Lecture 2

Basic Laws

Basic Laws

In order to determine circuit parameters (Resistance, Voltage, Current, Power, etc.)

- Resistance
- Ohm’s Law
- Kirchhoff’s Law

Resistance

- 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.***
- Copper, aluminum have low resistivities and mica, paper have high resistivities

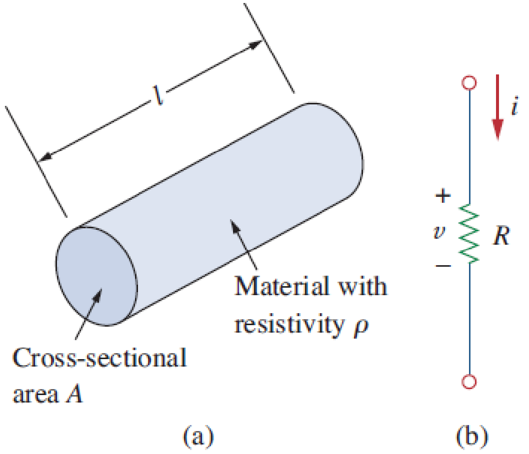

Figure 2.1
(a) Resistor, (b) Circuit symbol for resistance.

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

Resistance

TABLE 2.1

Resistivities of common materials.

Material	Resistivity (Ω·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

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.
- R represents the constant of proportionality denoted by ohm's

$$v \propto i \qquad \boxed{v = iR}$$

Ohm's Law

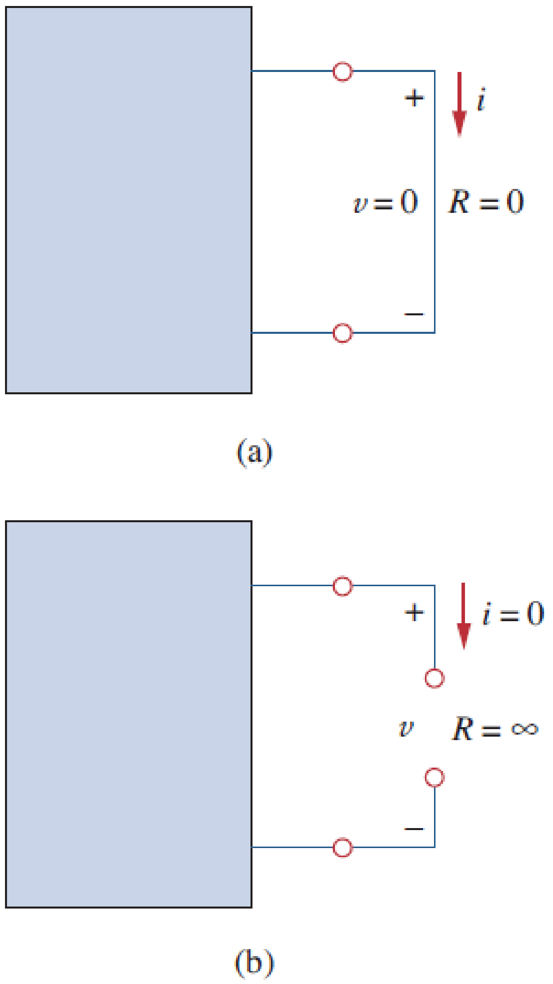

Figure 2.2
(a) Short circuit ($R = 0$), (b) Open circuit ($R = \infty$).

