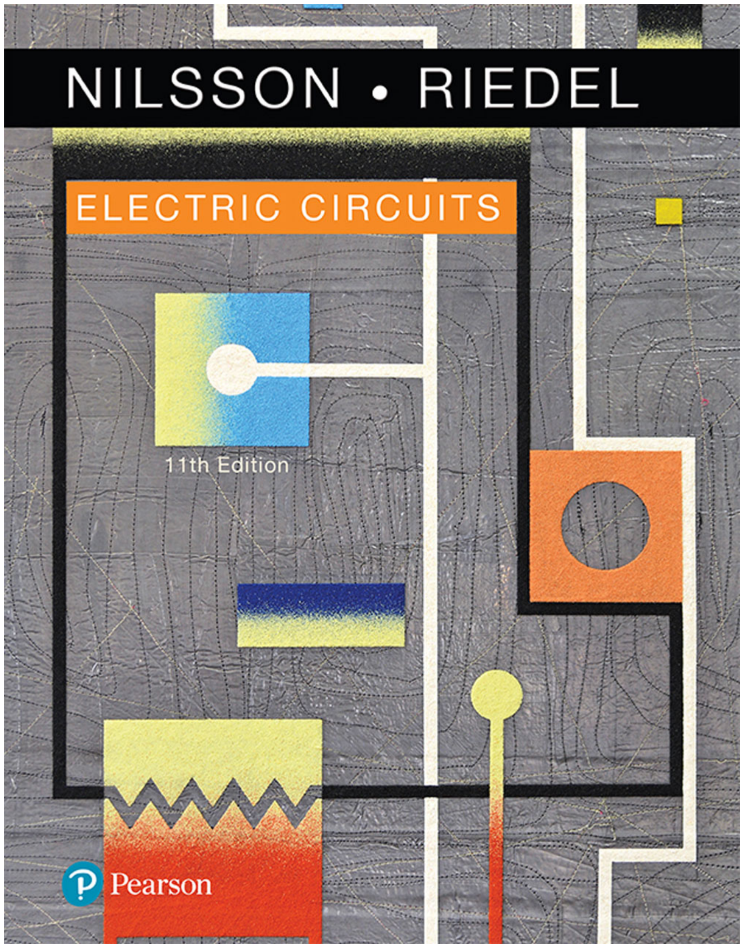
Electric Circuits

Eleventh Edition



Chapter 2

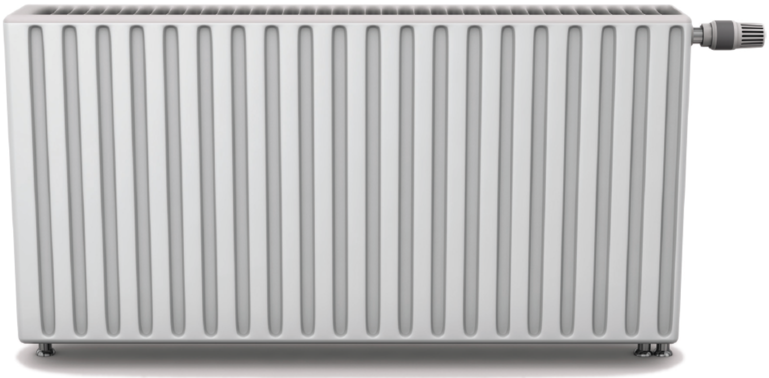
Circuit Elements

Pearson

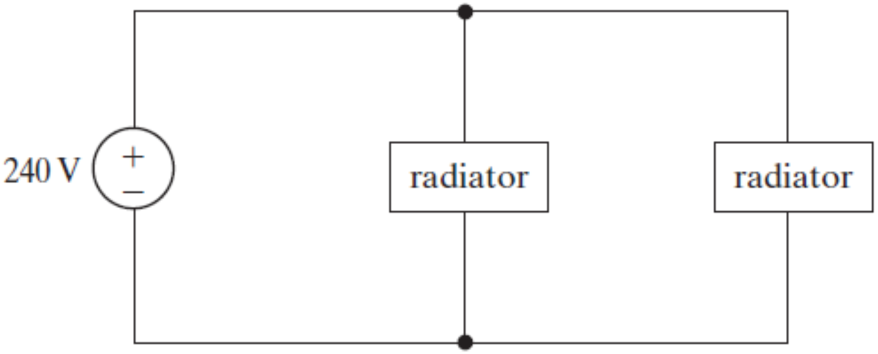
Learning Objectives

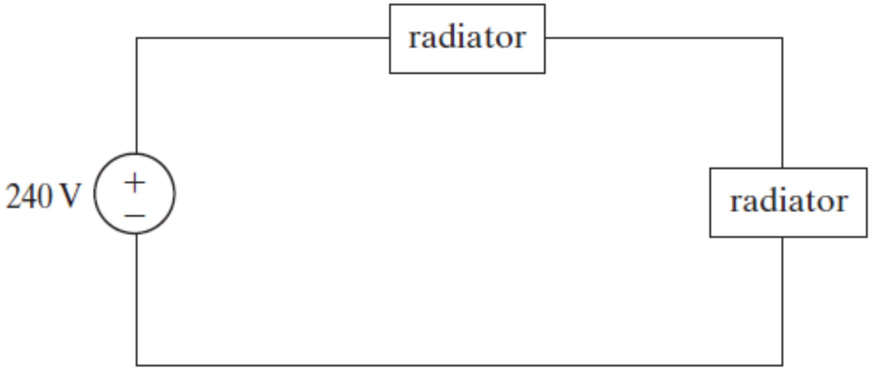
- Voltage and Current Sources
- Electrical Resistance (Ohm's Law)
- Construc<on of a Circuit Model
- Kirchhoff's Laws
- Analysis of a Circuit Containing Dependent Source

Practical Perspective – Heating with Electric Radiators



Style-Photography/Fotolia





2.1 Voltage & Current Sources

- When we speak of circuit elements, it is important to differentiate between the physical device itself and the mathematical model which we will use to analyze its behavior in a circuit.
