Fundamentals of Electric Circuits

Chapter 2
Basic Laws

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Basic Laws - Chapter 2

2.1 Ohm's Law.

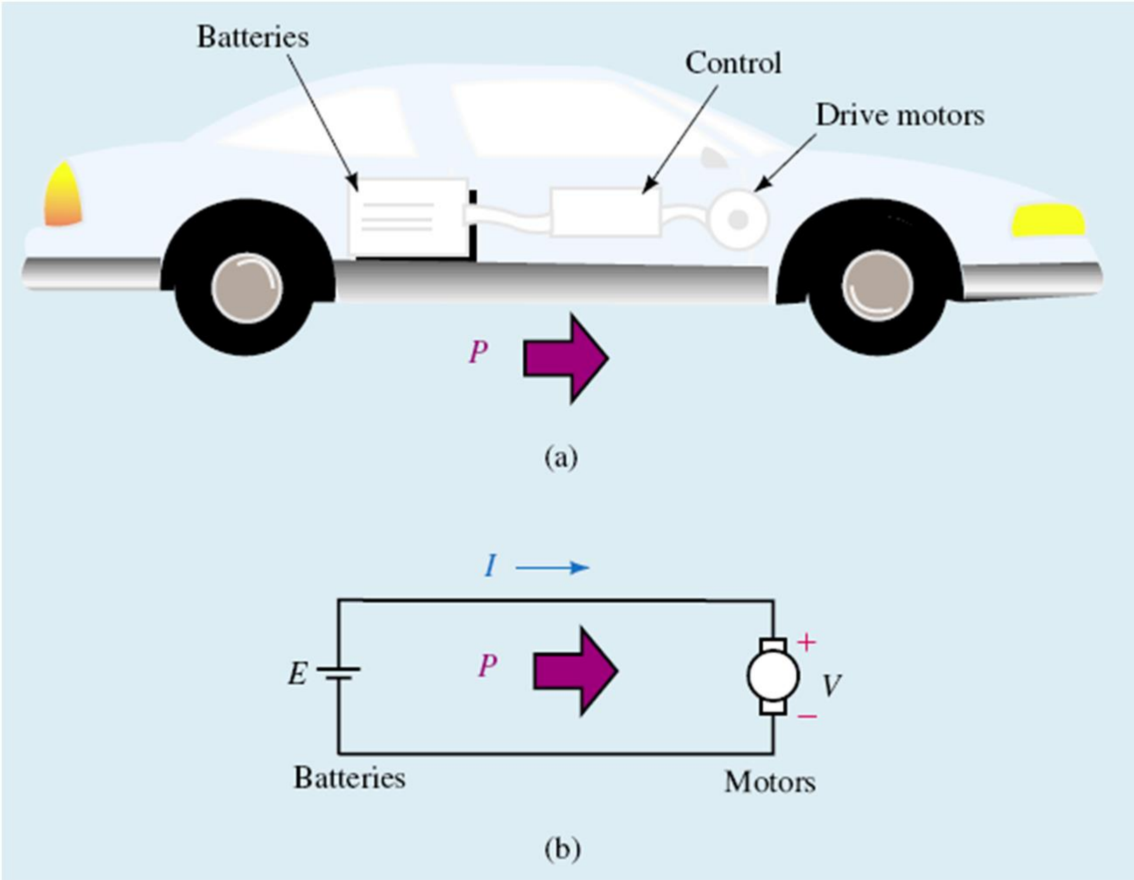
2.2 Nodes, Branches, and Loops.

2.3 Kirchhoff's Laws.

2.4 Series Resistors and Voltage Division.

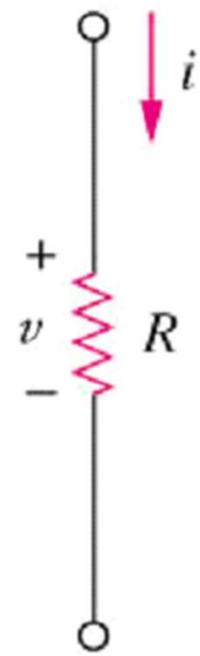
2.5 Parallel Resistors and Current Division.

2.6 Wye-Delta Transformations.



2.1 Ohms Law (1)

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

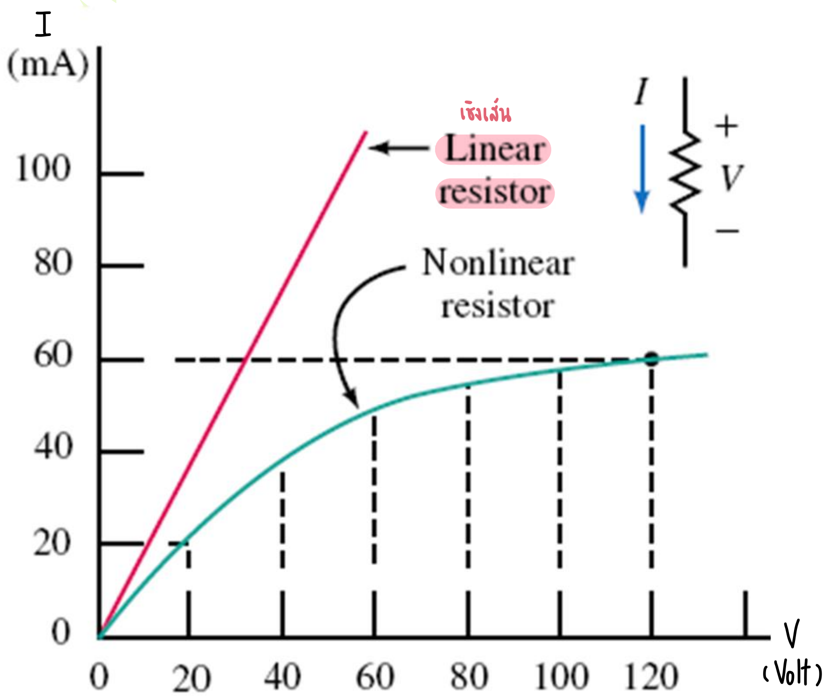


- Mathematical expression for Ohm's Law is as follows:

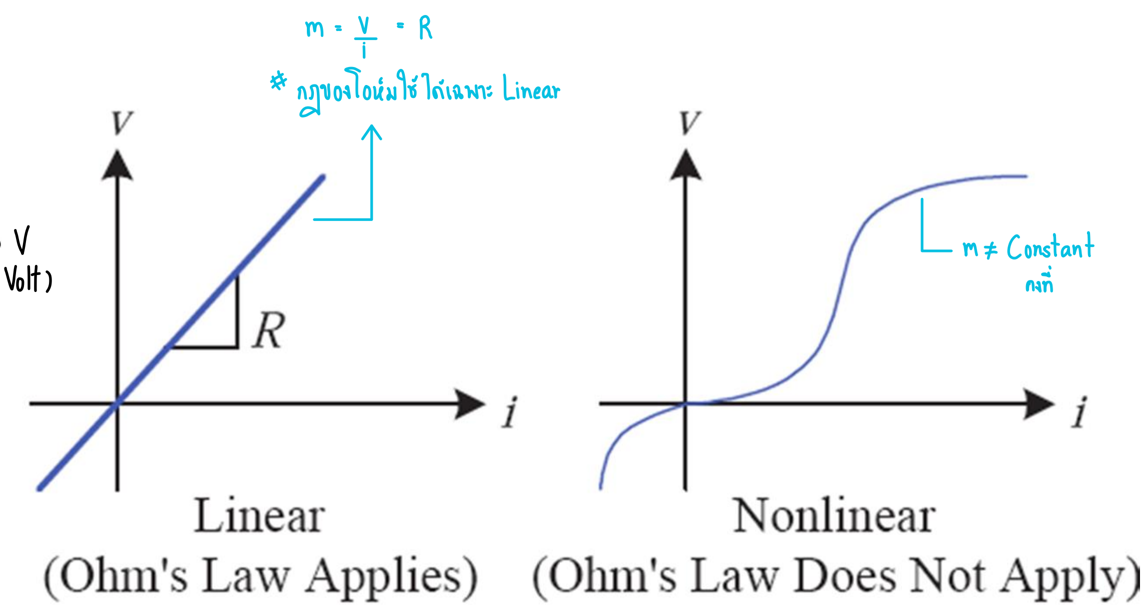
$$v = iR$$

- Two extreme possible values of R: **0 (zero) and ∞ (infinite)** are related with two basic circuit concepts: short circuit and open circuit.

