Chapter 1: Introduction

Outlines

1. Recognize interrelationships of electrical engineering with other fields of science and engineering.

2. List the major subfields of electrical engineering.

3. List several important reasons for studying electrical engineering.

4. Define current, voltage, and power, including their units.

5. Calculate power and energy, as well as determine whether energy is supplied or absorbed by a circuit element.

6. State and apply basic circuit laws.

7. Solve for currents, voltages, and powers in simple circuits.

Electrical systems have two main objectives:

- To gather, store, process, transport, and present *information*

- To distribute and convert *energy* between various forms

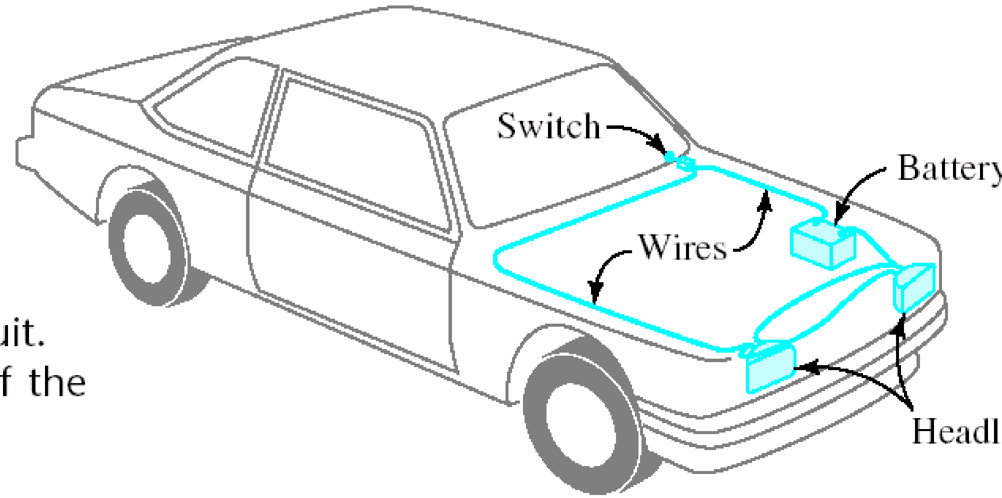
Electrical Engineering Subdivisions

- Communication systems
- Computer systems
- Control systems
- Electromagnetics
- Electronics
- Photonics
- Power systems
- Signal processing
- *(Circuit design)*
- *(Biomedical engineering)*

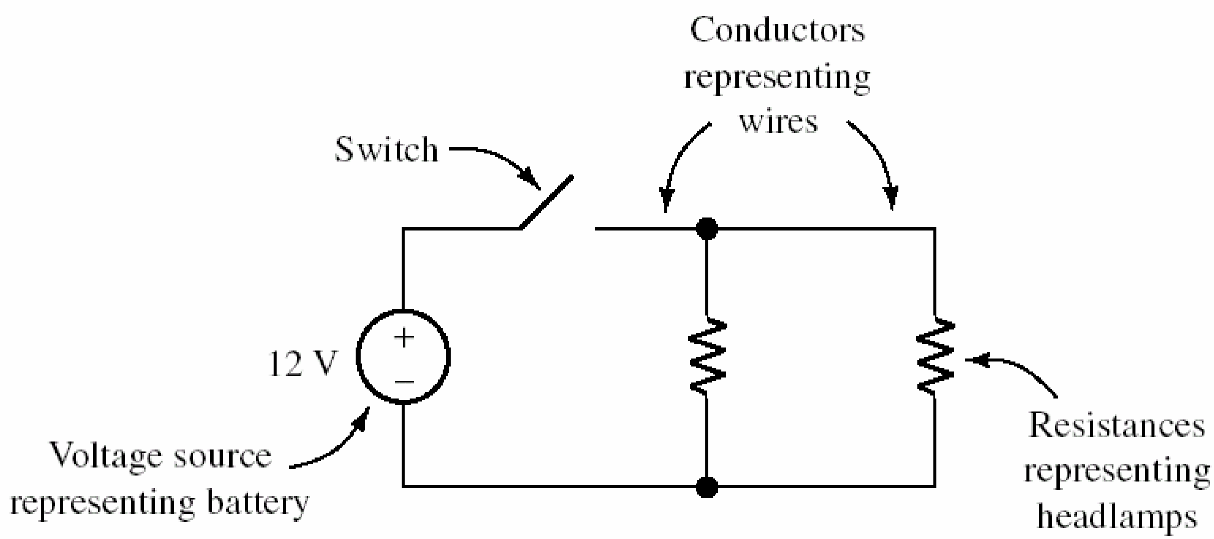
Why Study Electrical Engineering?

- *Because it is everywhere,…*

Figure 1.2 The headlight circuit. (a) The actual physical layout of the circuit. (b) The circuit diagram.



(a) Physical configuration

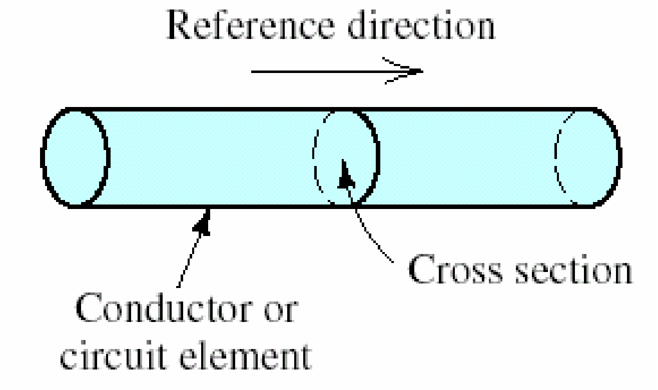


(b) Circuit diagram

Electrical Current

Electrical current is the time rate of flow of electrical charge through a conductor or circuit element. The units are amperes (A), which are equivalent to coulombs per second (C/s).