- We will use the expression **circuit element** to refer to the **mathematical model**.
- All the simple circuit elements that we will consider can be classified according to the relationship between current through the element to the voltage across the element.

Five ideal basic circuit elements

Voltage source

Current source

Active elements

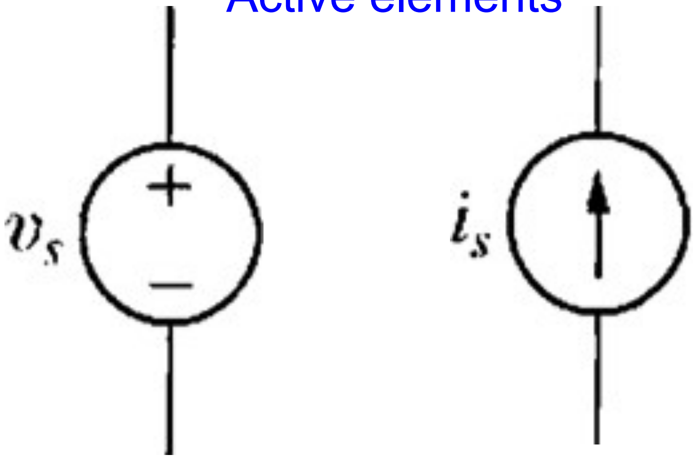
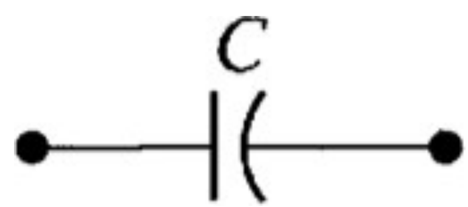


Figure 2.1: The circuit symbols for (a) an ideal independent voltage source and (b) an ideal independent current source.

Resistor

Figure 2.5: The circuit symbol for a resistor having a resistance R.

