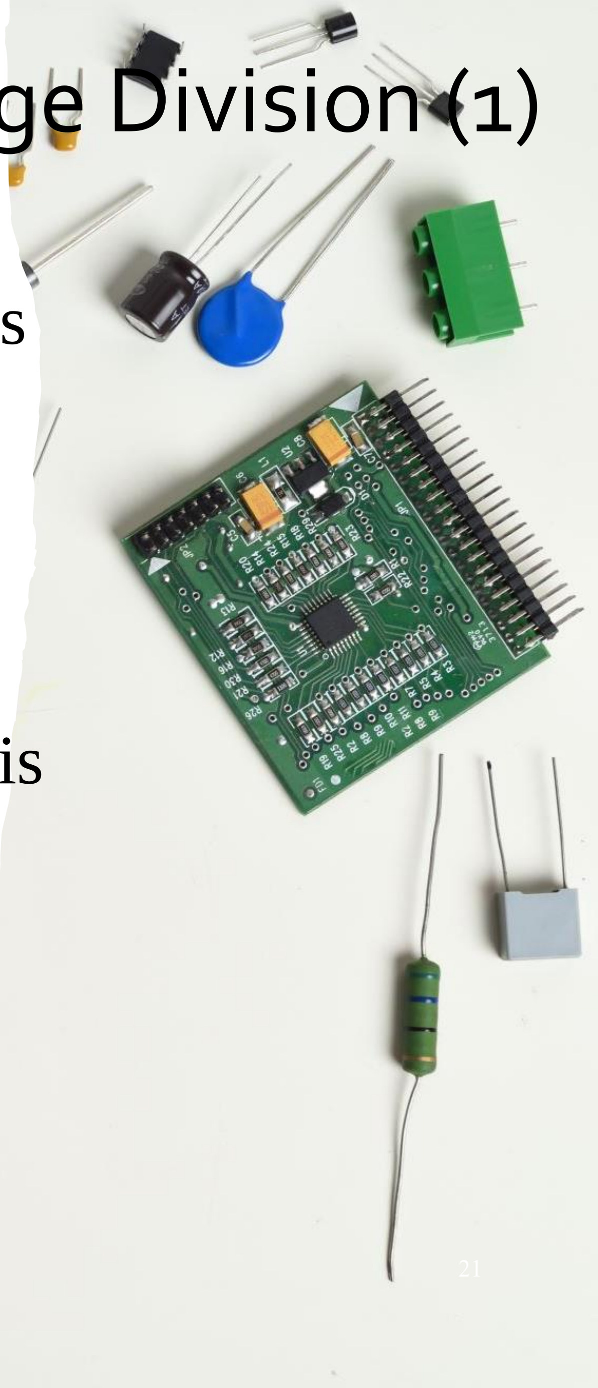
2.4 Series Resistors and Voltage Division (1)