Linear and nonlinear resistance

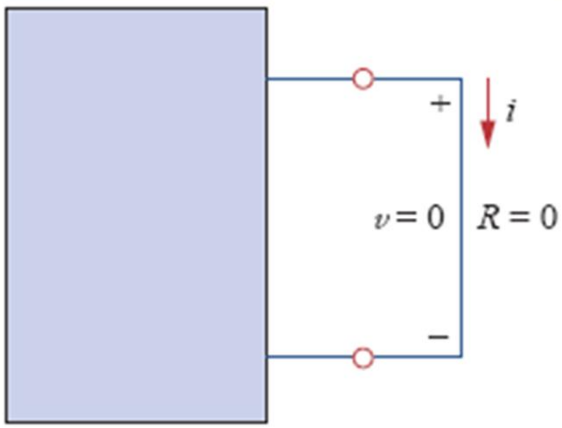


Linear and nonlinear resistance characteristics.

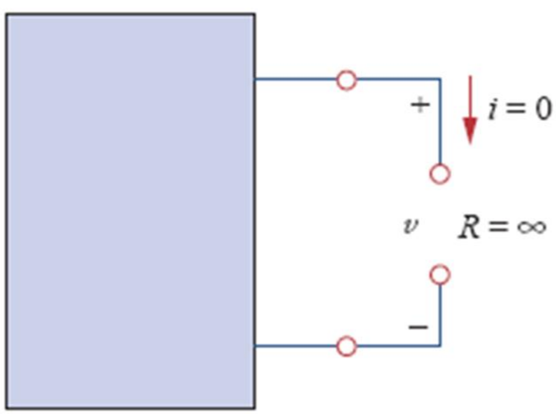


Short and open circuit

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

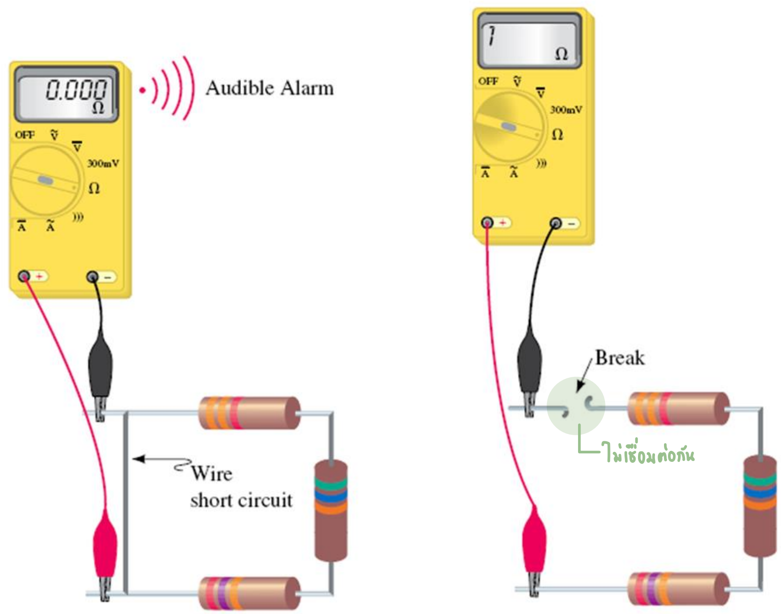


An **open circuit** is a circuit element with resistance approaching infinity.



(b)

* Low Voltage < 1 KV.



(a) Short circuit

(b) Open circuit

2.1 Ohms Law (2)

- *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.

ส่วนกลับ

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

V = IR

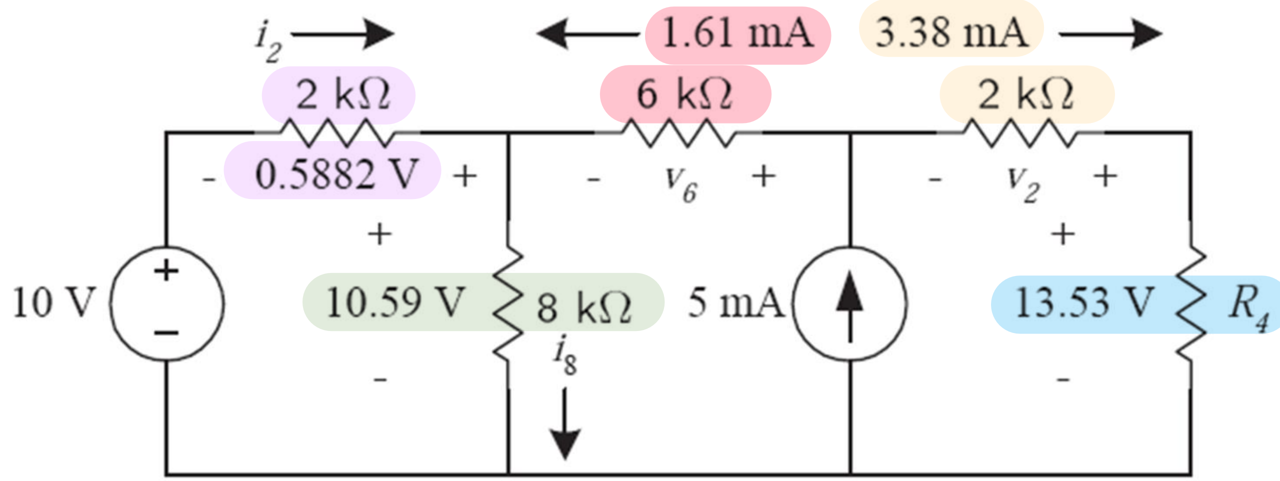
- The power dissipated by a resistor:

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

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

Example

$\boxed{V = IR}$



$$i_2 = 0.5882\ \text{V} / 2\ \text{k}\Omega = 0.000241\ \text{A} = 0.294\ \text{mA} = 294.1\ \mu\text{A}$$

$$v_6 = 1.61 \times 10^{-3} \cdot 6 \times 10^{3} = 9.66\ \text{V}$$

$$R_4 = 13.53\ \text{V} / 3.38\ \text{mA} = 4.063\ \text{k}\Omega$$

$$v_2 = 3.38 \times 10^{-3} \cdot 2 \times 10^{3} = 6.76\ \text{V}$$

$$i_8 = 10.59\ \text{V} / 8\ \text{k}\Omega = 1.324\ \text{mA}$$

Conductance and resistivites

TABLE 2.1

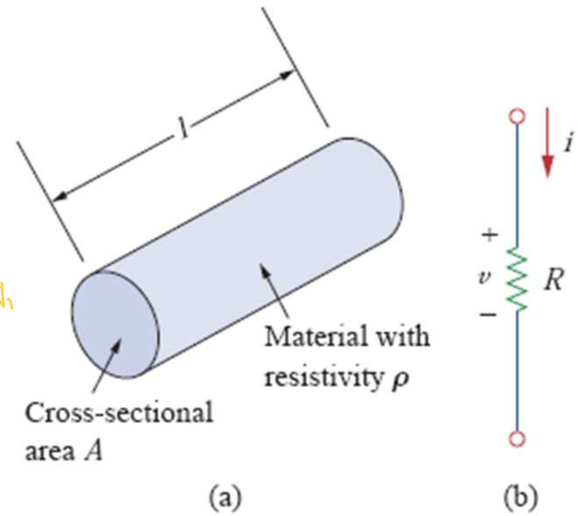
Resistivities of common materials.