Inductor



Capacitor

Passive elements

Dependent Sources

- A **dependent source** establishes a voltage or current whose value depends on the value of a voltage or current elsewhere in the circuit. *You cannot specify the value of a dependent source unless you know the value of the voltage or current on which it depends.*
- Four kind of controlled sources,
  - current-controlled current source, CCCS;
  - voltage-controlled current source, VCCS;
  - voltage-controlled voltage source, VCVS;
  - current-controlled voltage source, CCVS .

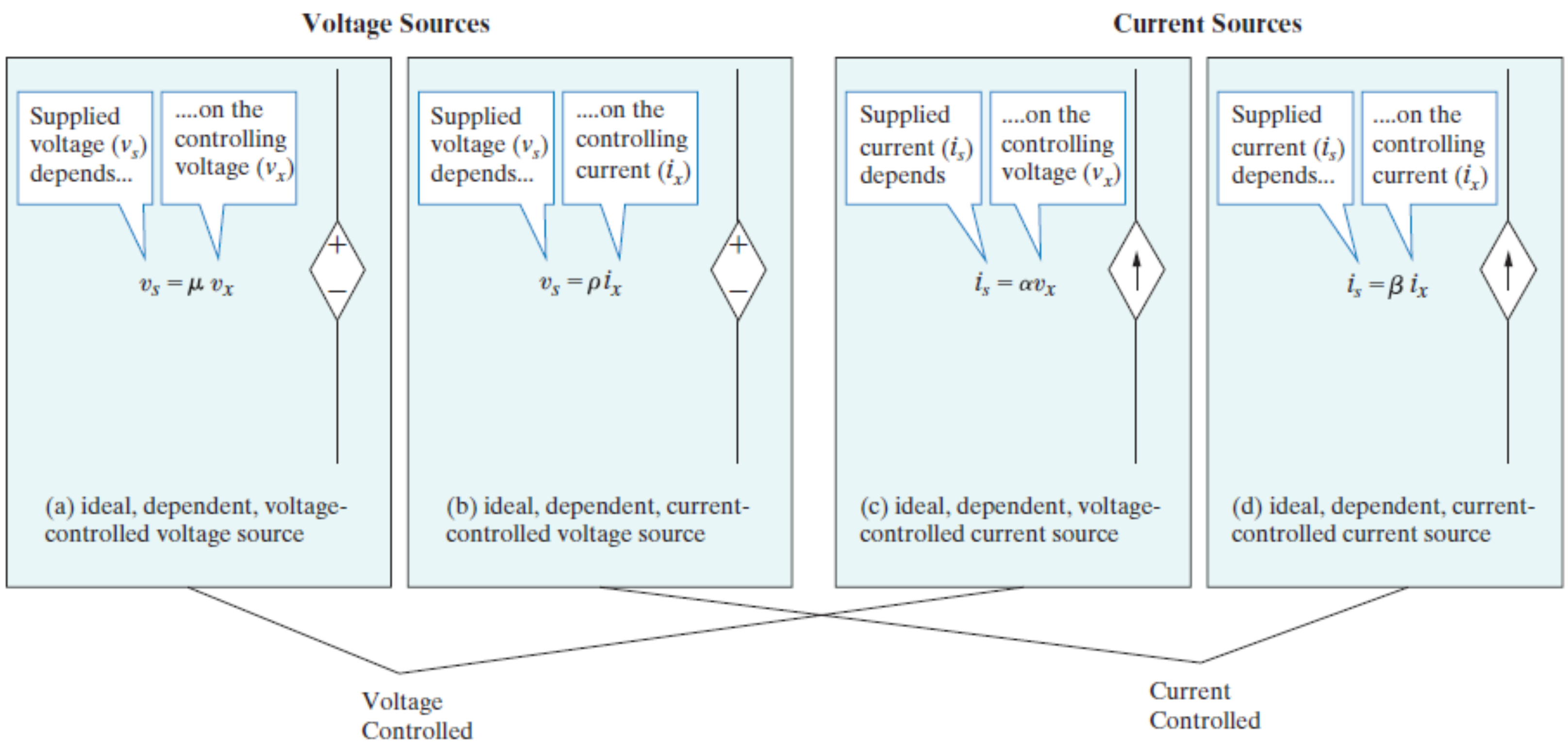
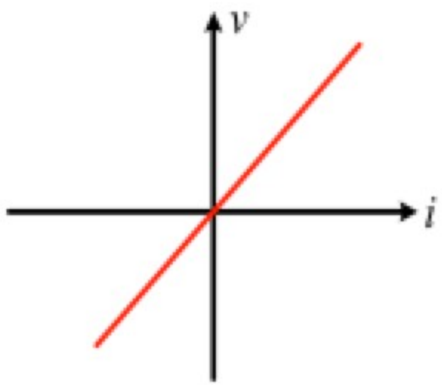