Ohm's Law

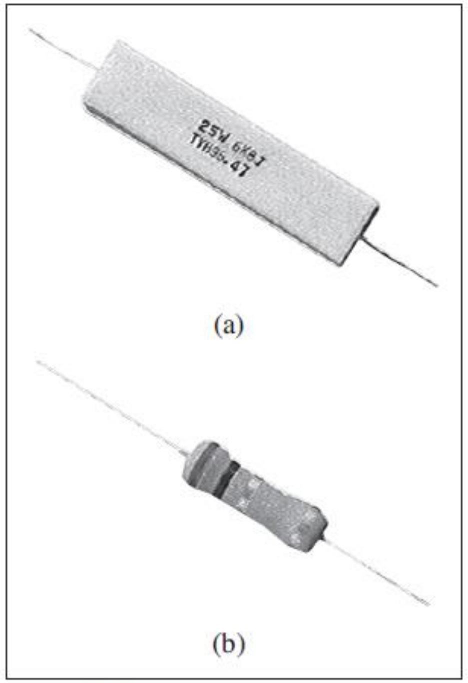

Figure 2.3
Fixed resistors: (a) wirewound type,
(b) carbon film type.
Courtesy of Tech America.

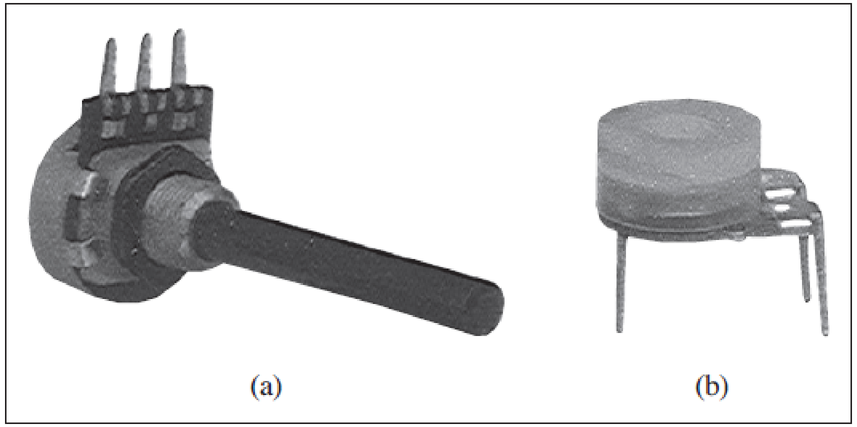

Figure 2.5
Variable resistors: (a) composition type, (b) slider pot.
Courtesy of Tech America.

Ohm's Law

In the circuit shown in Fig. 2.8, calculate the current i, the conductance G, and the power p.

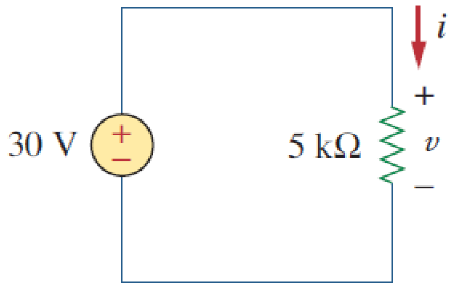

Figure 2.8
For Example 2.2.

Ohm's Law

Solution:

The voltage across the resistor is the same as the source voltage (30 V) because the resistor and the voltage source are connected to the same pair of terminals. Hence, 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 using either Eqs. (1.7), (2.10), or (2.11).