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

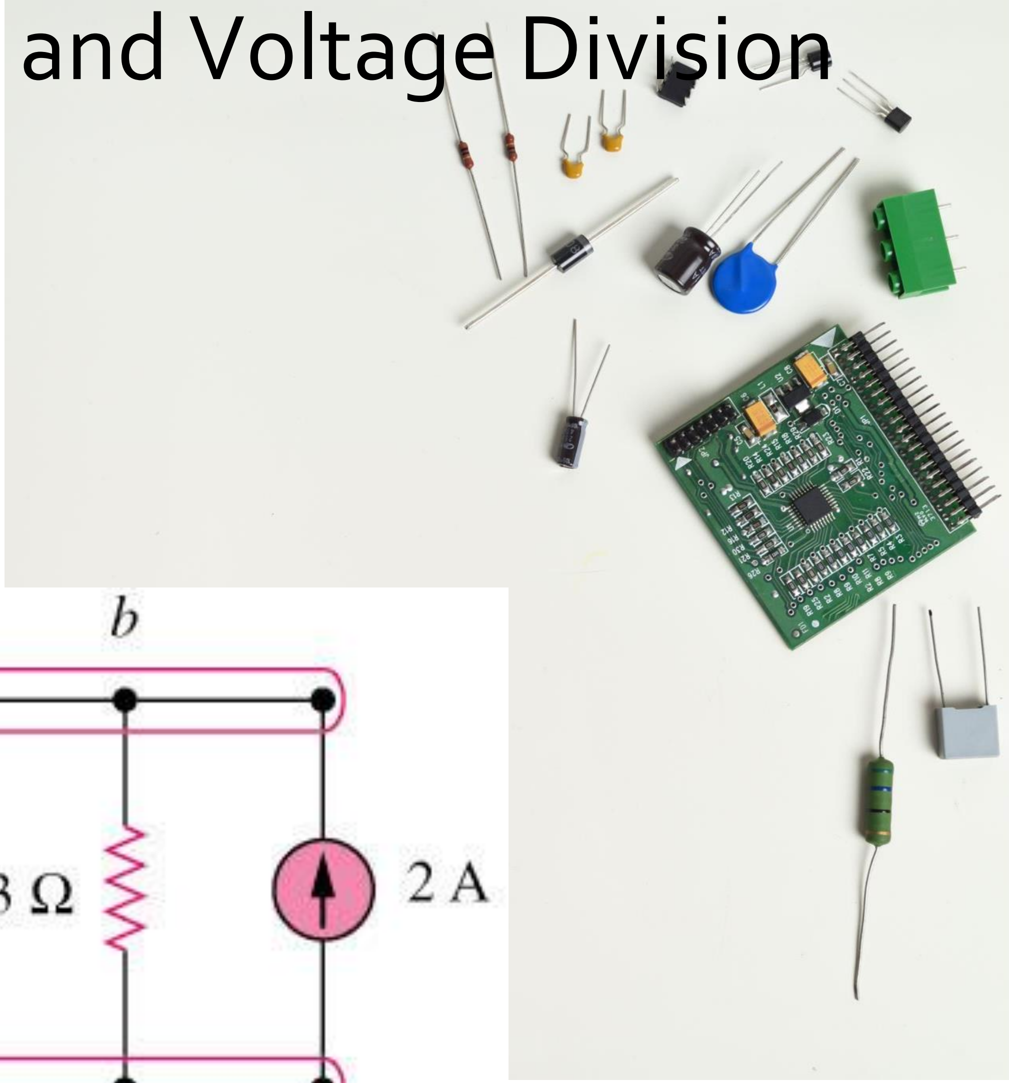
- The equivalent resistance (R_{eq}) of any number of resistors connected in a series is the sum of the individual resistances.

- The voltage divider can be expressed as

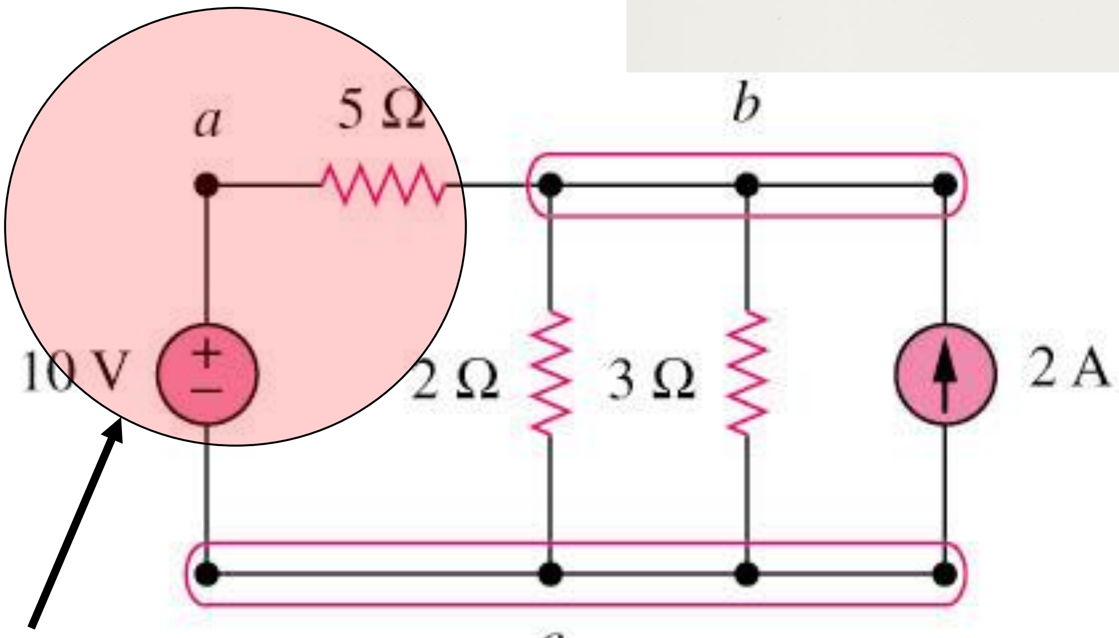
$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$