Figure 2.2: (a) (b) Circuit symbols for ideal dependent voltage sources and (c) (d) ideal dependent current sources.

2.2 Electrical Resistance (Ohm’s Law)

- Resistance is the capacity of materials to <u>impede</u> the flow of current or, more specifically, the flow of electric charge. The circuit element used to model this behavior is the **resistor.**
- The linear resistor is the simplest passive element. Its symbol and characteristic are as following:



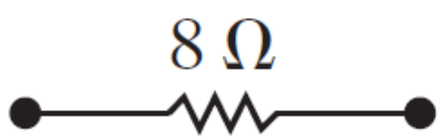
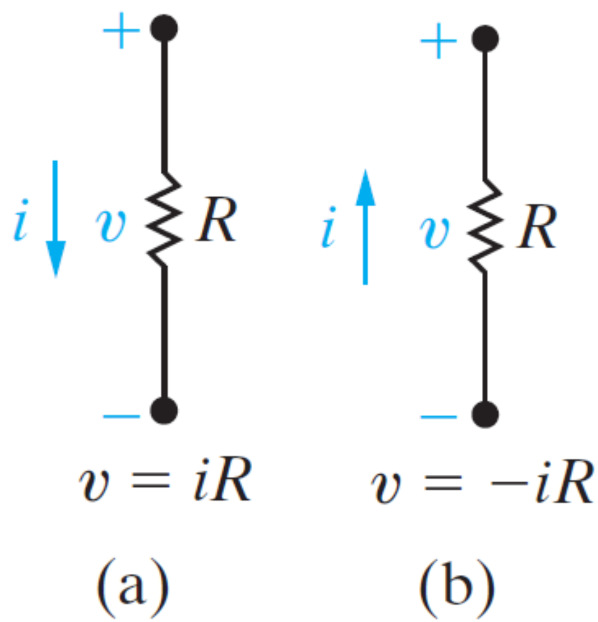


Figure 2.7: The circuit symbol for an 8Ω resistor.

Ohm’s Law

$$\boxed{v = iR}$$



v = the voltage in volts,

i = the current in amperes,

R = the resistance in ohms.

Figure 2.6 Two possible reference choices for the current and voltage at the terminals of a resistor and the resulting equations. (a) In the direction of the voltage drop across the resistor (b) In the direction of the voltage rise across the resistor

Other Forms of Ohm's Law

- Current is in the direction of the voltage ***drop*** across the resistor

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

- Current is in the direction of the voltage ***rise*** across the resistor

$$i = -\frac{v}{R}$$

- **Conductance:** the reciprocal of the resistance, which is symbolized by the letter G, and is measured in Siemens (S)

$$G = \frac{1}{R}\ \mathrm{S}$$

2.3 Construction of a Circuit Model

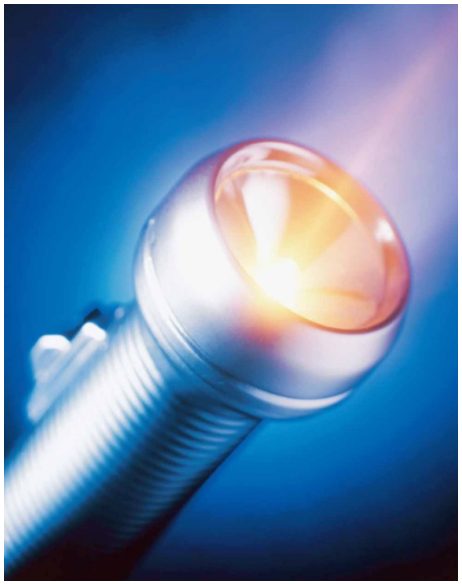


Figure 2.9: A flashlight can be viewed as an electrical system.