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

or

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

or

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

Nodes, Branches, and Loops

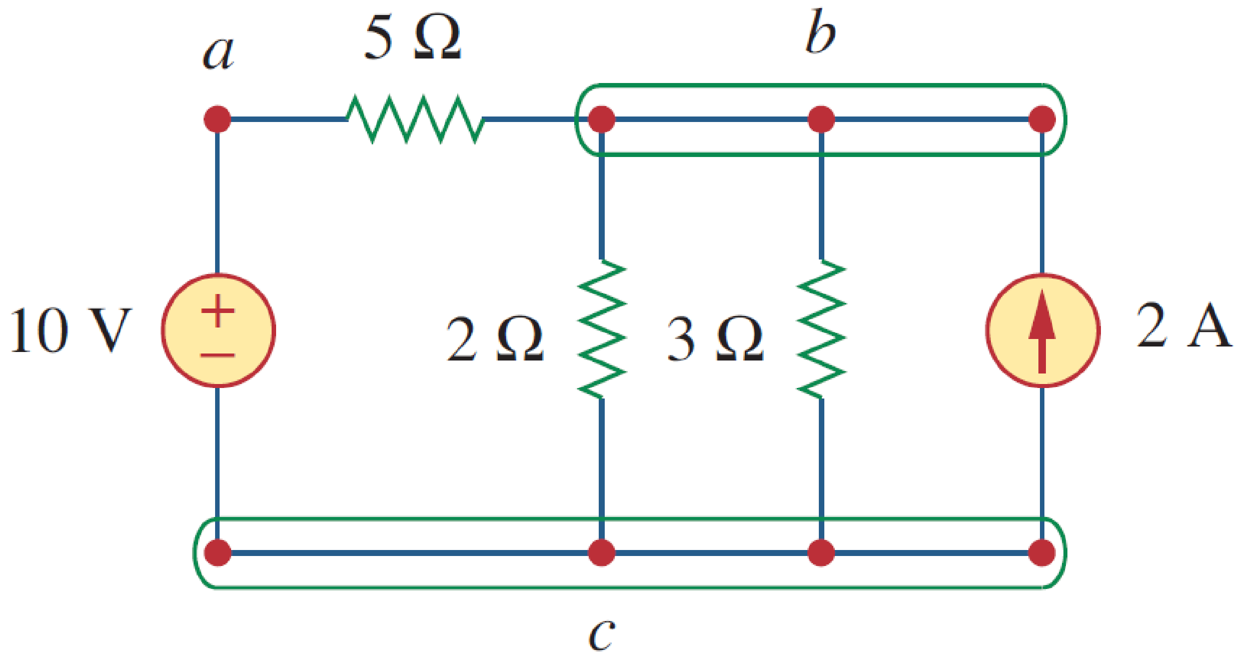

Figure 2.10
Nodes, branches, and loops.

Kirchhoff’s Laws

- How to pronounce **Kirchhoff**?
- (কিরচফ, কিরকফ)

Kirchhoff’s Laws

- KCL- It states that the algebraic sum of currents entering a node (or a closed boundary) is zero.

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

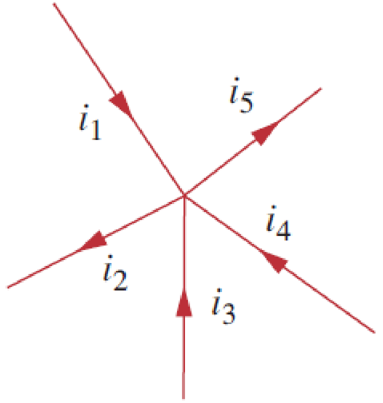

Figure 2.16
Currents at a node illustrating KCL.

Kirchhoff's Laws

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

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

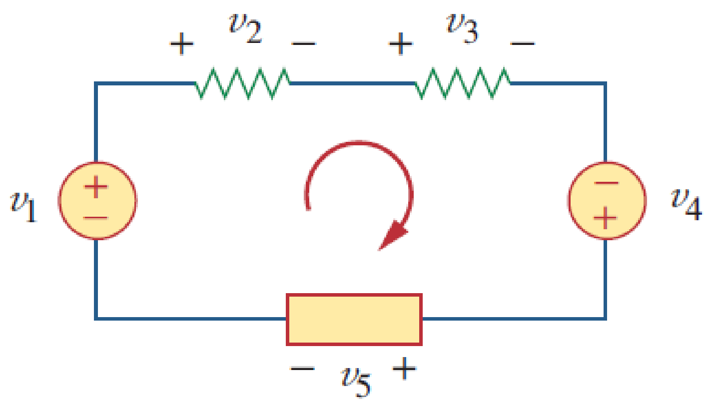

Figure 2.19
A single-loop circuit illustrating KVL.