Electrical Current



$$i(t) = \frac{dq(t)}{dt}$$

$$q(t) = \int_{t_0}^{t} i(t)\,dt + q(t_0)$$

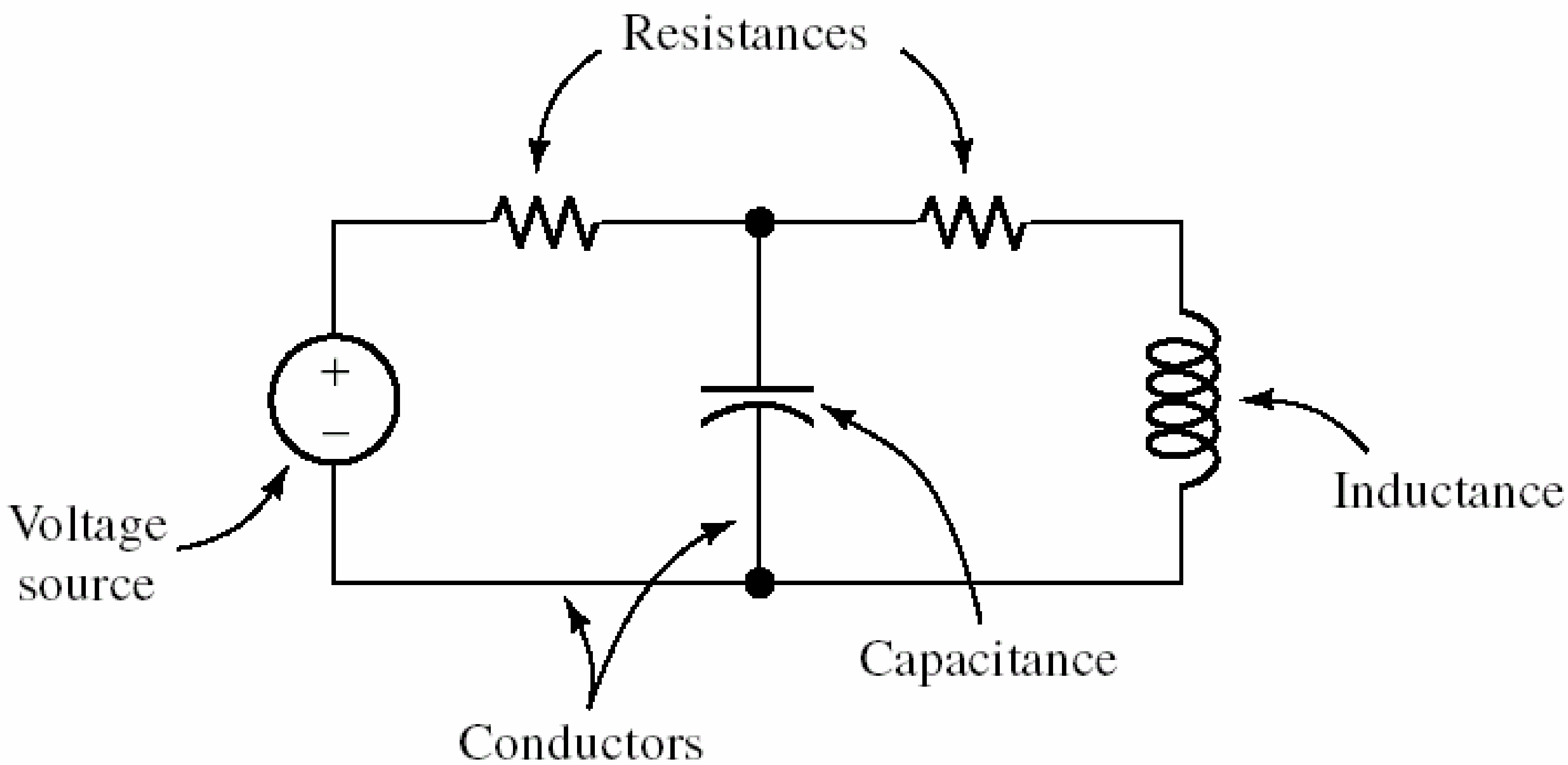


Figure 1.3 An electrical circuit consists of circuit elements, such as voltage sources, resistances, inductances, and capacitances, connected in closed paths by conductors.

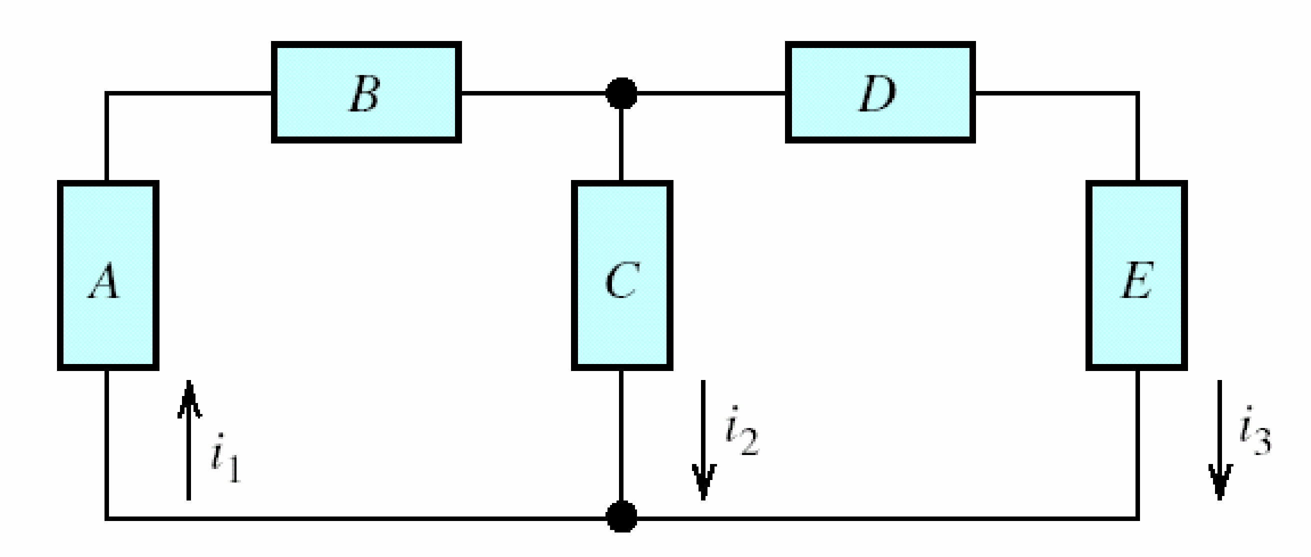
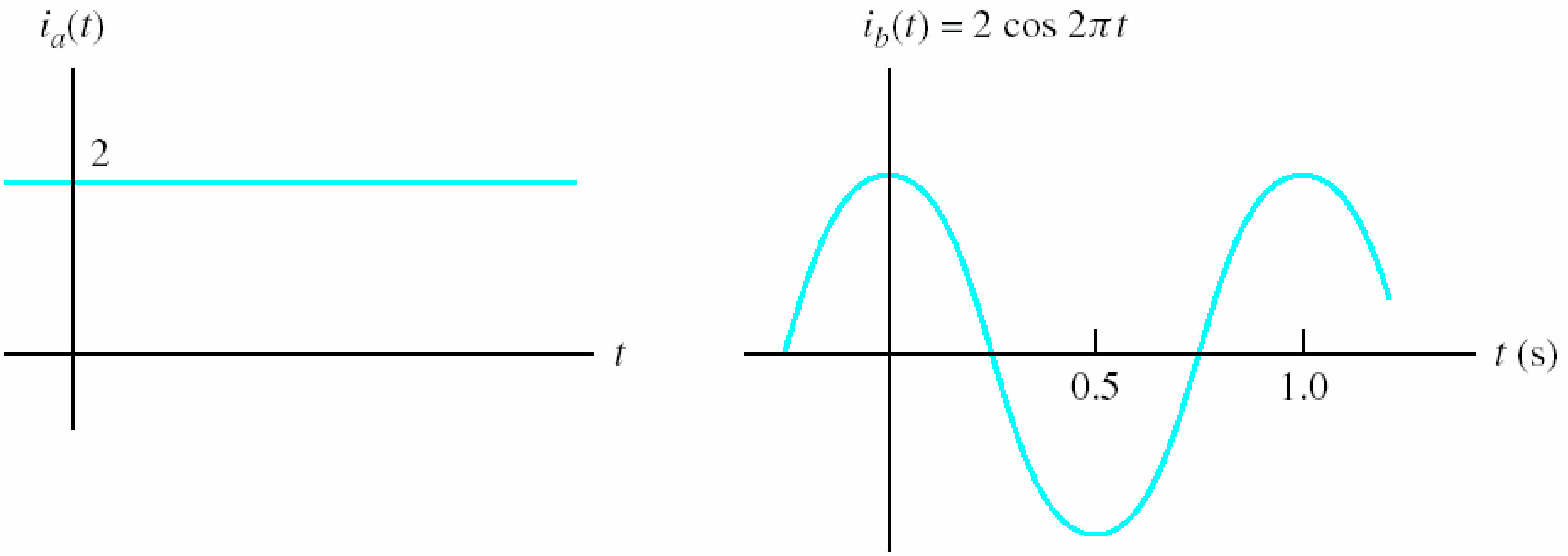


Figure 1.6 In analyzing circuits, we frequently start by assigning current variables i_1, i_2, i_3, and so forth.

Direct Current
Alternating Current

When a current is constant with time, we say that we have **direct current**, abbreviated as dc. On the other hand, a current that varies with time, reversing direction periodically, is called **alternating current**, abbreviated as ac.

Figure 1.7 Examples of dc and ac currents versus time.



(a) Dc current

(b) Ac current

Figure 1.8 Ac currents can have various waveforms.