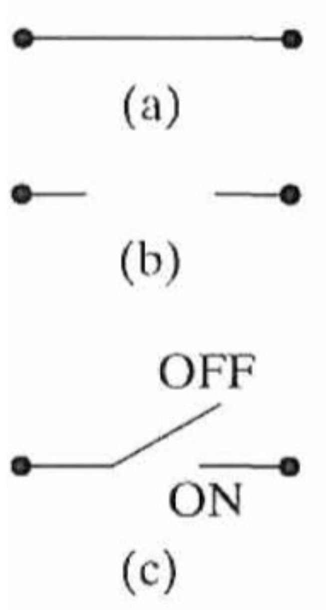


Figure 2.11: Circuit symbols. (a) Short circuit. (b) Open circuit. (c) Switch.

An ideal switch offers no resistance to the current when it is in the ON state, but it offers infinite resistance to current when it is in the OFF state.

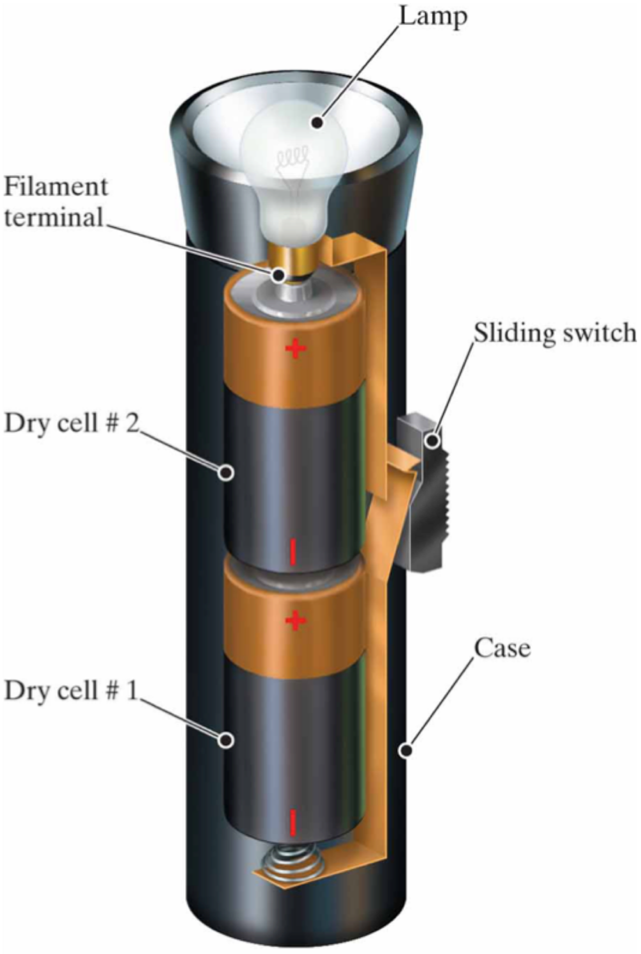


Figure 2.10: The arrangement of flashlight components.