2.4 Series Resistors and Voltage Division (2)



Ex.8



10V and 5Ω are in series

2.5 Parallel Resistors and Current Division (1)

- Parallel: Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them.
- The equivalent resistance of a circuit with N resistors in parallel is :

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

- The total current *i* is shared by the resistors in inverse proportion to their resistances. The current divider can be expressed as

$$i_n = \frac{v}{R_n} = \frac{iR_{eq}}{R_n}$$

2.5 Parallel Resistors and Current Division (2)

- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \Longrightarrow R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

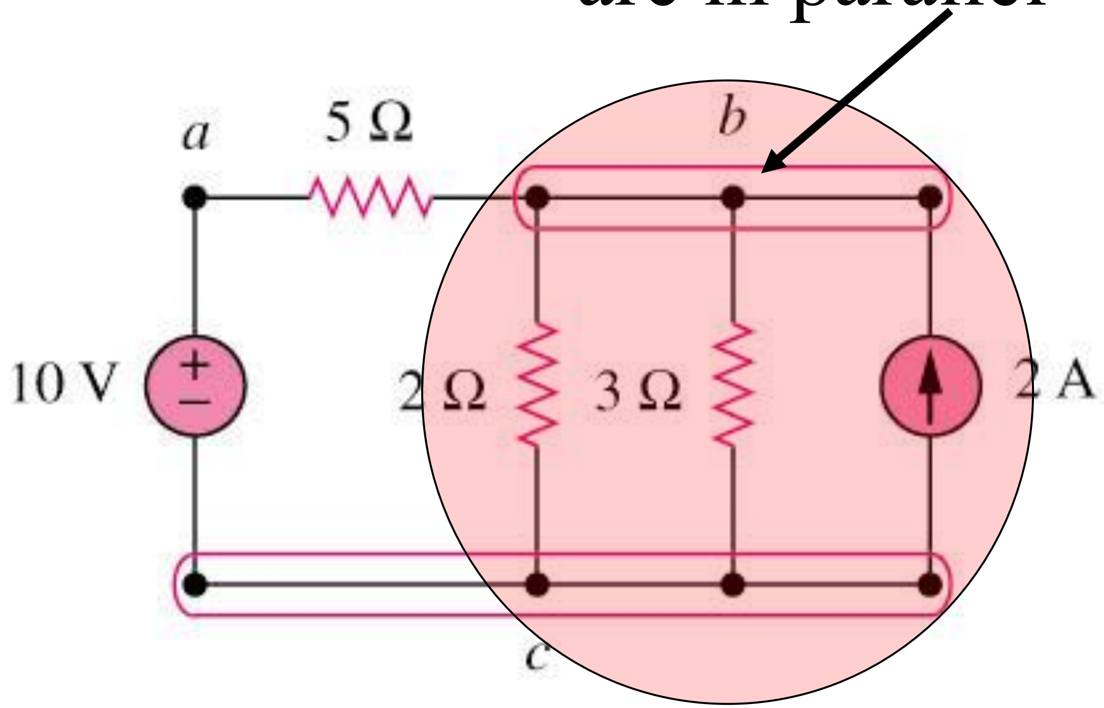
$$\Longrightarrow R_{eq} = \frac{R_1 R_2 R_3}{R_2 R_3 + R_1 R_3 + R_1 R_2}$$

- $\frac{1}{R_{eq}} = \underbrace{\frac{1}{R} + \frac{1}{R} + \cdots + \frac{1}{R}}_{N} \Longrightarrow R_{eq} = \frac{R}{N}$