Material	Resistivity ($\Omega \cdot m$) ต้านทานไฟฟ้า	Usage
Silver	1.64×10^{-8} นำไฟฟ้ามาก	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 * ฉนวนไฟฟ้า	10^{10}	Insulator
Mica	5×10^{11}	Insulator
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator

ตัวนำไฟฟ้า (Conductor)

กึ่งตัวนำไฟฟ้า (Semiconductor)

ไม่นำไฟฟ้า (Insulator)



$$R = \rho \frac{L}{A} \quad \text{or} \quad R = \frac{L}{\sigma A}.$$

R: Ω

ρ: Resistvity
ค่าความต้านทานต่อหน่วยพื้นที่

L: m

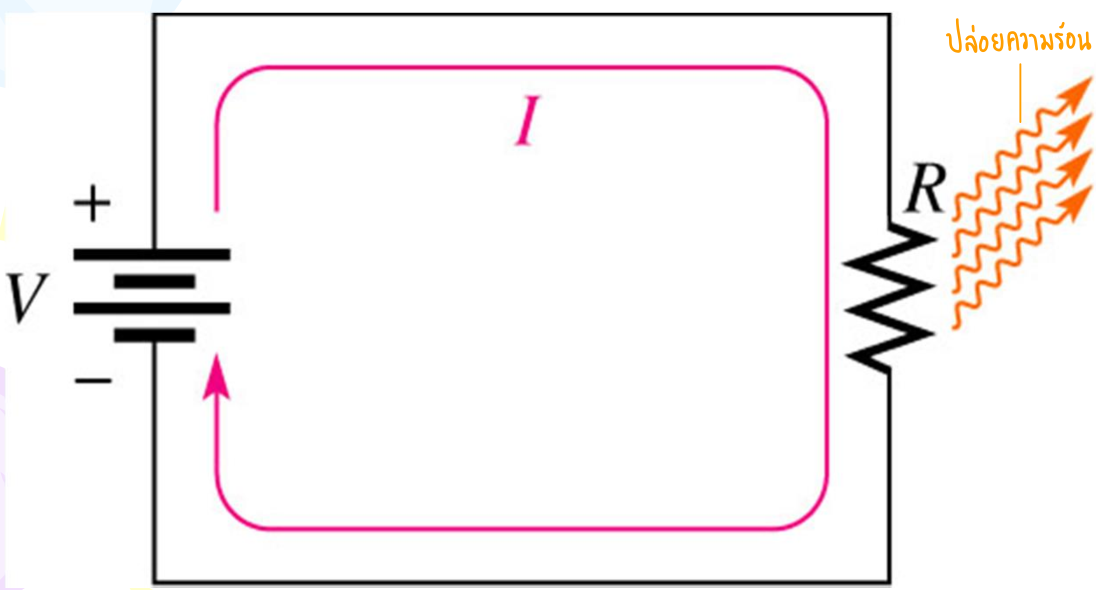
A: m²

* ความยาวสั้น
พื้นที่ใหญ่ : นำไฟฟ้าดี 👍

Heat produced by Current

- When there is current through resistance, the collisions of the electrons produce heat, as a result of the conversion of electrical energy.

พลังงาน $\xrightarrow{\text{เปลี่ยน}}$ ความร้อน

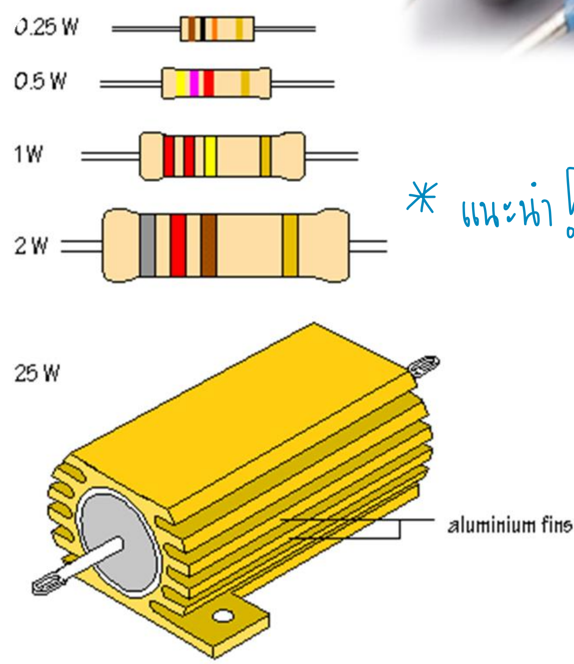


Heat produced by current through resistance is a result of energy conversion.

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

Resistor Power Rating

Resistor power rating is not related to ohmic value (resistance) but rather is determined by the physical composition, size and shape of the resistor.

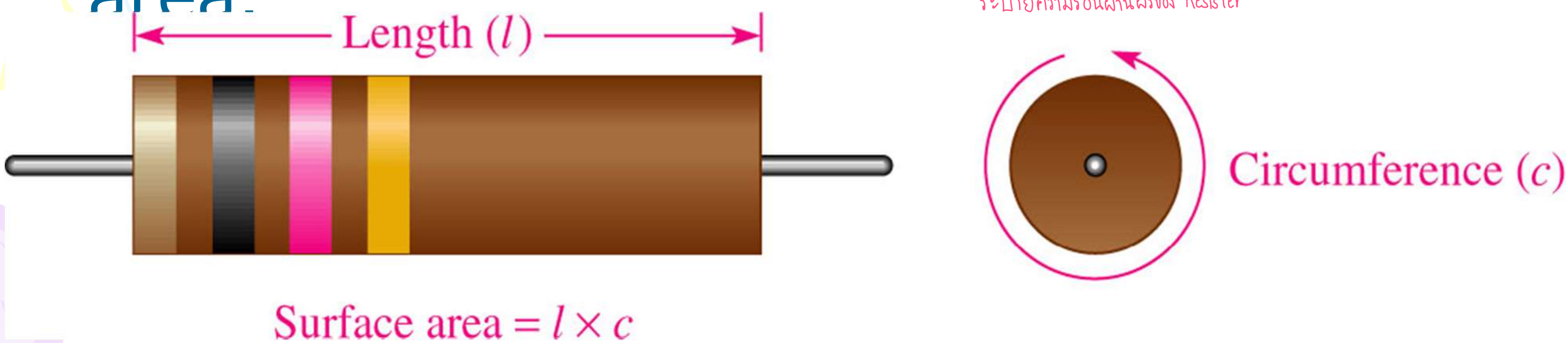


* แนะนำ ! : $W_{\text{คำนวณ}} \times 2 = W_{\text{ที่ควรใช้}}$

Resistor Power Rating

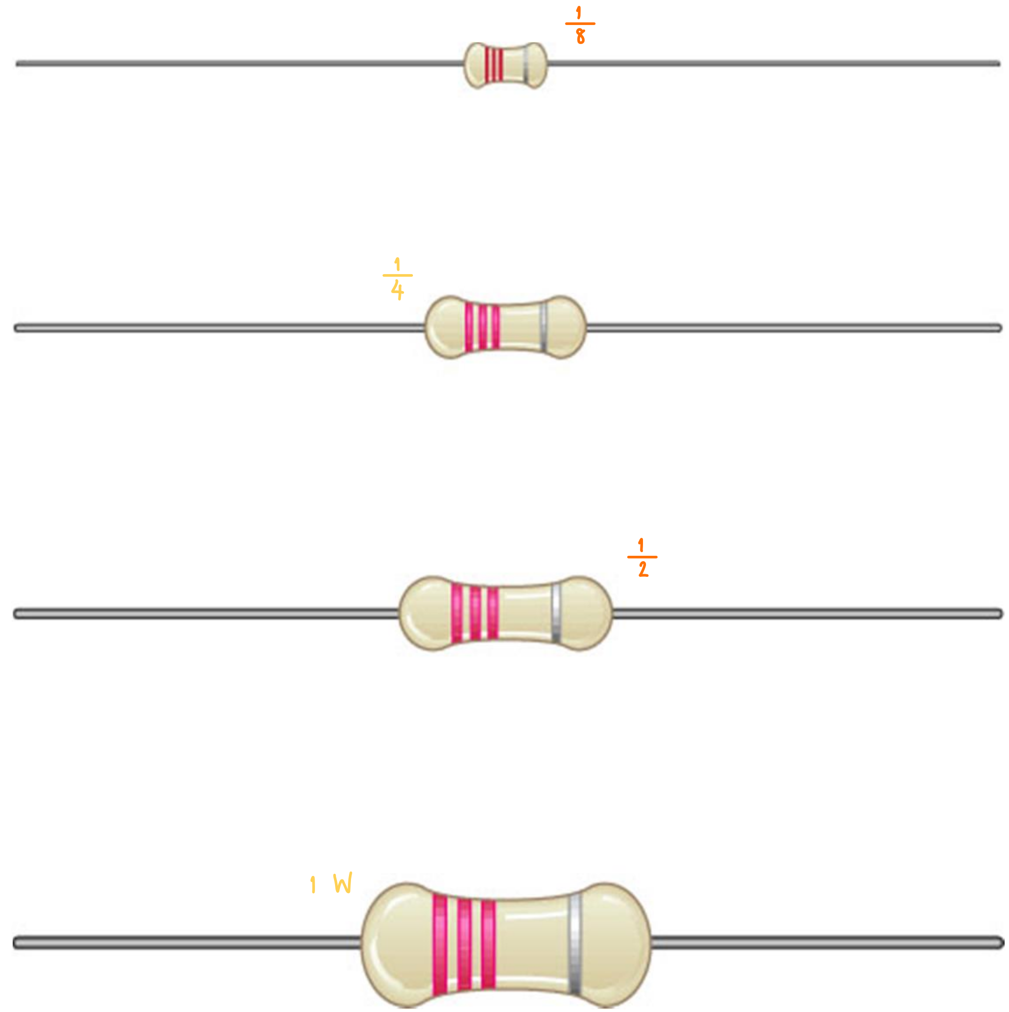
- Power rating of a resistor is the maximum amount of power that a resistor can dissipate without being damaged by excessive heat buildup.
- Power rating is directly related to surface area.