Kirchhoff’s Laws

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

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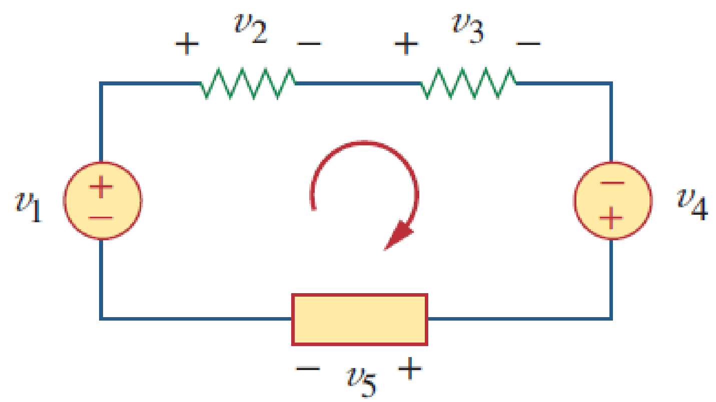

Figure 2.19
A single-loop circuit illustrating KVL.

Kirchhoff's Laws

For the circuit in Fig. 2.21(a), find voltages v_1 and v_2.

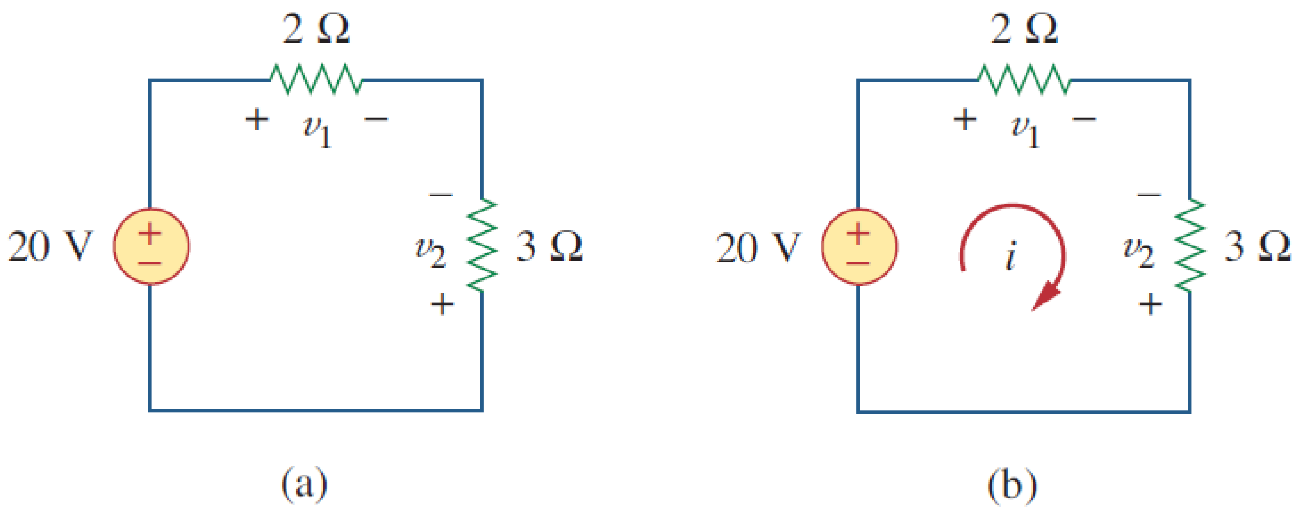

Figure 2.21
For Example 2.5.