2.5 Parallel Resistors and Current Division (3)

Ex.9

2 Ω, 3 Ω and 2A are in parallel



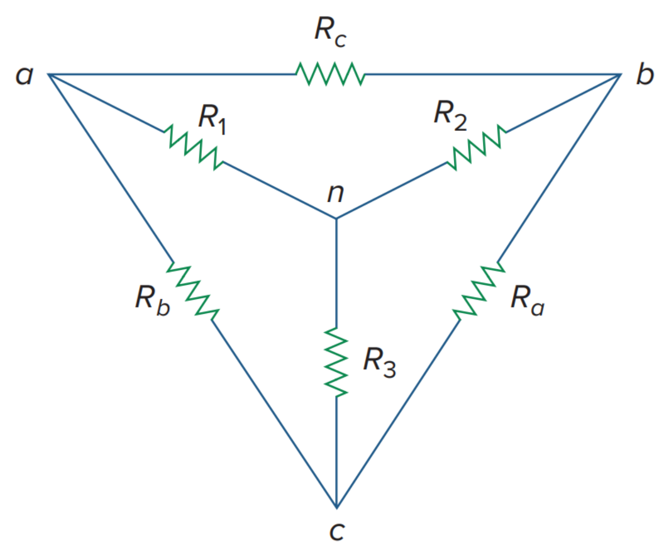
2.6 Wye-Delta Transformations

$$\Delta \longrightarrow Y \qquad\qquad Y \longrightarrow \Delta$$

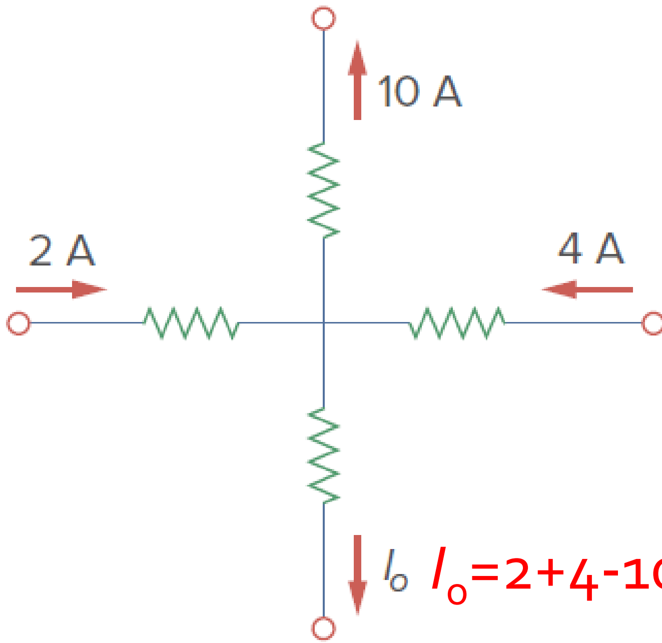
$$R_1 = \frac{R_b R_c}{(R_a + R_b + R_c)} \iff R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

$$R_2 = \frac{R_c R_a}{(R_a + R_b + R_c)} \iff R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

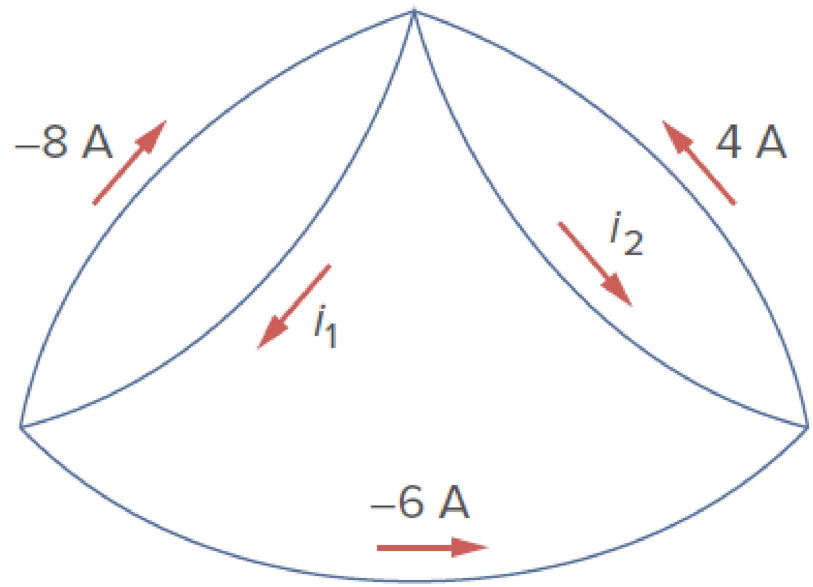
$$R_3 = \frac{R_a R_b}{(R_a + R_b + R_c)} \iff R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