* ระบายความร้อนผ่านผิวของ Resister



Metal-film Resistors

Metal-film resistors have standard power ratings of 1/8 W, 1/4 W, 1/2 W, and 1 W.

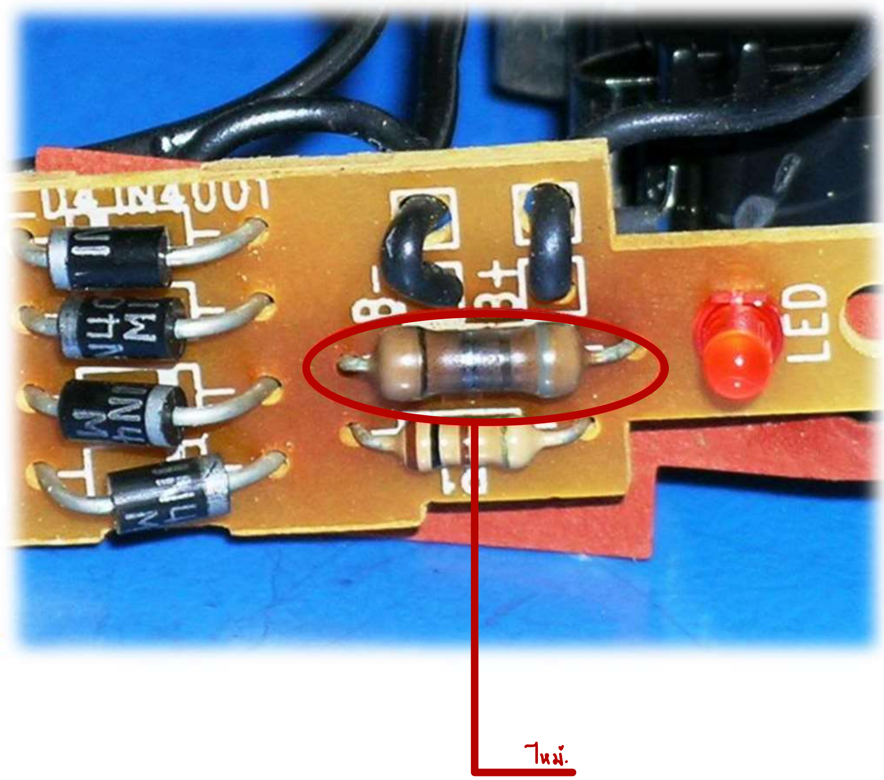


Selecting the Proper Power Rating

- A resistor used in a circuit must have a power rating in excess of what it will have to handle.
- Ideally, a rating that is approximately twice the actual power should be used when possible.

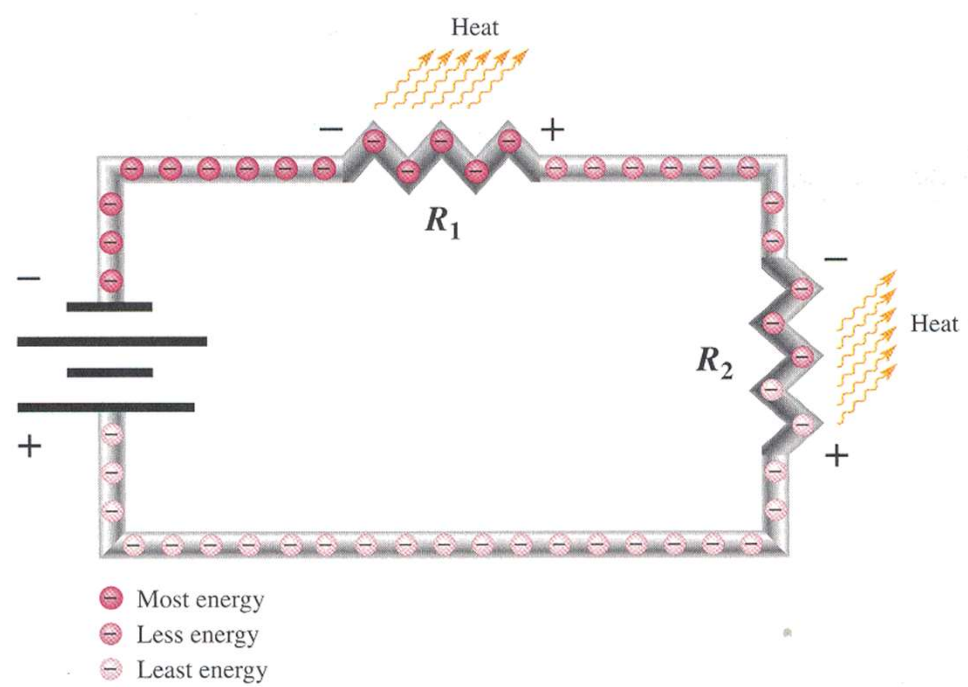
Resistor Failures

- When excessive power is applied to a resistor, the resistor will overheat.
- The resistor will burn open, or its resistance value will be greatly altered.
- Overheated resistors may be charred, or the surface color may change.
- Resistors suspected of being damaged should be removed from the circuit and checked with an ohmmeter.



Energy Conversion and Voltage Drop in Resistance

- As electrons flow through resistors, some of their energy is given up as heat.
- The same number of electrons entering a resistor will exit it, only their energy will be less, so the voltage exiting a resistor is less than the voltage entering the resistor.



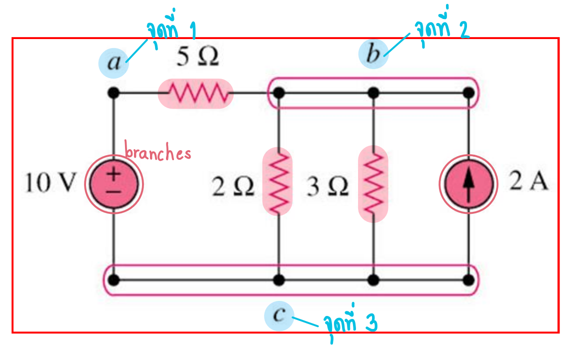
2.2 Nodes, Branches and Loops (1)

- A branch represents a single element such as a voltage source or a resistor. อุปกรณ์ไฟฟ้าที่อยู่ในวงจร : นับว่ากี่ตัว
- A node is the point of connection between two or more branches. ตัวเชื่อมจุด
- A loop is any closed path in a circuit. ส่วน(จุด) ที่ทำให้วงจรปิด
- Network = interconnection of elements or devices
- Circuit = a network with closed paths
- 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)

