Problems

Section 1.2

1.1 Some species of bamboo can grow 250 mm/day. Assume individual cells in the plant are 10 μm long.

a) How long, on average, does it take a bamboo stalk to grow 1 cell length?

b) How many cell lengths are added in one week, on average?

1.2 One liter (L) of paint covers approximately 10 m^2 of wall. How thick is the layer before it dries? (*Hint*: $1 \text{ L} = 1 \times 10^6 \text{ mm}^3$.)

1.3 There are approximately 260 million passenger vehicles registered in the United States. Assume that the battery in the average vehicle stores 540 watt-hours (Wh) of energy. Estimate (in gigawatt-hours) the total energy stored in U.S. passenger vehicles.

1.4 The 16 giga-byte (GB = 2^{30} bytes) flash memory chip for an MP3 player is 11 mm by 15 mm by 1 mm. This memory chip holds 20,000 photos.

a) How many photos fit into a cube whose sides are 1 mm?

b) How many bytes of memory are stored in a cube whose sides are 200 μm?

1.5 A hand-held video player displays 480×320 picture elements (pixels) in each frame of the video. Each pixel requires 2 bytes of memory. Videos are displayed at a rate of 30 frames per second. How many hours of video will fit in a 32 gigabyte memory?

1.6 The line described in Assessment Problem 1.7 is 845 mi in length. The line contains four conductors, each weighing 2526 lb per 1000 ft. How many kilograms of conductor are in the line?

Section 1.4

1.7 How much energy is imparted to an electron as it flows through a 6 V battery from the positive to the negative terminal? Express your answer in attojoules.

1.8 In electronic circuits it is not unusual to encounter currents in the microampere range. Assume a 35 μA current, due to the flow of electrons. What is the average number of electrons per second that flow past a fixed reference cross section that is perpendicular to the direction of flow?

1.9 A current of 1600 A exists in a rectangular (0.4-by-16 cm) bus bar. The current is due to free electrons moving through the wire at an average velocity of v meters/second. If the concentration of free electrons is 10^{29} electrons per cubic meter and if they are uniformly dispersed throughout the wire, then what is the average velocity of an electron?

1.10 The current entering the upper terminal of Fig. 1.5 is

$$i = 20 \cos 5000t \text{ A}.$$

Assume the charge at the upper terminal is zero at the instant the current is passing through its maximum value. Find the expression for $q(t)$.

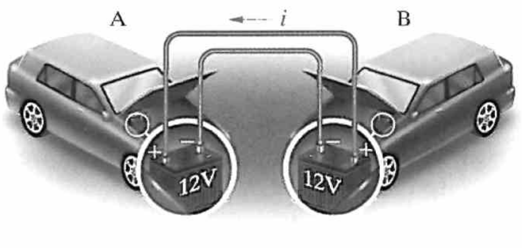
Sections 1.5–1.6

1.11 When a car has a dead battery, it can often be started by connecting the battery from another car across its terminals. The positive terminals are connected together as are the negative terminals. The connection is illustrated in Fig. P1.11. Assume the current i in Fig. P1.11 is measured and found to be 30 A.

a) Which car has the dead battery?

b) If this connection is maintained for 1 min, how much energy is transferred to the dead battery?

Figure P1.11



1.12 One 12 V battery supplies 100 mA to a boom box. How much energy does the battery supply in 4 h?

1.13 The manufacturer of a 1.5 V D flashlight battery says that the battery will deliver 9 mA for 40 continuous hours. During that time the voltage will drop from 1.5 V to 1.0 V. Assume the drop in voltage is linear with time. How much energy does the battery deliver in this 40 h interval?

1.14 Two electric circuits, represented by boxes A and B, are connected as shown in Fig. P1.14. The reference direction for the current i in the interconnection and the reference polarity for the voltage v across the interconnection are as shown in the figure. For each of the following sets of numerical values, calculate the power in the interconnection and state whether the power is flowing from A to B or vice versa.

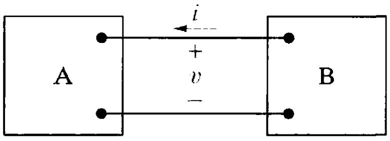
a) $i = 10$ A, $v = 125$ V

b) $i = 5$ A, $v = -240$ V

c) $i = -12$ A, $v = 480$ V

d) $i = -25$ A, $v = -660$ V

Figure P1.14



1.15 The references for the voltage and current at the terminal of a circuit element are as shown in Fig. 1.6(d). The numerical values for v and i are 40 V and −10 A.

a) Calculate the power at the terminals and state whether the power is being absorbed or delivered by the element in the box.

b) Given that the current is due to electron flow, state whether the electrons are entering or leaving terminal 2.

c) Do the electrons gain or lose energy as they pass through the element in the box?