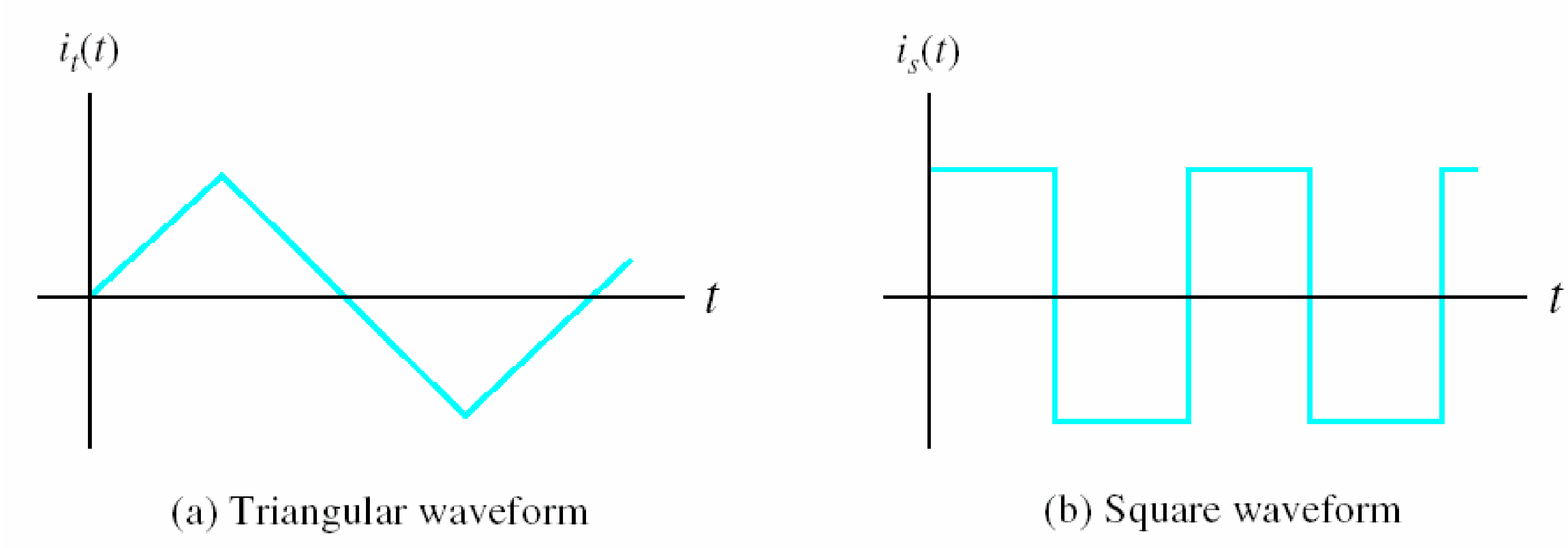
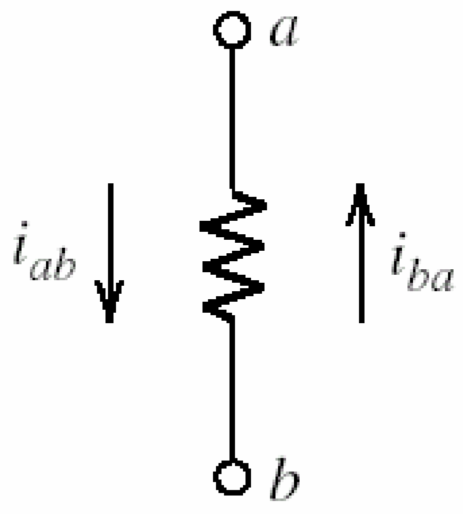


Figure 1.9 Reference directions can be indicated by labeling the ends of circuit elements and using double subscripts on current variables. The reference direction for i_{ab} points from a to b. On the other hand, the reference direction for i_{ba} points from b to a.



Voltages

The **voltage** associated with a circuit element is the energy transferred per unit of charge that flows through the element. The units of voltage are volts (V), which are equivalent to joules per coulomb (J/C).

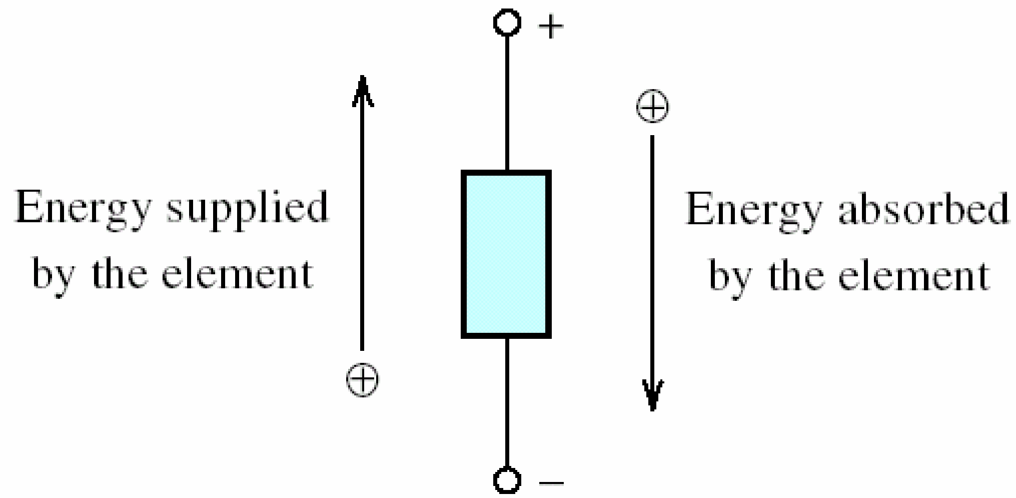


Figure 1.10 Energy is transferred when charge flows through an element having a voltage across it.

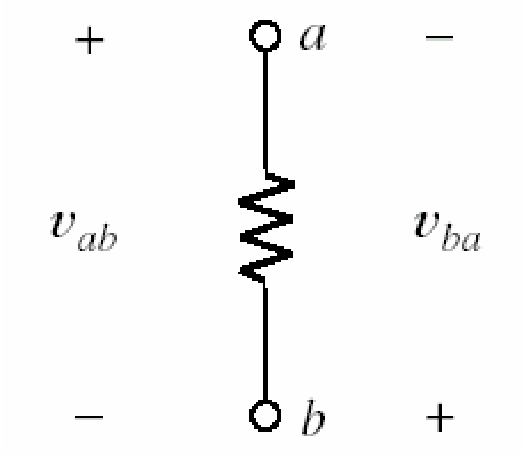


Figure 1.12 The voltage v_{ab} has a reference polarity that is positive at point a and negative at point b.

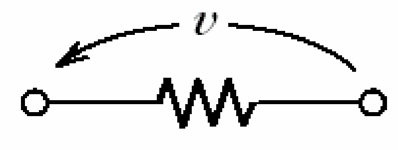


Figure 1.13 The positive reference for v is at the head of the arrow.

POWER AND ENERGY

$$p(t) = v(t)i(t)$$

$$w = \int_{t_1}^{t_2} p(t)dt$$

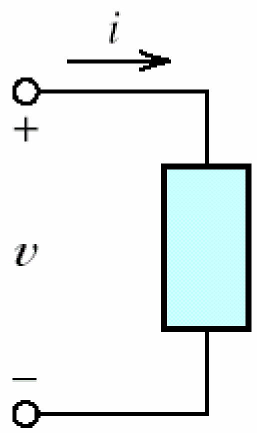


Figure 1.14 When current flows through an element and voltage appears across the element, energy is transferred. The rate of energy transfer is $p = vi$.