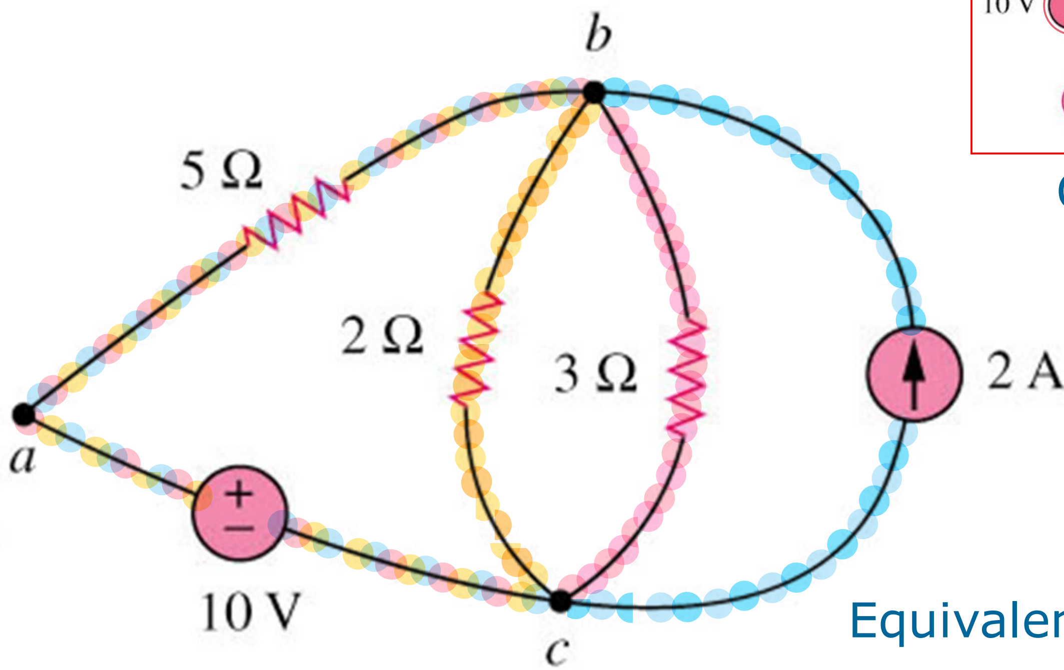
Example 1



Original circuit

$\boxed{b = l + n - 1}$

$\rightarrow 5 = 3 + 3 - 1$



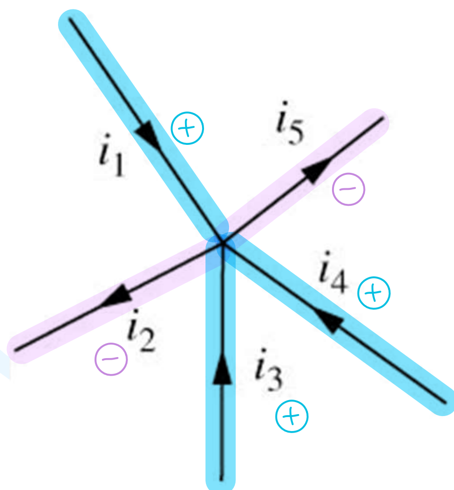
Equivalent circuit

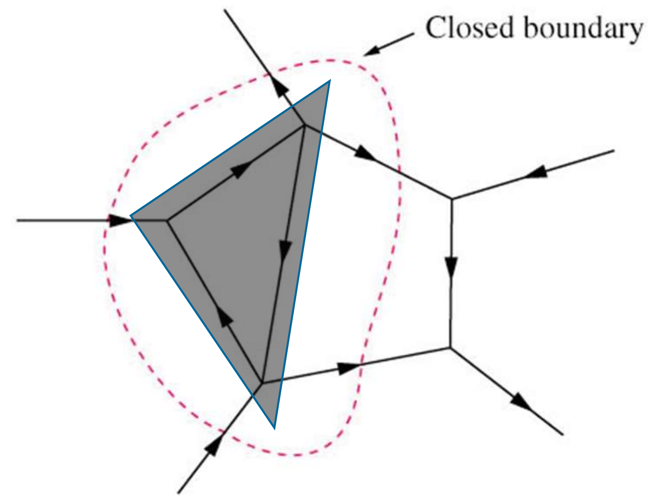
5 ตัว 3 ตัว 3 ตัว

How many branches, nodes and loops are there?

2.3 Kirchhoff's Laws (1)

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





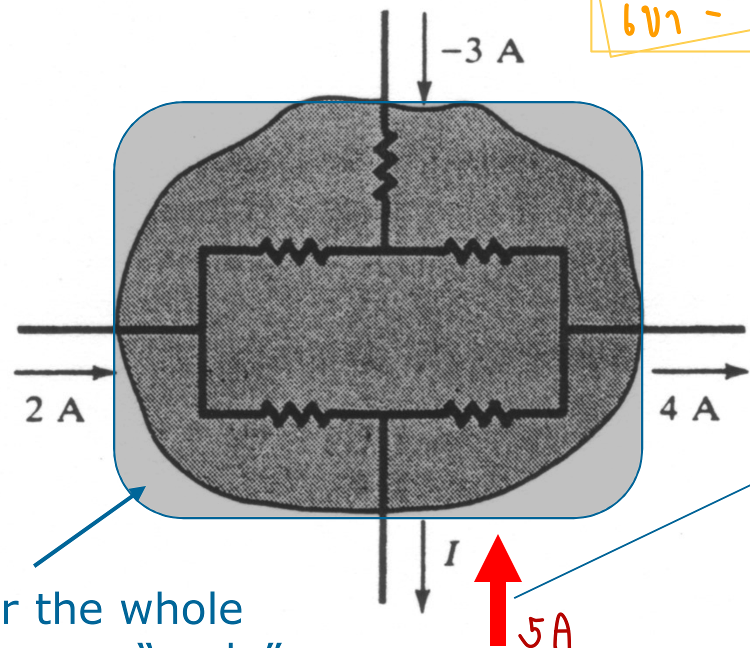
Mathematically, $$\sum_{n=1}^{N} i_n = 0$$

2.3 Kirchhoff's Laws (2)

Example 4

- Determine the current I for the circuit shown in the figure below.

ออก +
เข้า -



$I + 4-(-3)-2 = 0$

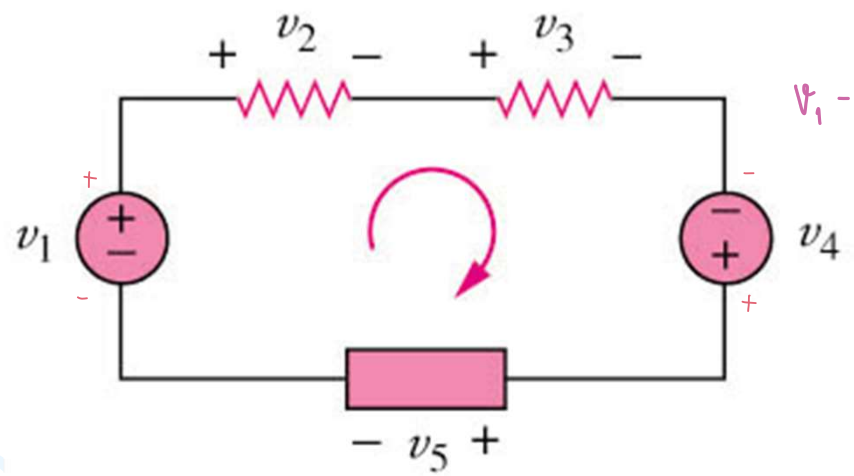
$\Rightarrow I = -5A$

We can consider the whole enclosed area as one "node".

This indicates that the actual current for I is flowing in the opposite direction.