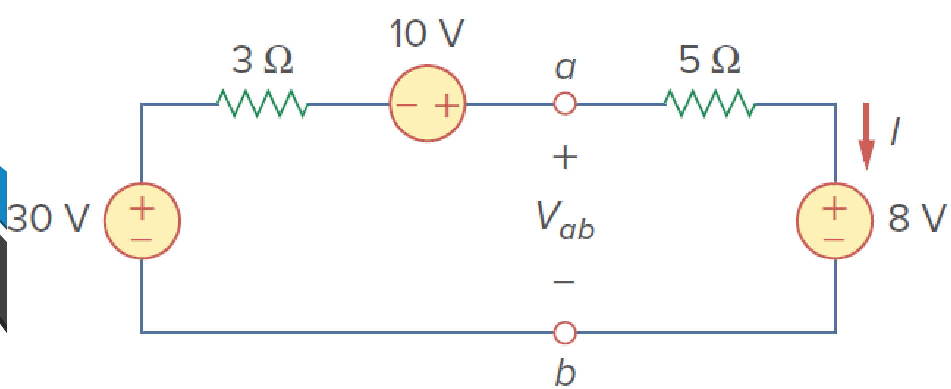


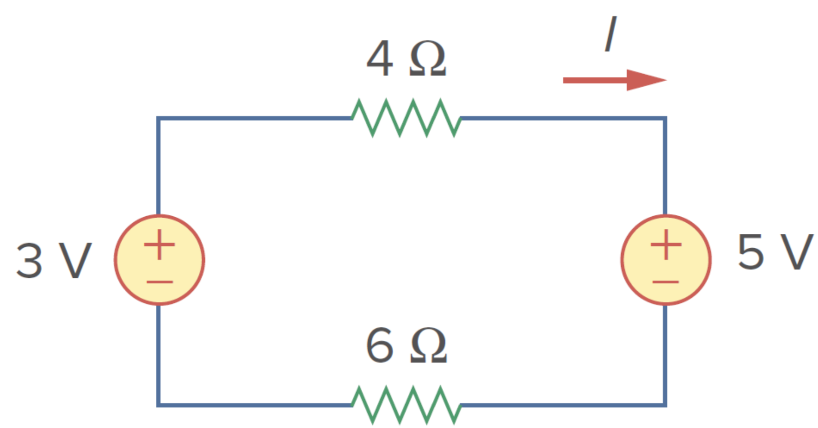
2.7 Problems(1)



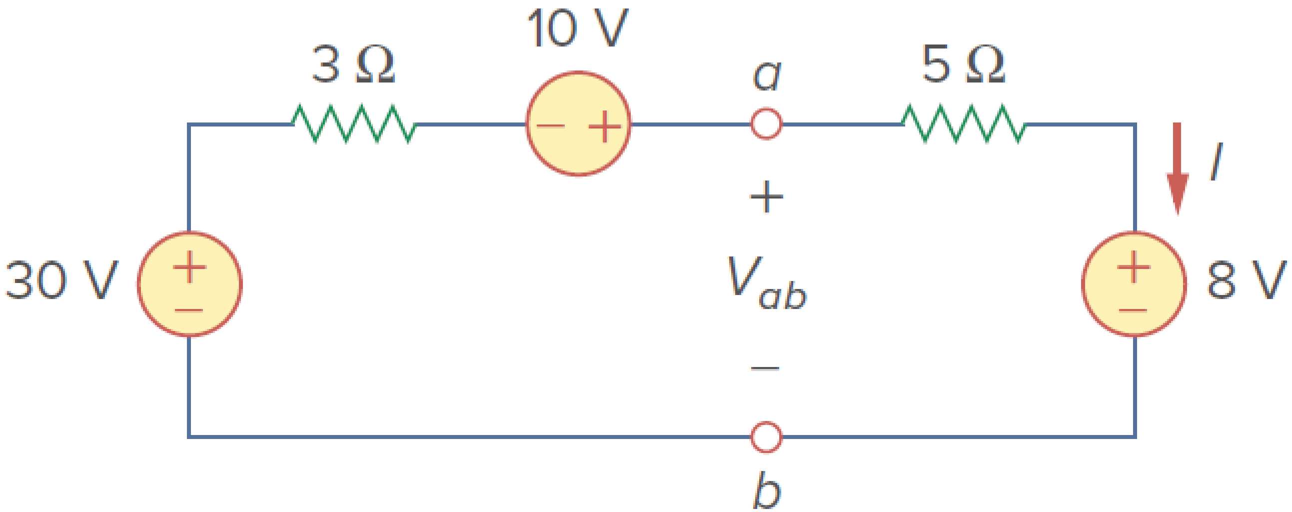
I_o=2+4-10=-6 A







2.7 Problems(2)



I=v/R=(-8+30+10)/(3+5)=4 A

V_{ab}=30-12+10=28 V ,หรือ V_{ab}=20+8=28V