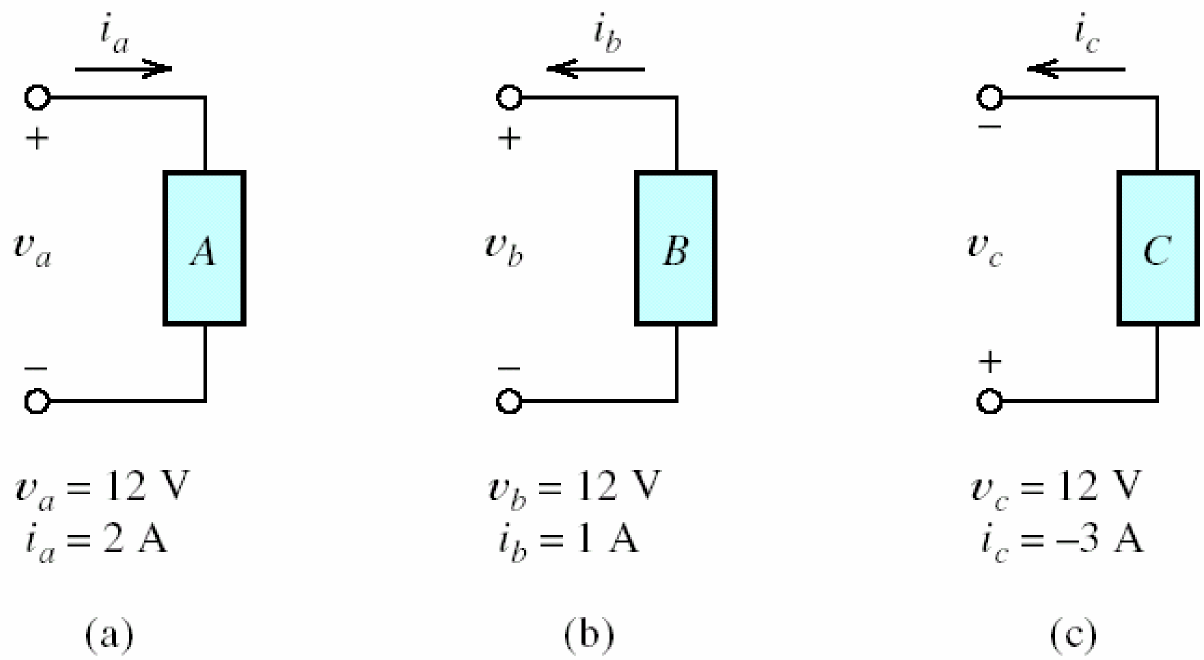


Figure 1.15 Circuit elements for Example 1.2.

KIRCHHOFF’S CURRENT LAW

- *The net current entering a node is zero.*
- *Alternatively, the sum of the currents entering a node equals the sum of the currents leaving a node.*

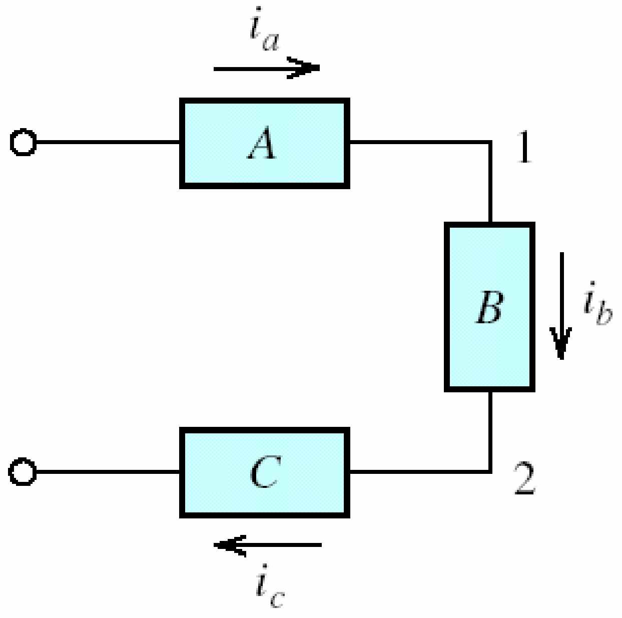


Figure 1.20 Elements A, B, and C are connected in series.

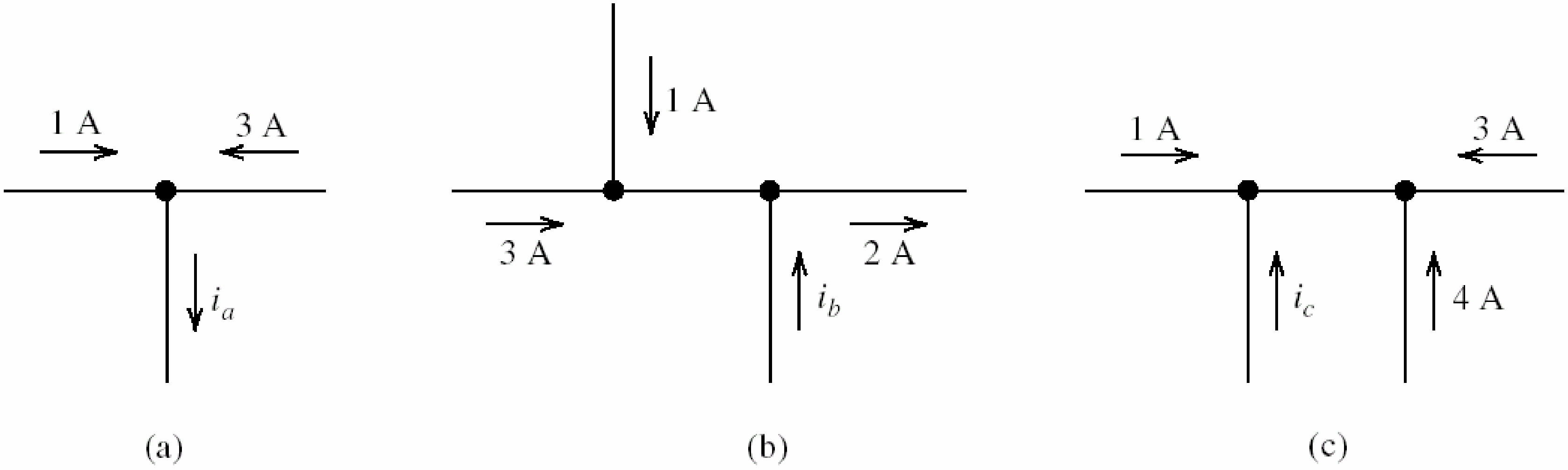


Figure 1.21 See Exercise 1.7.

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- Fig. 1.18

Series Circuits

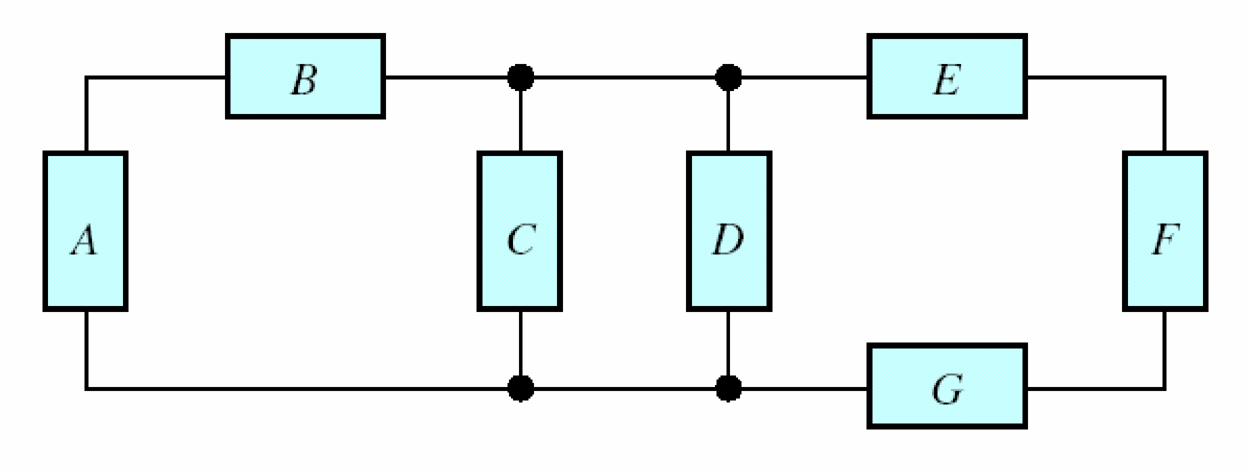
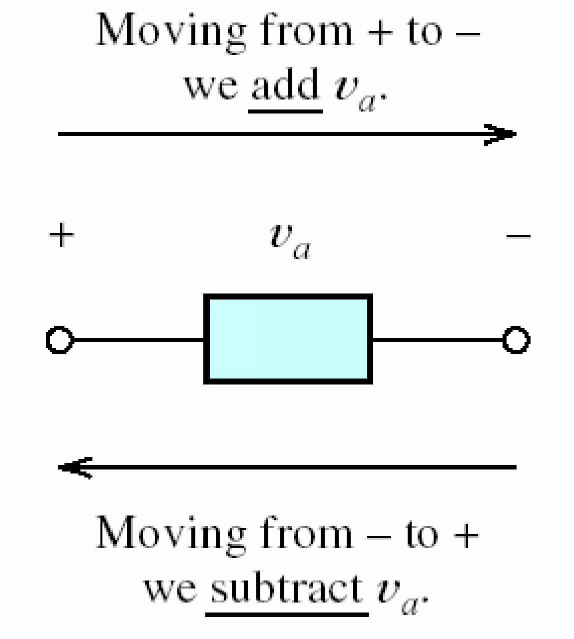


Figure 1.22 Circuit for Exercise 1.8.