2.3 Kirchhoff's Laws (3)

- Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

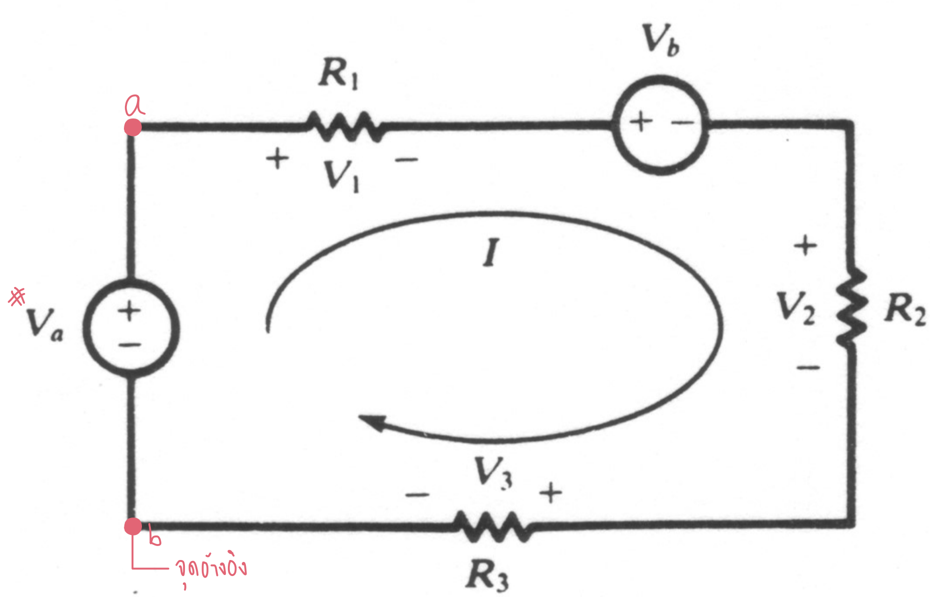


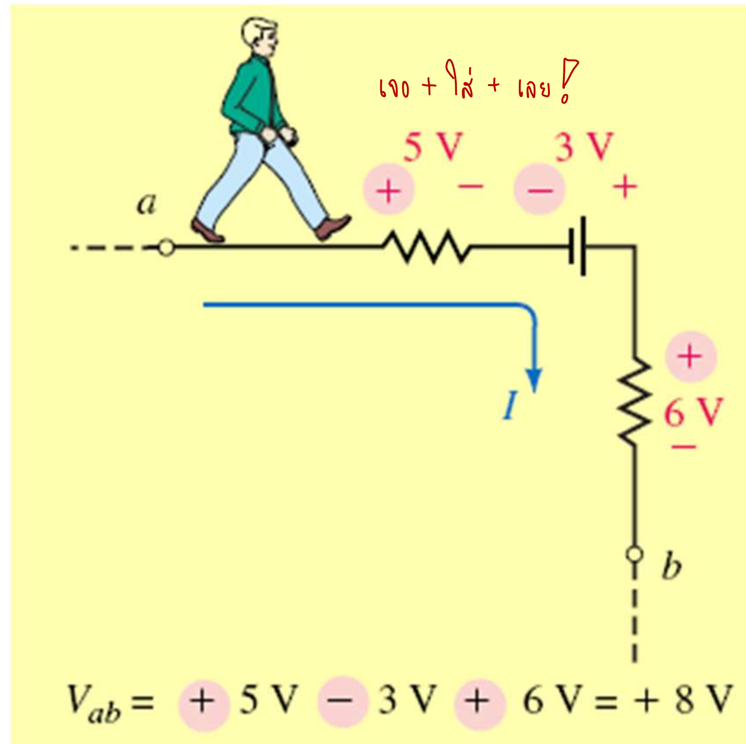
$v_1 - v_2 - v_3 + v_4 - v_5 = 0$

Mathematically, $$\sum_{m=1}^{M} v_n = 0$$

2.3 Kirchhoff's Laws (4)

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





$$v_a - v_1 - v_b - v_2 - v_3 = 0$$

$$v_1 = IR_1 \quad v_2 = IR_2 \quad v_3 = IR_3$$

$$\Rightarrow v_a - v_b = I(R_1 + R_2 + R_3)$$

$$I = \frac{v_a - v_b}{R_1 + R_2 + R_3} \longrightarrow I = \frac{\Delta V}{\Delta R}$$

2.4 Series Resistors and Voltage Division (1)

อนุกรม

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

สมบูรณ์

- The equivalent resistance of any number of resistors connected in a series is the sum of the individual resistances.

$$* \quad R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

- The voltage divider can be expressed as

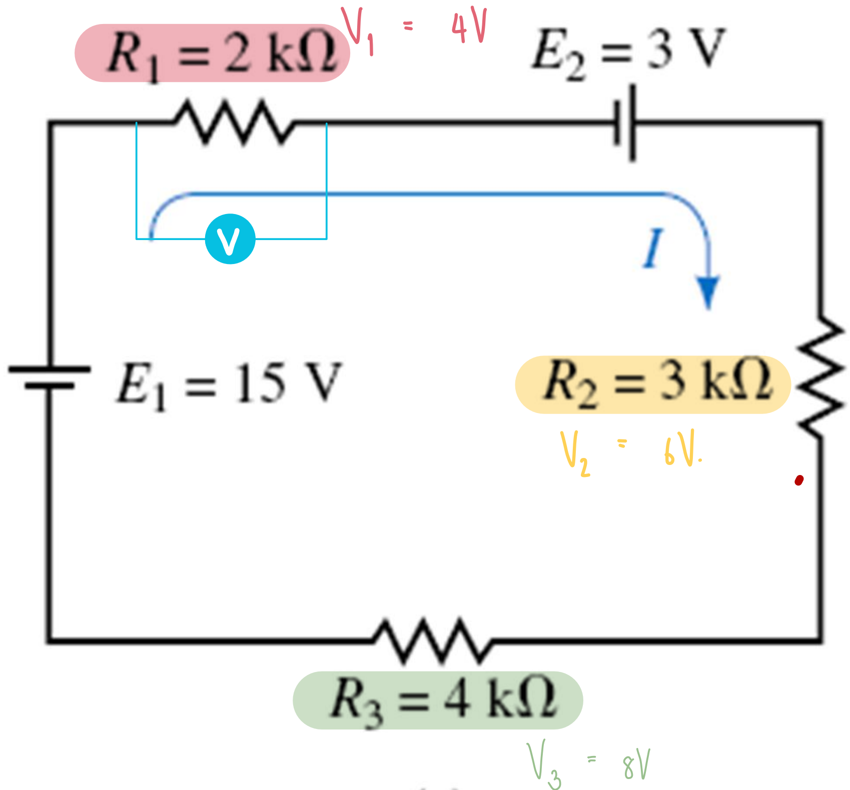
$$* \quad v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

Vรวม

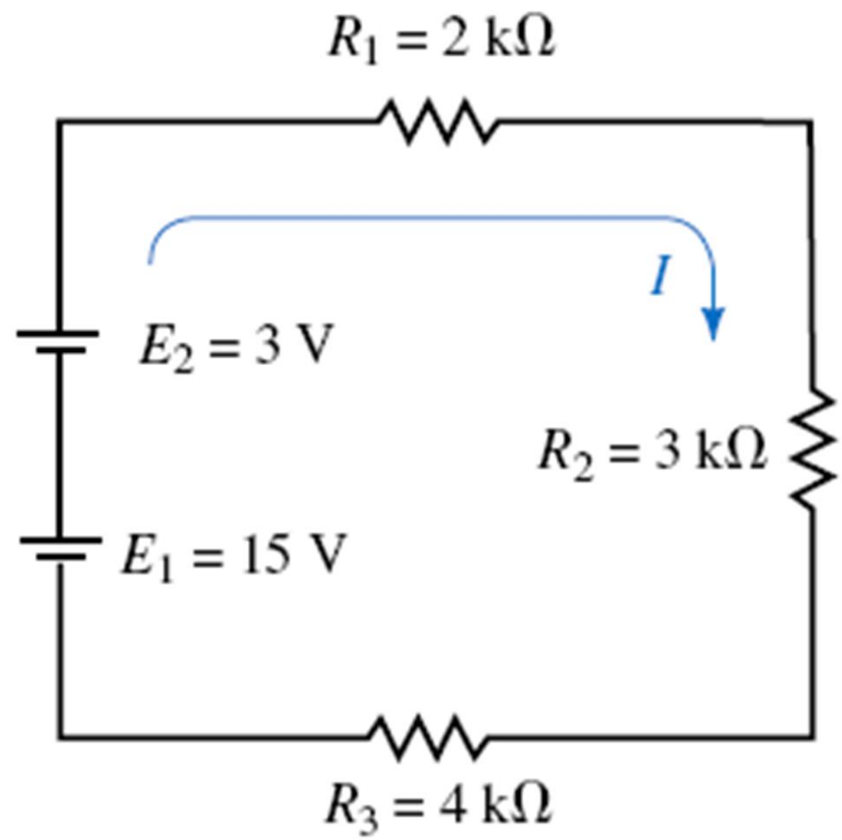
Iรวม

Interchanging Series Components

$I = \dfrac{15 + 3\ (V)}{2K + 3K + 4K\,(R)} = 2.0\ mA$



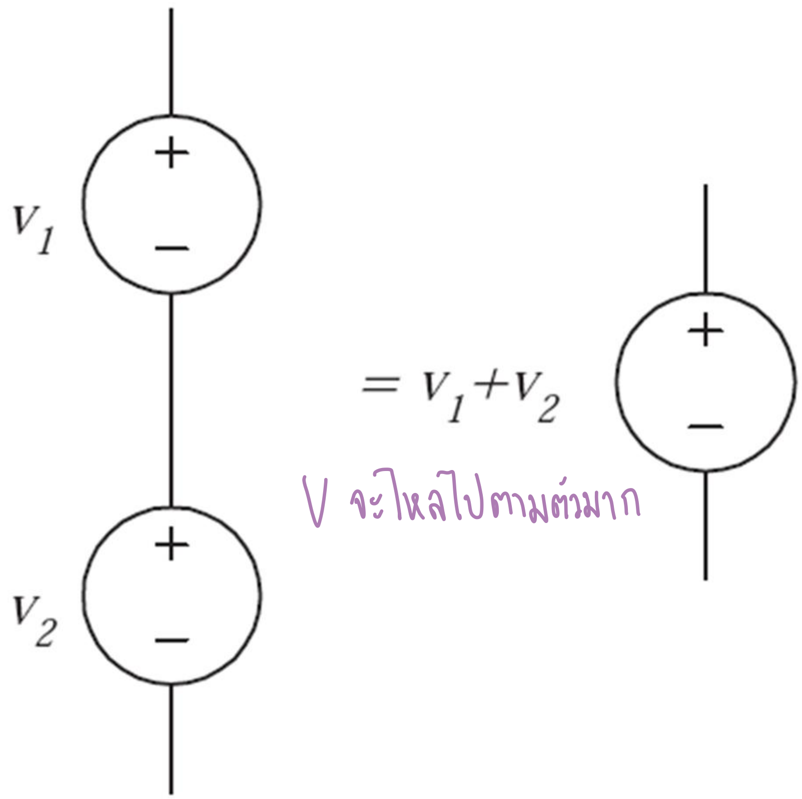
(a)