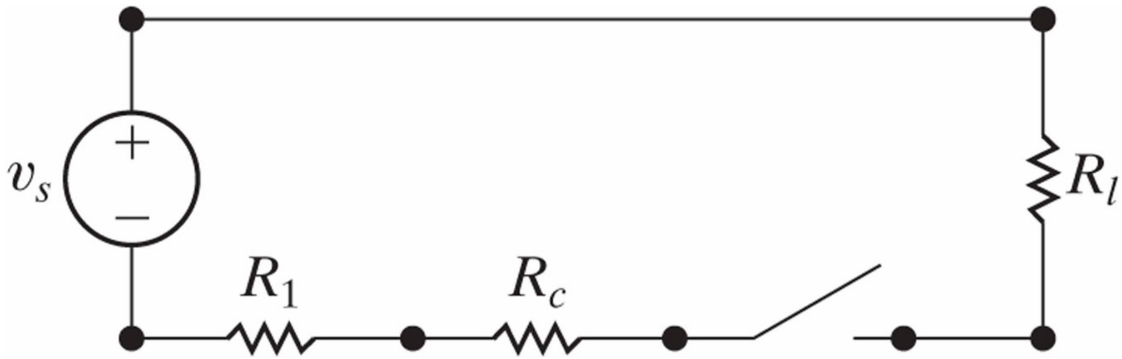


Figure 2.12: A circuit model for a flashlight.

- In developing a circuit model, the *electrical* behavior of each physical component is of primary interest: a lamp, a coiled wire, and a metal case.
- Circuit models may need to account for undesired as well as desired electrical effects: light and heat.
- Modeling requires approximati4on.

2.4 Kirchhoff's Law

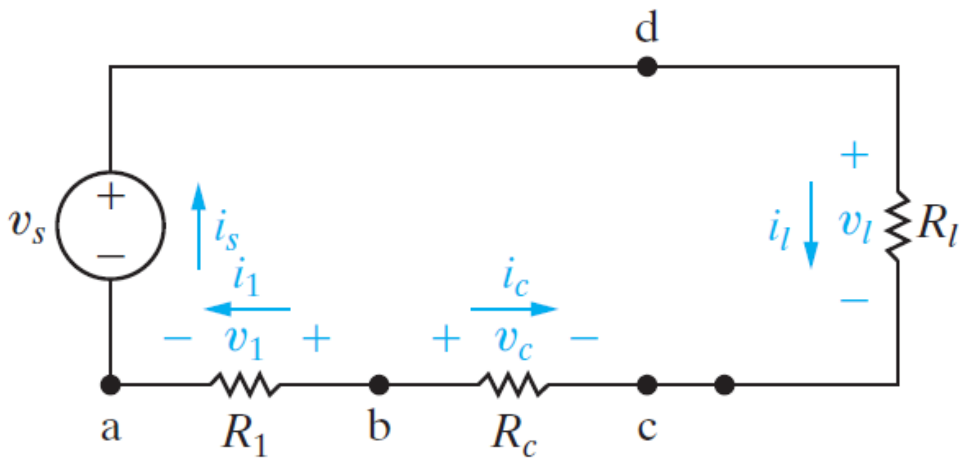


Figure 2.15: Circuit model of the flashlight with assigned voltage and current variables.

A **node** is a point where two or more circuit elements meet.

Based on Ohm's law:

$$v_1 = i_1 R_1,$$

$$v_c = i_c R_c,$$

$$v_l = i_l R_l.$$

Ohm's law may not be enough to provide a complete solution!

Kirchhoff's current law (KCL): The algebraic sum of all the currents at any node in a circuit equals zero.

Kirchhoffs voltage law (KVL): The algebraic sum of all the voltages around any closed path in a circuit equals zero.

Reference direction is important!

KCL: Assign a positive sign to a current leaving a node requires assigning a negative sign to a current entering a node, or vice versa.

KVL: As we trace a closed path, assign a positive sign to a voltage rise requires assigning a negative sign to a voltage drop, or vice versa.