KIRCHHOFF'S VOLTAGE LAW

The algebraic sum of the voltages equals zero for any closed path (loop) in an electrical circuit.

Figure 1.23 In applying KVL to a loop, voltages are added or subtracted depending on their reference polarities relative to the direction of travel around the loop.



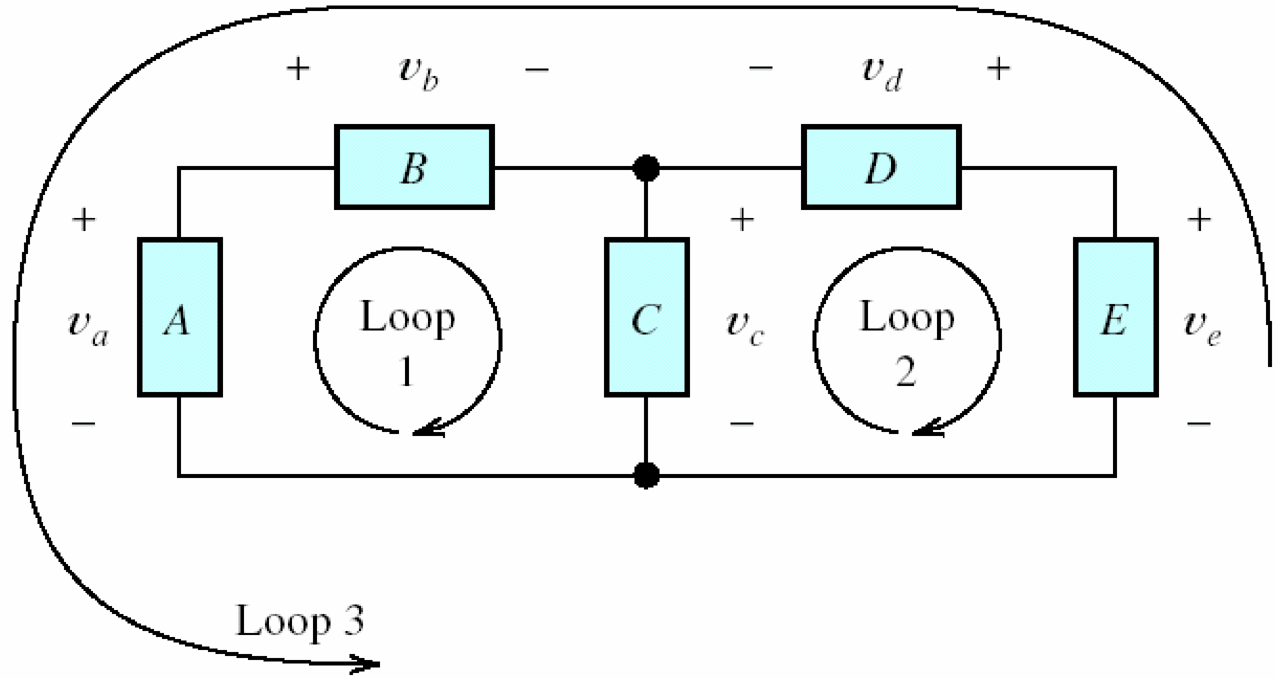


Figure 1.24 Circuit used for illustration of Kirchhoff's voltage law.

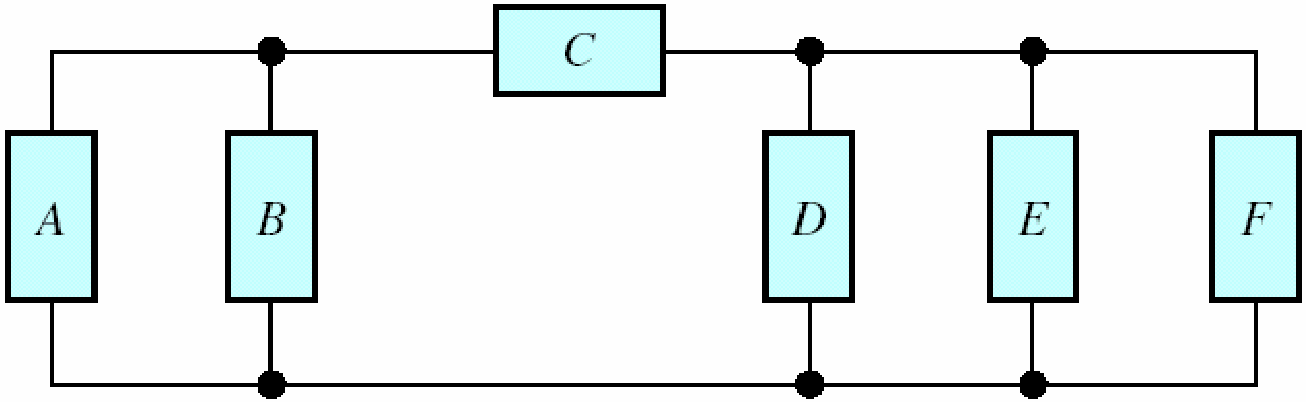


Figure 1.26 In this circuit, elements A and B are in parallel. Elements D, E, and F form another parallel combination.

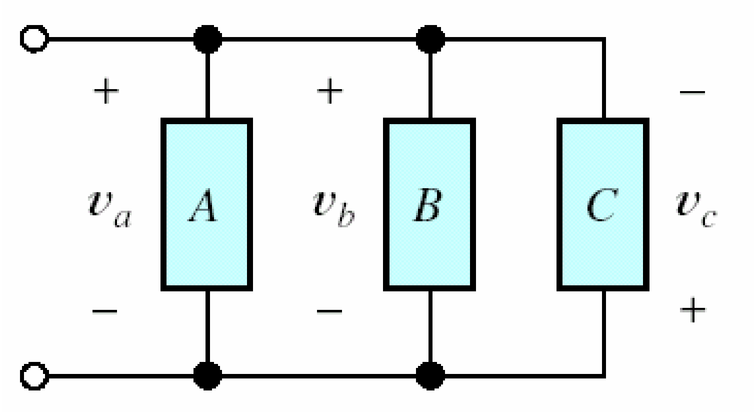


Figure 1.27 For this circuit, we can show that $v_a = v_b = -v_c$. Thus the magnitudes and *actual* polarities of all three voltages are the same.