(b)

* ต่ออนุกรมจะสลับที่ได้ แต่ค่า +/- เหมือนกัน

Voltage source in series

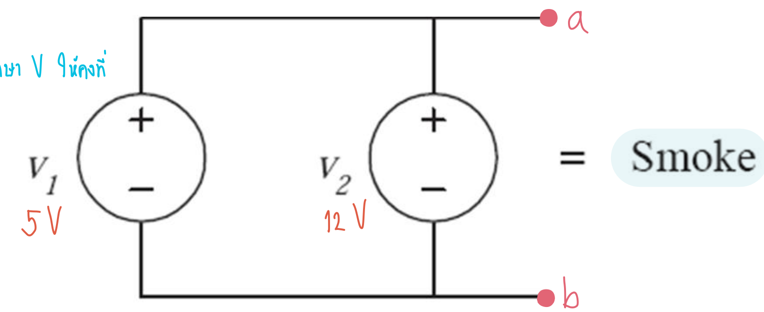


V จะไหลไปตามตัวมาก

- Ideal voltage sources connected in series add

Voltage source in parallel

จะรักษา V ให้คงที่



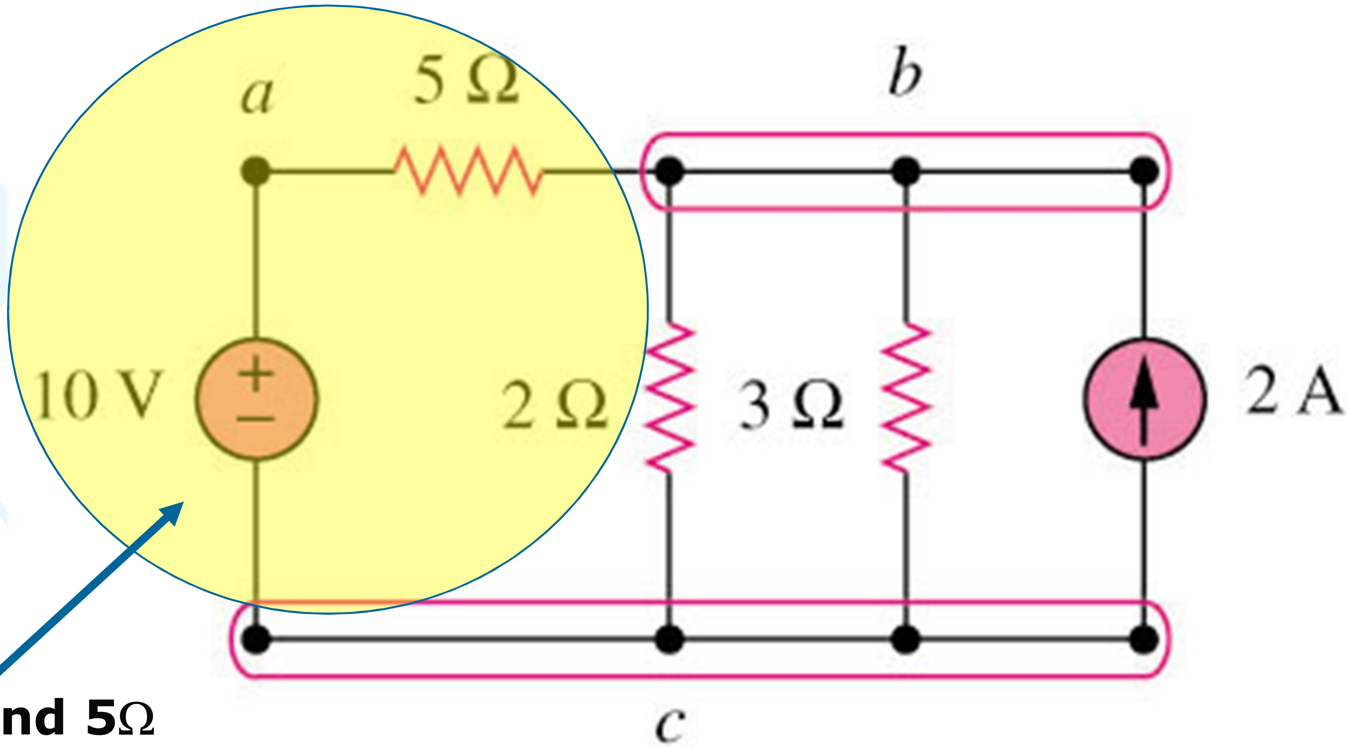
ได้ V อุดมคติ ต่อไม่ได้ ขนาน

- Ideal voltage sources *cannot* be connected in parallel
- Recall: ideal voltage sources guarantee the voltage between two terminals is at the specified potential (voltage)
- Immovable object meets unstoppable force
- In practice, the stronger source would win
- Could easily cause component failure (smoke)
- Ideal sources do not exist
- Technically allowed if $V_1 = V_2$, but is a bad idea

※ More : mAH = มิลลิแอมป์ชั่วโมง

2.4 Series Resistors and Voltage Division (1)

Example 3

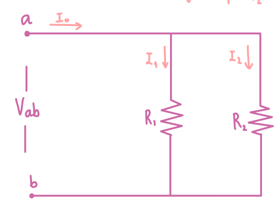


10V and 5Ω are in series

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.

$i_0 = i_1 + i_2$



$V_{R_1} = V_{ab}$

$V_{R_2} = V_{ab}$

$\therefore\ i_1 = \frac{V_{ab}}{R_1},\ i_2 = \frac{V_{ab}}{R_2}$

- The equivalent resistance of a circuit with N resistors in parallel is:

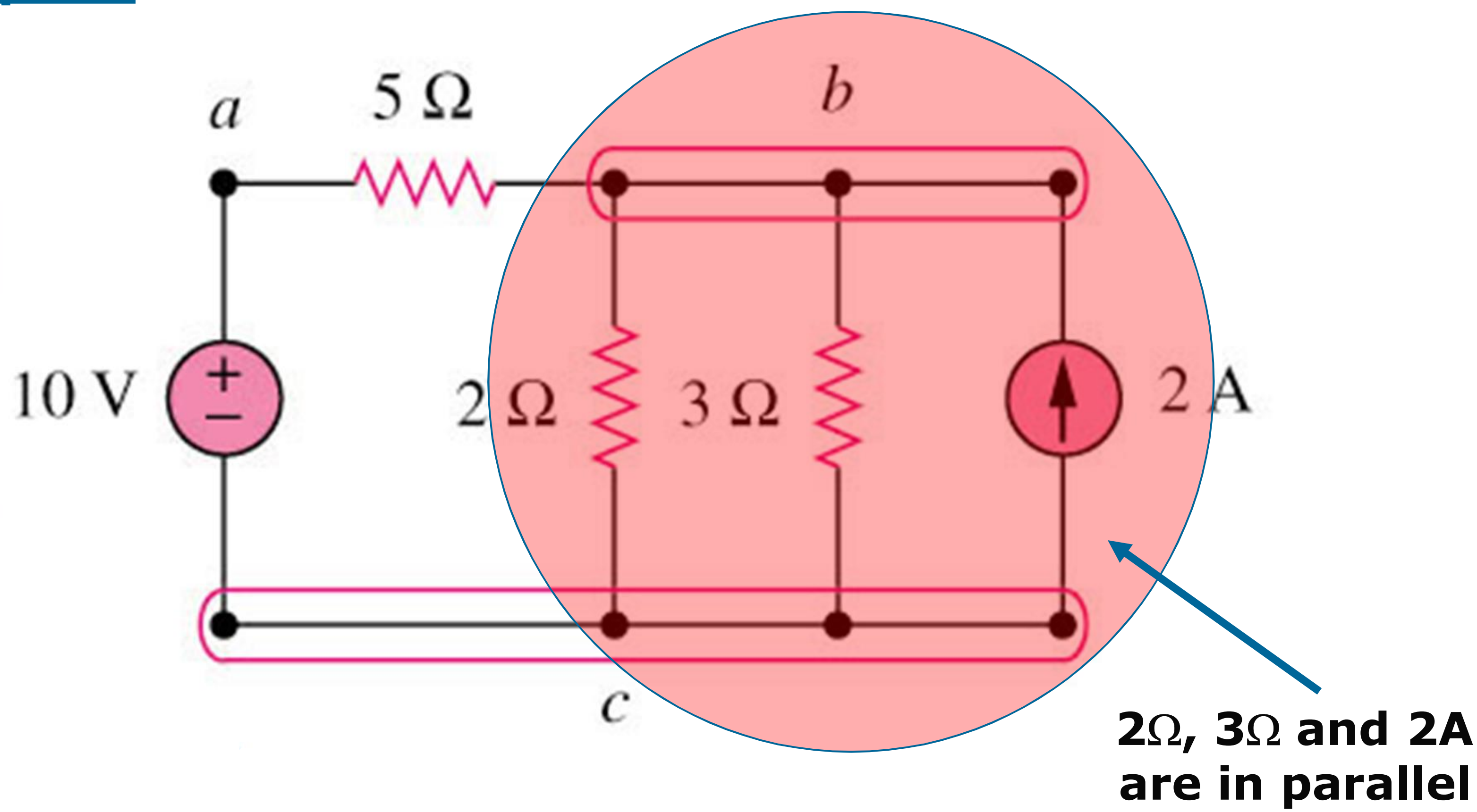
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

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

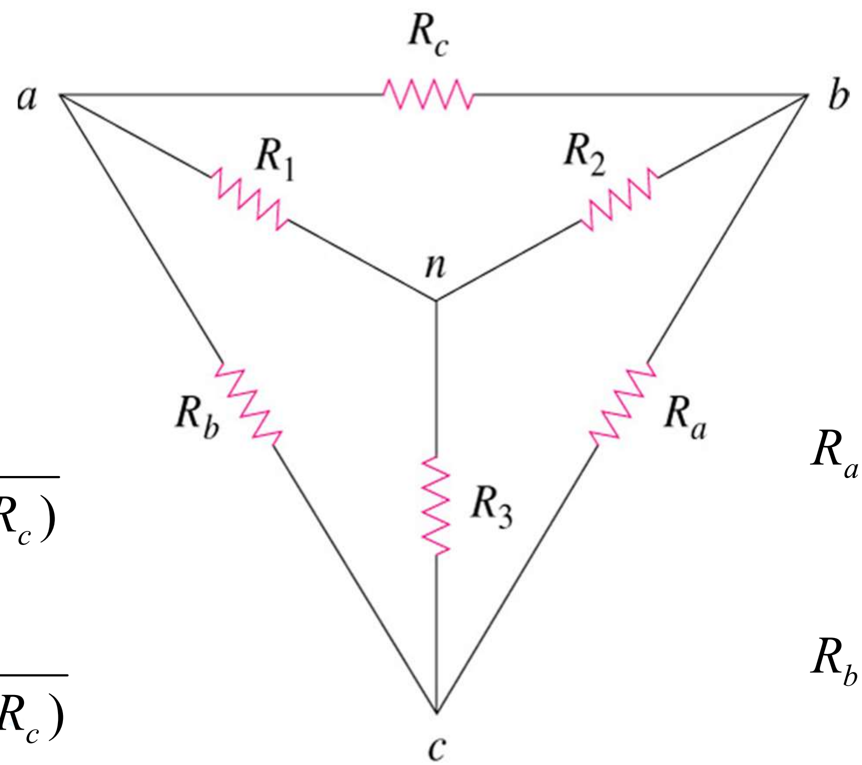
$$i_n = \frac{v}{R_n} = \frac{iR_{eq}}{R_n}$$

2.5 Parallel Resistors and Current Division (1)

Example 4



2.6 Wye-Delta Transformations



Delta -> Star

$$R_1 = \frac{R_b R_c}{(R_a + R_b + R_c)}$$

$$R_2 = \frac{R_c R_a}{(R_a + R_b + R_c)}$$

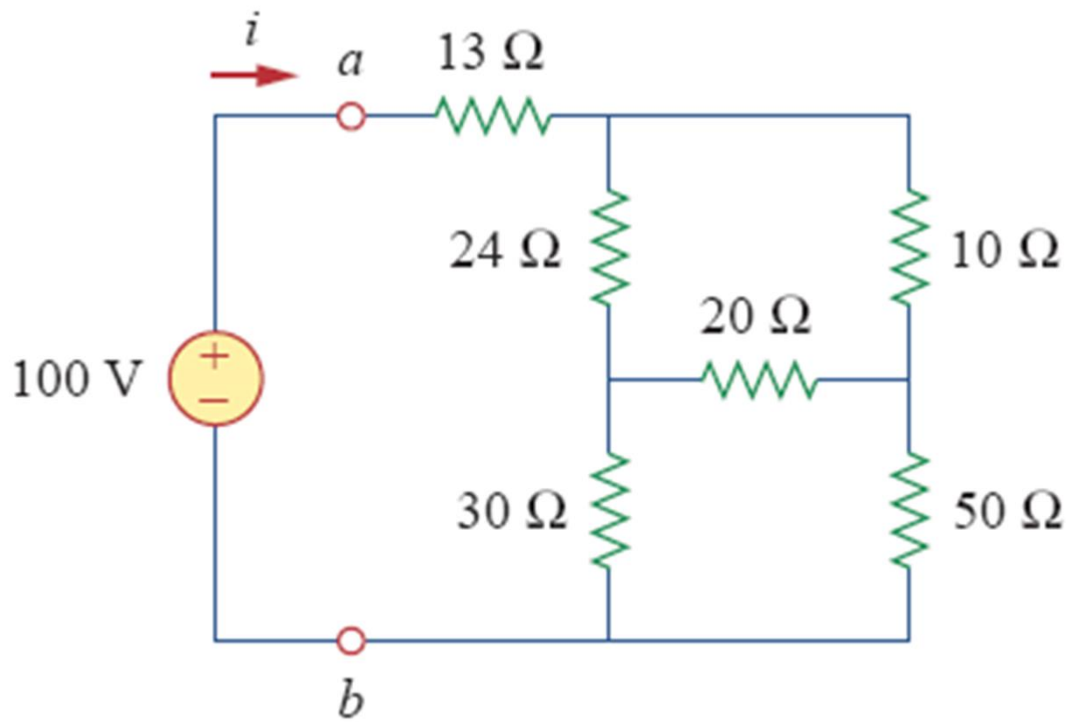
$$R_3 = \frac{R_a R_b}{(R_a + R_b + R_c)}$$

Star -> Delta

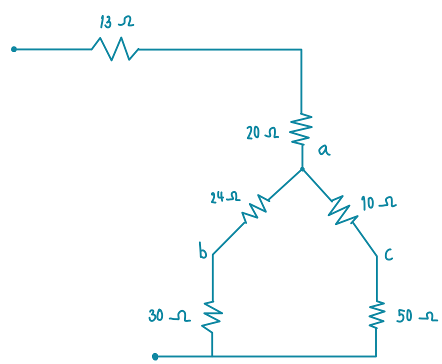
$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

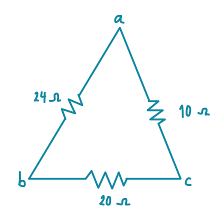
$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$


i
a
13 Ω
24 Ω
10 Ω
20 Ω
100 V
30 Ω
50 Ω
b

เปลี่ยนเป็น


13 Ω
20 Ω
a
24 Ω
10 Ω
b
c
30 Ω
50 Ω


a
24 Ω
10 Ω
b
20 Ω
c