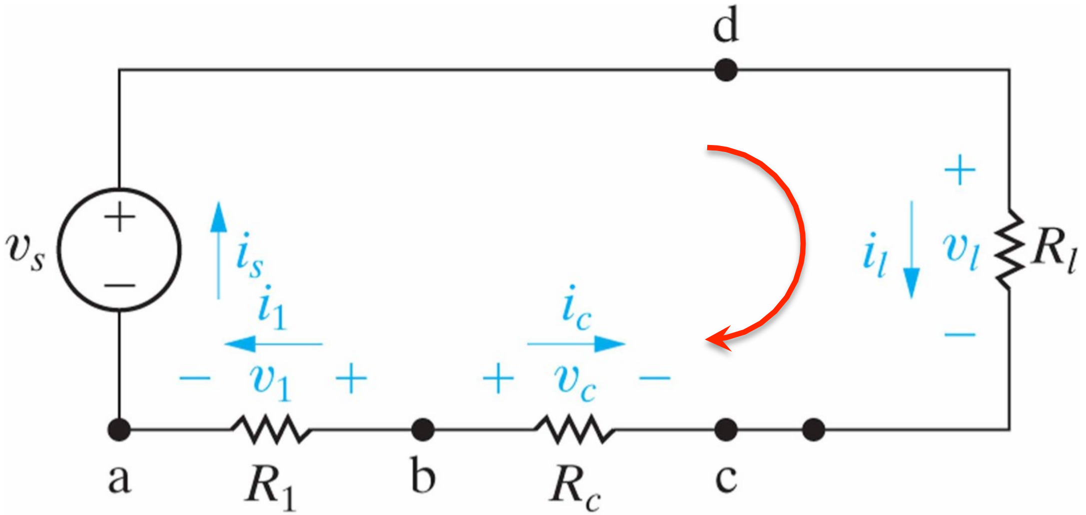
node a $\quad i_s - i_1 = 0,$

node b $\quad i_1 + i_c = 0,$

node c $\quad -i_c - i_l = 0,$

node d $\quad i_l - i_s = 0.$

KCL



Circuit model for the flashlight

$$v_l - v_c + v_1 - v_s = 0.$$

KVL

2.5 Analysis of a Circuit Containing Dependent Sources

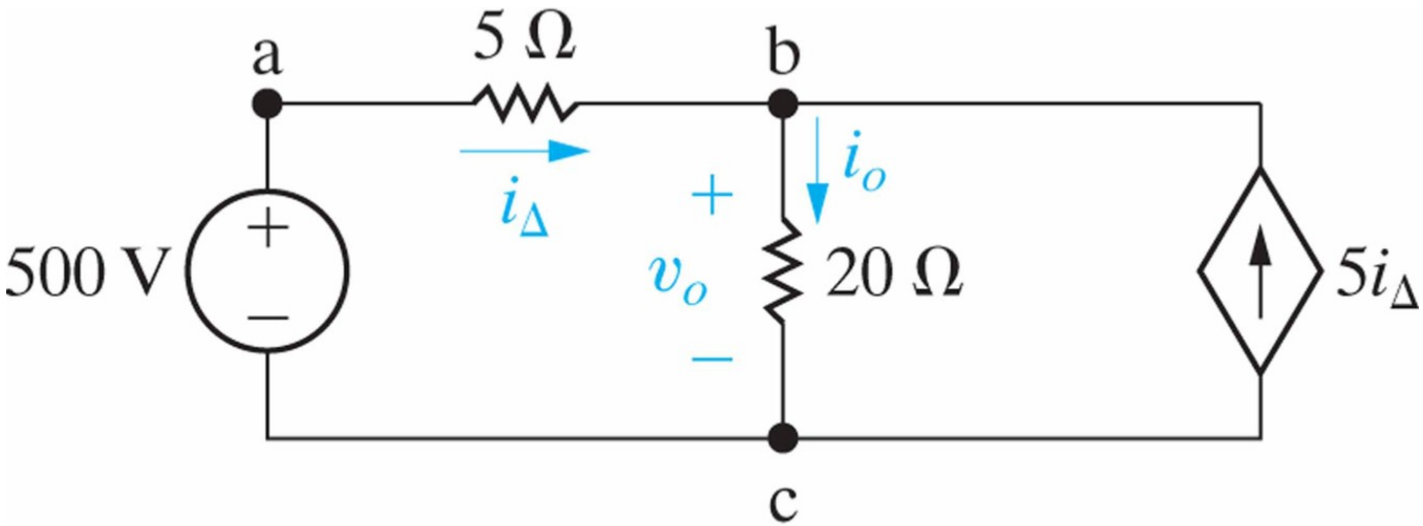


Figure 2.22: A circuit with a dependent source.