Find voltages
Find series/parallel connection

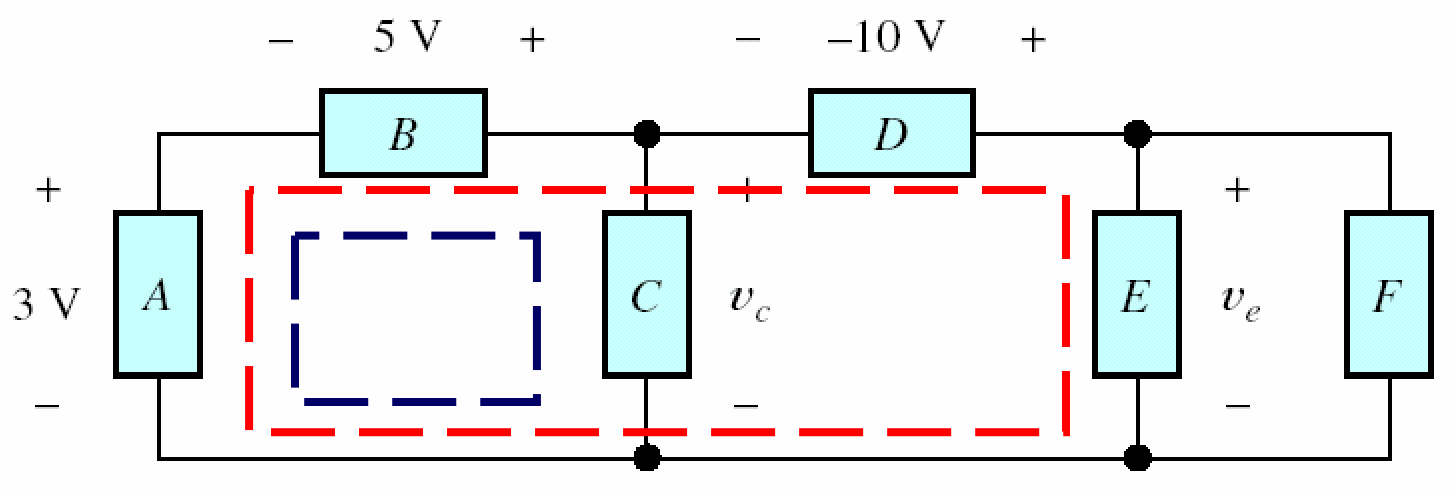
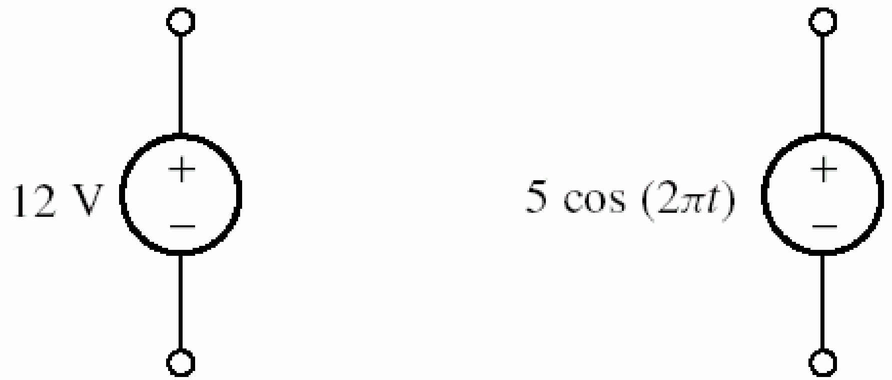


Figure 1.29 Circuit for Exercises 1.9 and 1.10.

Figure 1.30 Independent voltage sources.



(a) Constant or dc voltage source

(b) Ac voltage source

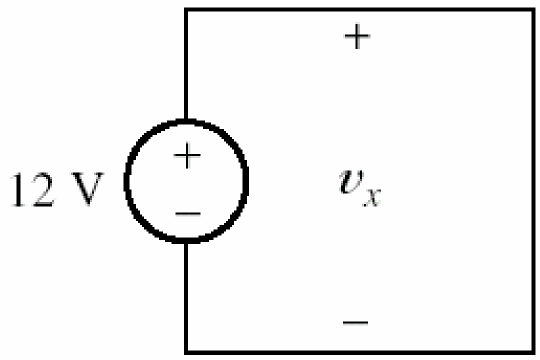


Figure 1.31 We avoid self-contradictory circuit diagrams such as this one.

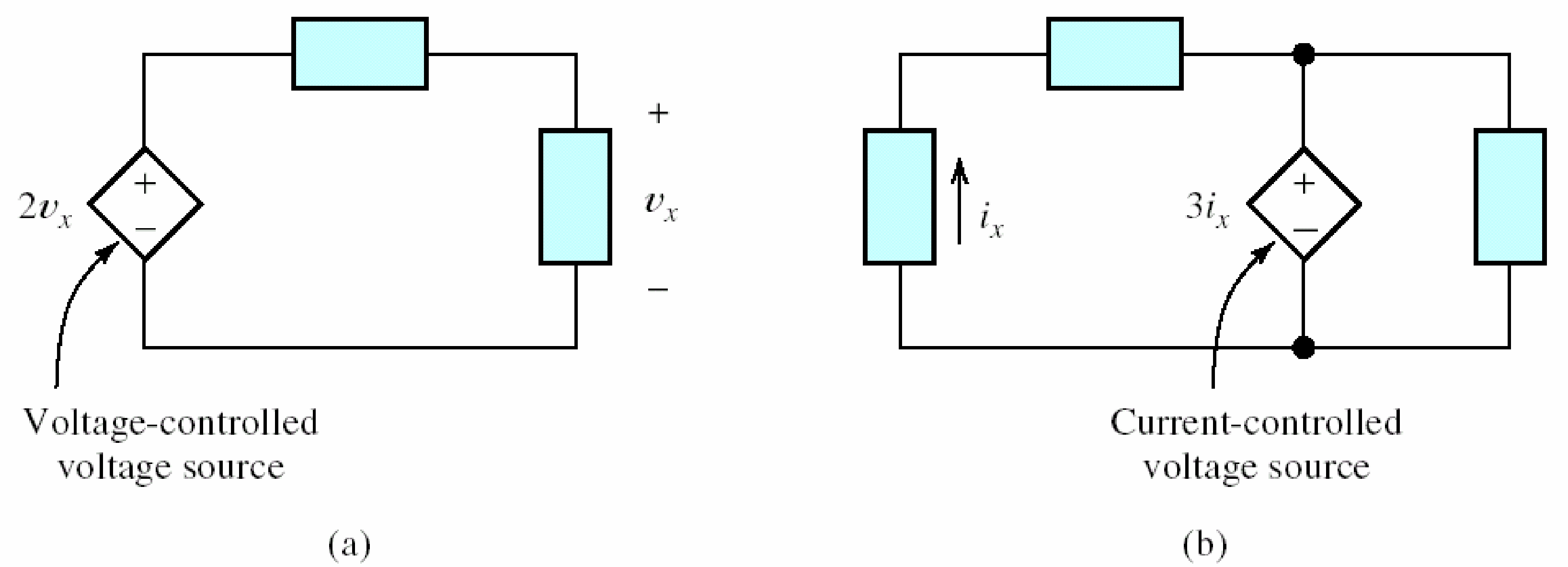
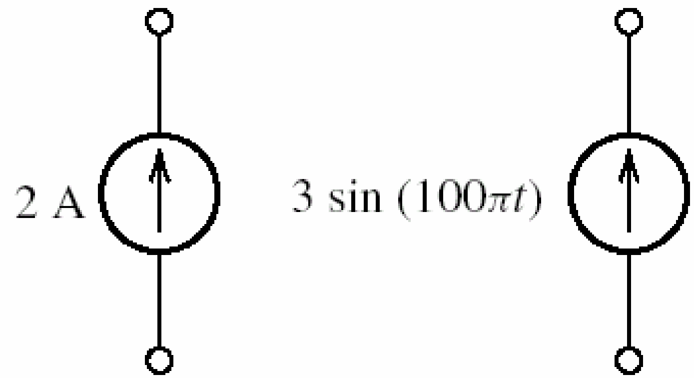


Figure 1.32 Dependent voltage sources (also known as controlled voltage sources) are represented by diamond-shaped symbols. The voltage across a controlled voltage source depends on a current or voltage that appears elsewhere in the circuit.

Figure 1.33 Independent current sources.