Kirchhoff's Laws

Solution:

To find v_1 and v_2, we apply Ohm's law and Kirchhoff's voltage law. Assume that current i flows through the loop as shown in Fig. 2.21(b). From Ohm's law,

$$v_1 = 2i, \qquad v_2 = -3i \tag{2.5.1}$$

Applying KVL around the loop gives

$$-20 + v_1 - v_2 = 0 \tag{2.5.2}$$

Substituting Eq. (2.5.1) into Eq. (2.5.2), we obtain

$$-20 + 2i + 3i = 0 \qquad \text{or} \qquad 5i = 20 \qquad \Rightarrow \qquad i = 4 \text{ A}$$

Substituting i in Eq. (2.5.1) finally gives

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

Kirchhoff's Laws

Determine v_o and i in the circuit shown in Fig. 2.23(a).

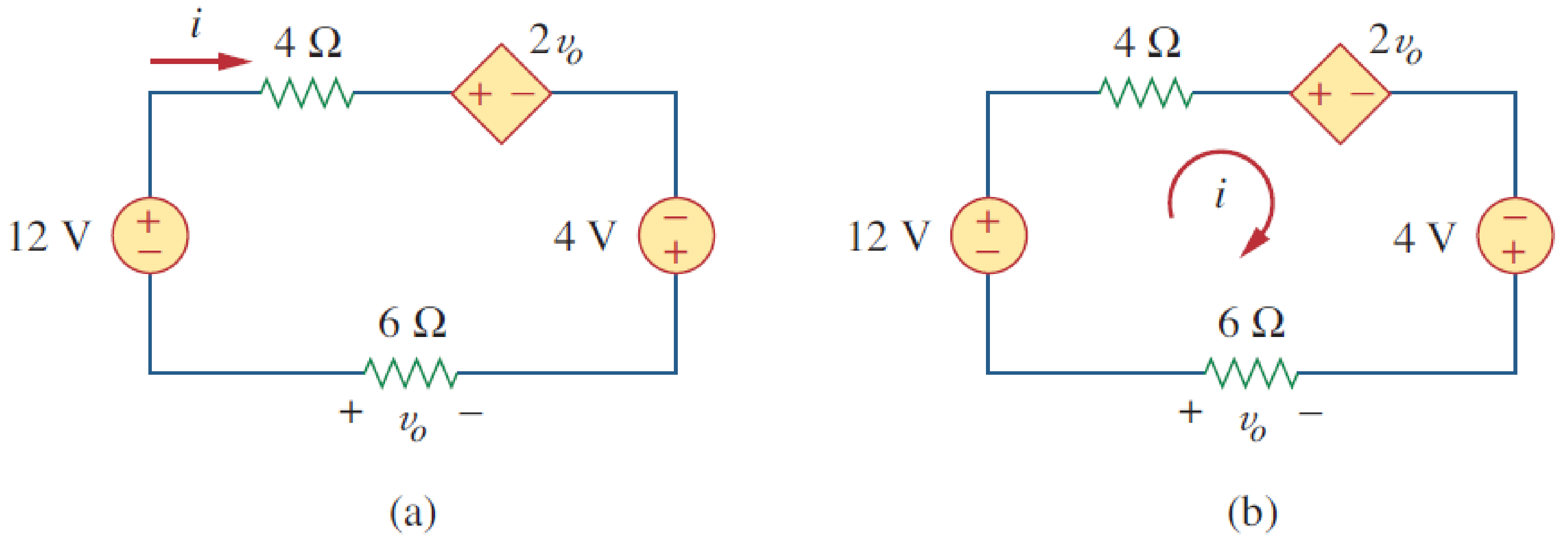

Figure 2.23
For Example 2.6.

Kirchhoff's Laws

Solution:

We apply KVL around the loop as shown in Fig. 2.23(b). The result is

$$-12 + 4i + 2v_o - 4 + 6i = 0 \qquad \textbf{(2.6.1)}$$

Applying Ohm's law to the 6-Ω resistor gives

$$v_o = -6i \qquad \textbf{(2.6.2)}$$

Substituting Eq. (2.6.2) into Eq. (2.6.1) yields

$$-16 + 10i - 12i = 0 \qquad \Rightarrow \qquad i = -8 \text{ A}$$

and $v_o = 48$ V.