KCL $\quad i_o = i_\Delta + 5i_\Delta = 6i_\Delta$

KVL $\quad 500 = 5i_\Delta + 20i_o$

$$i_\Delta = 4 \text{ A},$$

$$i_o = 24 \text{ A}.$$

$$v_o = 20i_o = 480 \text{ V}$$

Practical Perspective – Heating with Electric Radiators

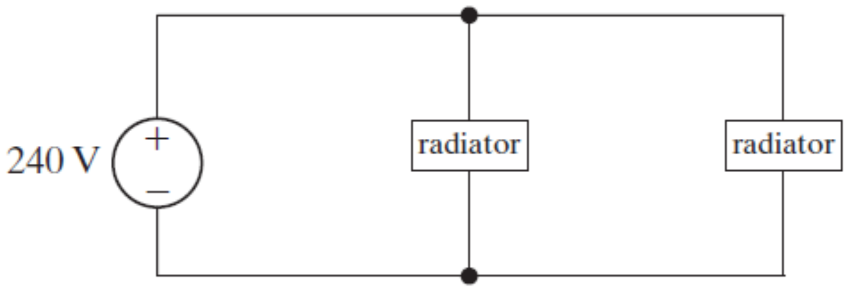


Figure 2.25: A wiring diagram for two radiators.

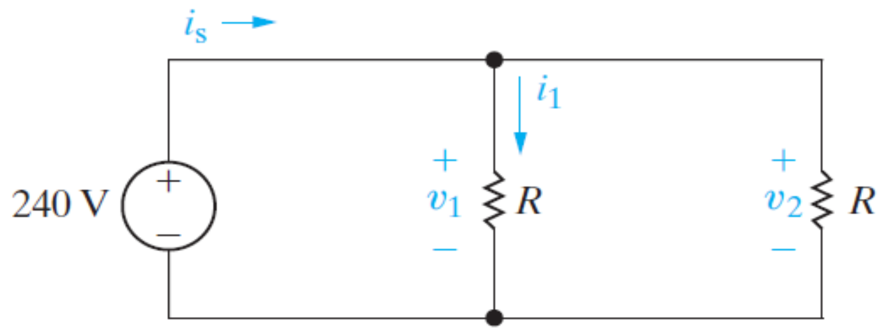


Figure 2.26: A circuit based on Fig. 2.25.

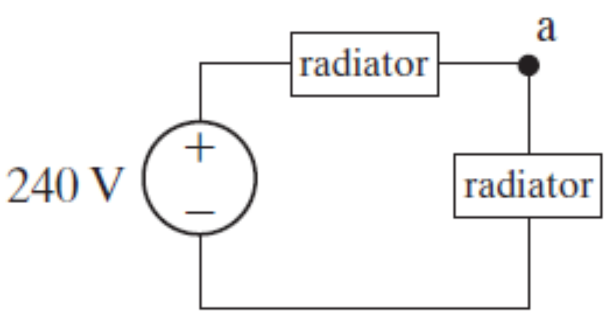


Figure 2.27: Another way to wire two radiators.

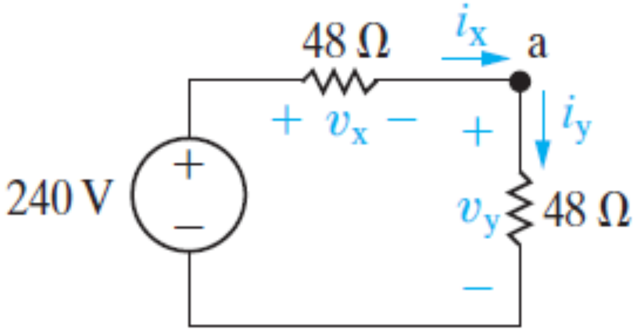


Figure 2.28: A circuit based on Fig. 2.27.

Pearson

Electrical Safety