(a) Dc current source

(b) Ac current source

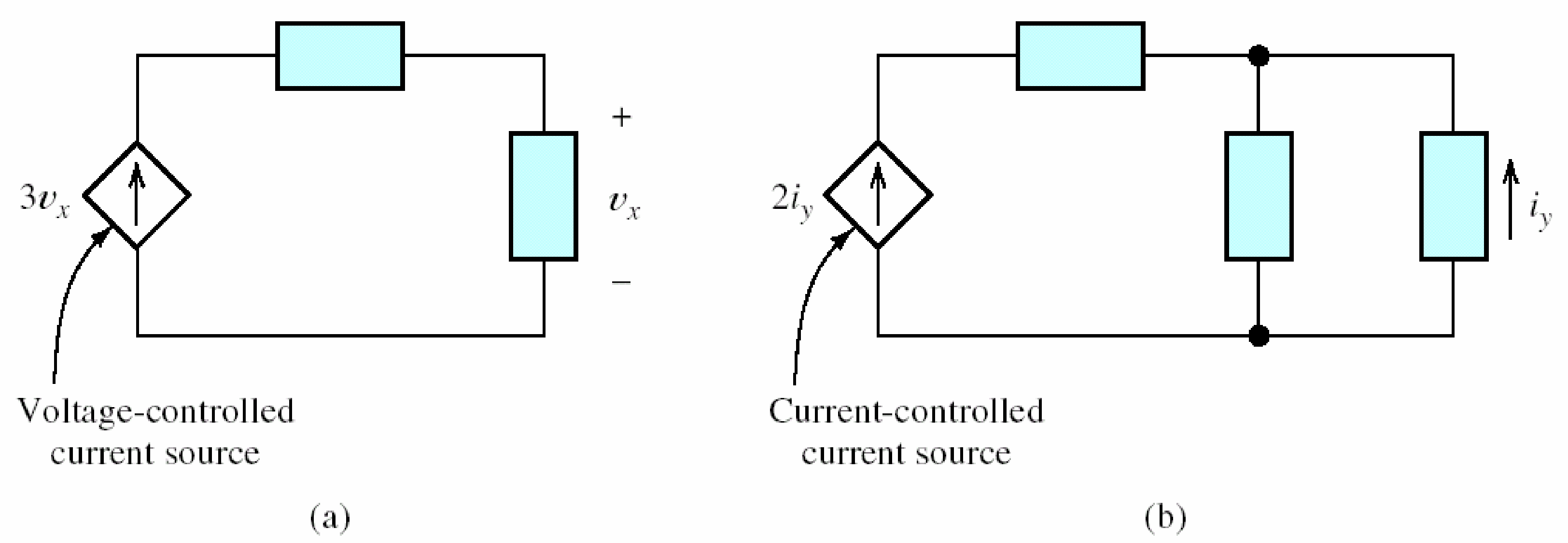
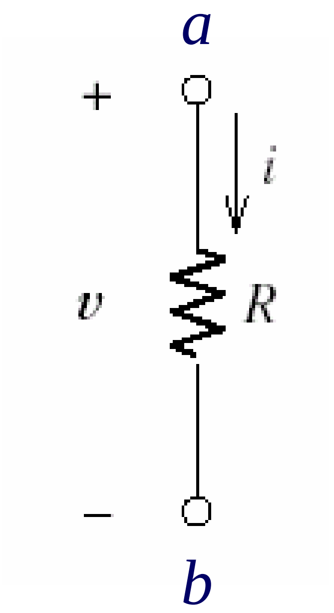


Figure 1.34 Dependent current sources. The current through a dependent current source depends on a current or voltage that appears elsewhere in the circuit.

Resistors and Ohm's Law



$$v = iR$$

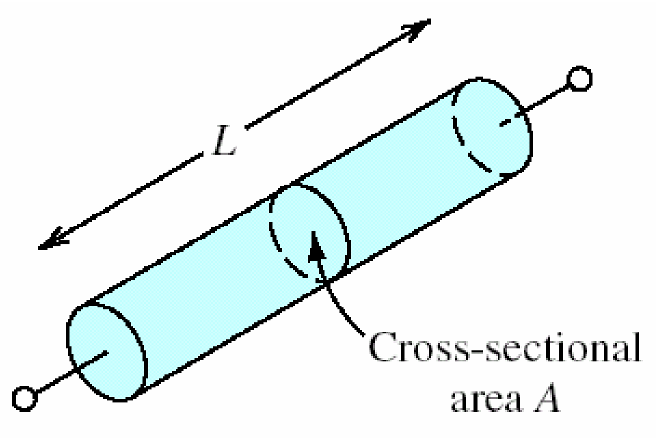
$$v_{ab} = i_{ab} R$$

Conductance

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

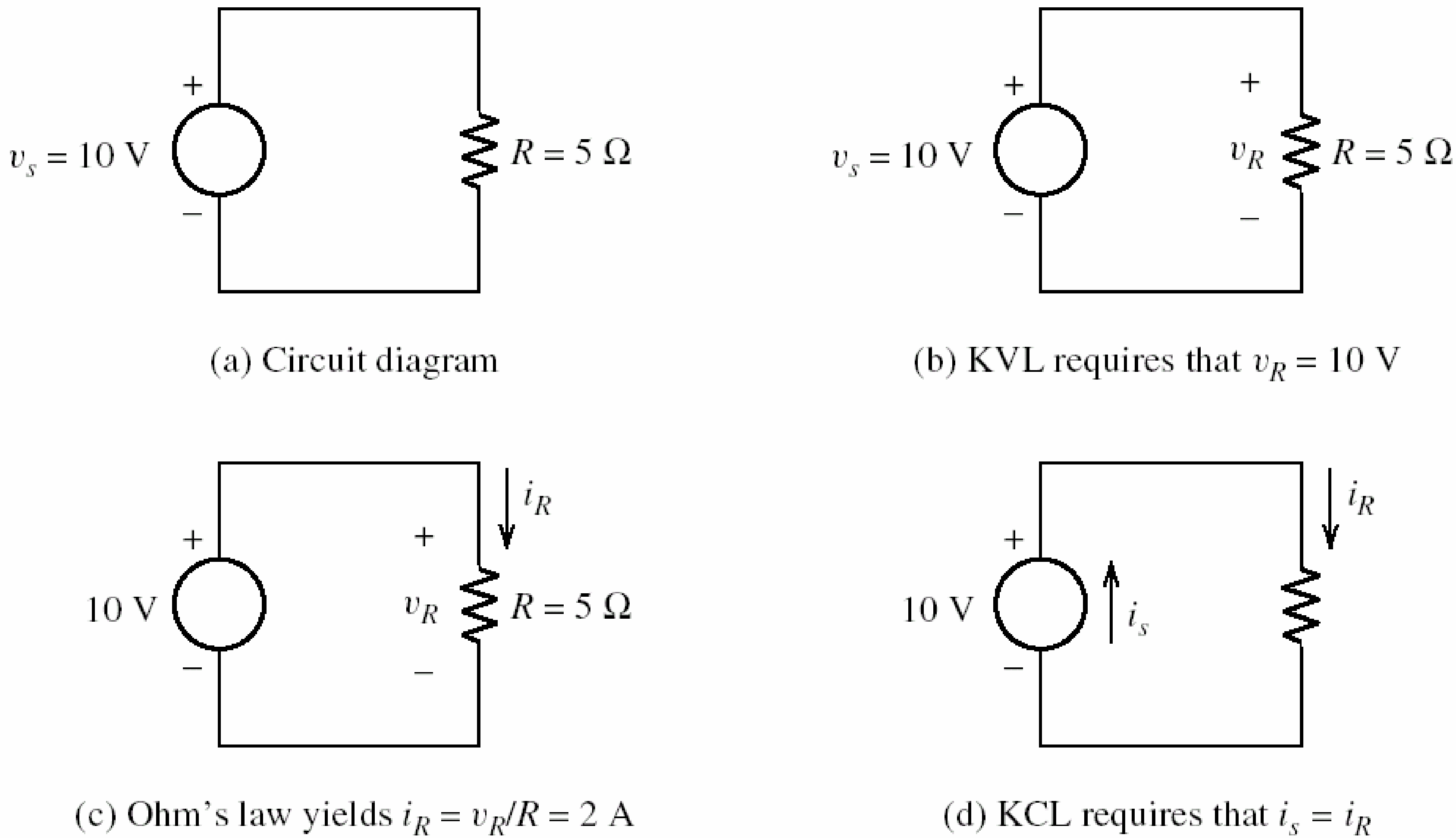
$$i = Gv$$

Resistance Related to Physical Parameters

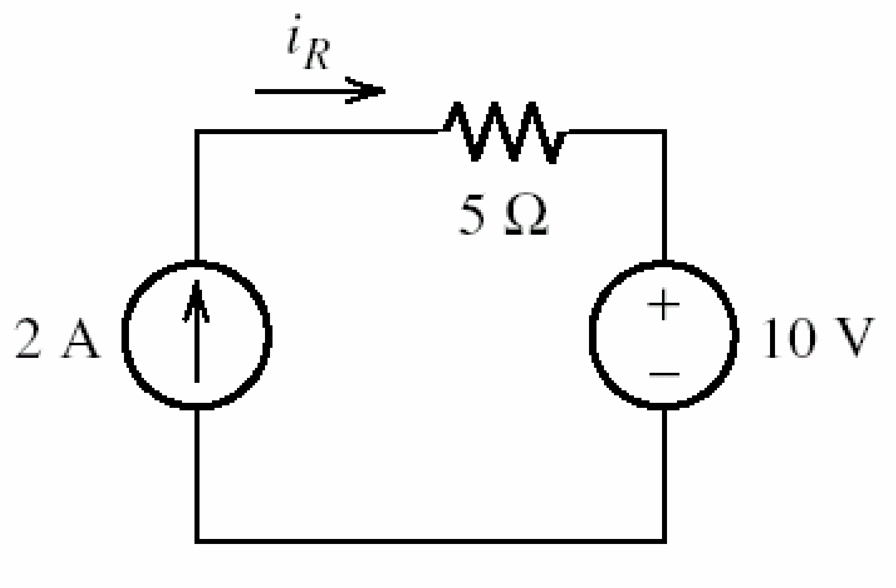


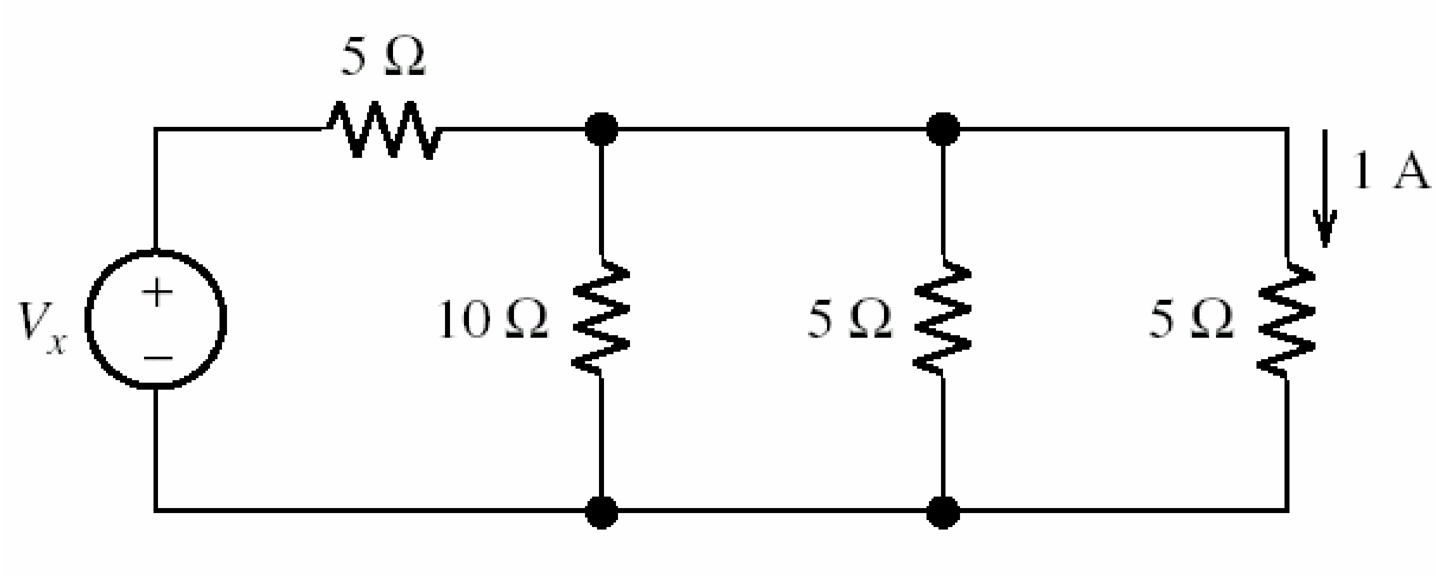
$$R = \frac{\rho L}{A}$$

Figure 1.39 A circuit consisting of a voltage source and a resistance.

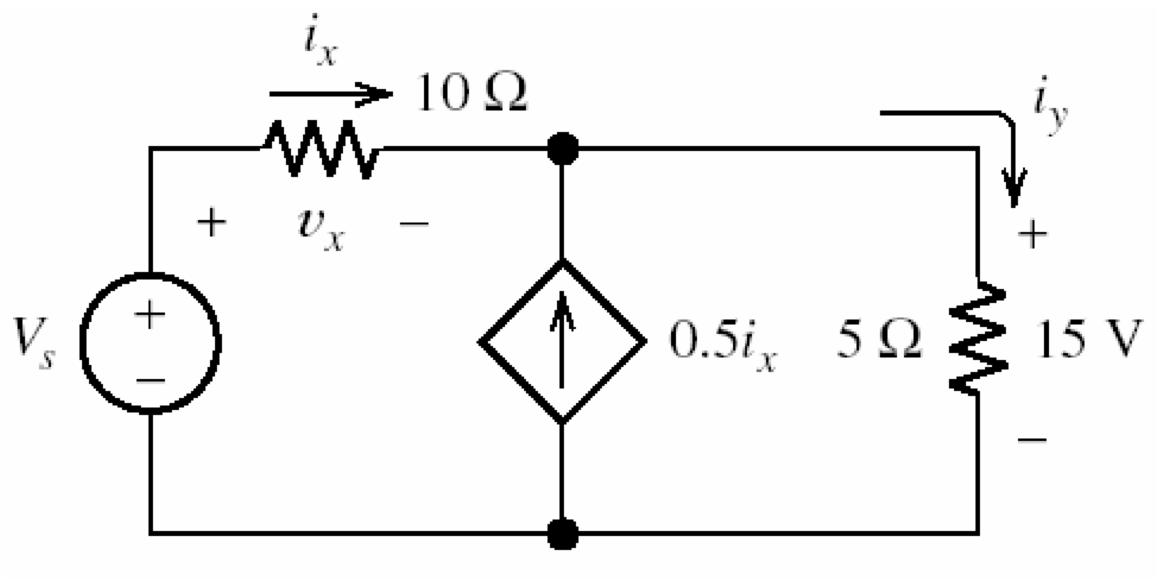


Voltage, current and power


i_R
5 Ω
2 A
+
−
10 V


5 Ω
1 A
V_x
+
−
10 Ω
5 Ω
5 Ω

Using KVL, KCL, and Ohm's Law to Solve a Circuit



$$i_y = \frac{15\,\text{V}}{5\,\Omega} = 3\,\text{A}$$

$$i_x + 0.5 i_x = i_y$$

$$i_x = 2\,\text{A}$$

$$v_x = 10 i_x = 20 \text{ V}$$

$$V_s = v_x + 15$$

$$V_s = 35 \text{ V}$$

Problem Set

- 6, 14, 19, 23, 28, 33, 48, 57