1.16 Repeat Problem 1.15 with a voltage of −60 V.

1.17 PSPICE MULTISIM The voltage and current at the terminals of the circuit element in Fig. 1.5 are zero for $t < 0$. For $t \geq 0$ they are

$$v = 75 - 75e^{-1000t}\ \text{V},$$

$$i = 50e^{-1000t}\ \text{mA}.$$

a) Find the maximum value of the power delivered to the circuit.

b) Find the total energy delivered to the element.

1.18 The voltage and current at the terminals of the circuit element in Fig. 1.5 are zero for $t < 0$. For $t \geq 0$ they are

$$v = 50e^{-1600t} - 50e^{-400t}\ \text{V},$$

$$i = 5e^{-1600t} - 5e^{-400t}\ \text{mA}.$$

a) Find the power at $t = 625\ \mu$s.

b) How much energy is delivered to the circuit element between 0 and 625 μs?

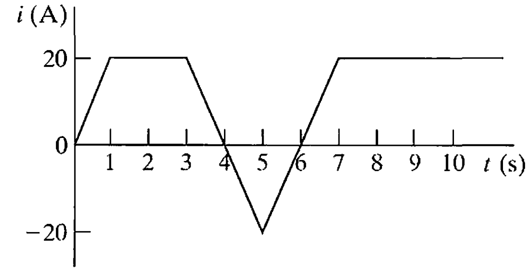
c) Find the total energy delivered to the element.

1.19 The voltage and current at the terminals of the circuit element in Fig. 1.5 are shown in Fig. P1.19.

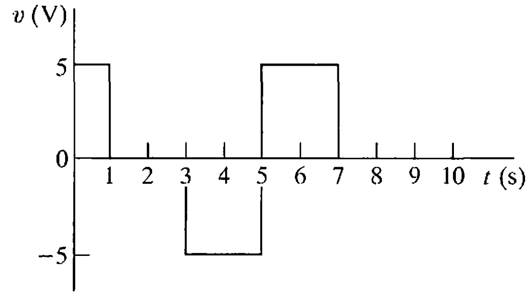
a) Sketch the power versus t plot for $0 \leq t \leq 10$ s.

b) Calculate the energy delivered to the circuit element at $t = 1$, 6, and 10 s.

Figure P1.19



(a)



(b)

1.20 PSPICE MULTISIM The voltage and current at the terminals of the circuit element in Fig. 1.5 are zero for $t < 0$. For $t \geq 0$ they are

$$v = 400e^{-100t} \sin 200t\ \text{V},$$

$$i = 5e^{-100t} \sin 200t\ \text{A}.$$

a) Find the power absorbed by the element at $t = 10$ ms.

b) Find the total energy absorbed by the element.

1.21 PSPICE MULTISIM The voltage and current at the terminals of the circuit element in Fig. 1.5 are zero for $t < 0$. For $t \geq 0$ they are

$$v = (16{,}000t + 20)e^{-800t}\ \text{V},$$

$$i = (128t + 0.16)e^{-800t}\ \text{A}.$$

a) At what instant of time is maximum power delivered to the element?

b) Find the maximum power in watts.

c) Find the total energy delivered to the element in millijoules.

1.22 PSPICE MULTISIM The voltage and current at the terminals of the circuit element in Fig. 1.5 are zero for $t < 0$. For $t \geq 0$ they are

$$v = (10{,}000t + 5)e^{-400t}\ \text{V}, \quad t \geq 0;$$

$$i = (40t + 0.05)e^{-400t}\ \text{A}, \quad t \geq 0.$$

a) Find the time (in milliseconds) when the power delivered to the circuit element is maximum.

b) Find the maximum value of p in milliwatts.

c) Find the total energy delivered to the circuit element in millijoules.

1.23 The voltage and current at the terminals of the element in Fig. 1.5 are
PSPICE
MULTISIM

$$v = 250 \cos 800\pi t \text{ V}, \quad i = 8 \sin 800\pi t \text{ A}.$$

a) Find the maximum value of the power being delivered to the element.

b) Find the maximum value of the power being extracted from the element.

c) Find the average value of p in the interval $0 \le t \le 2.5$ ms.

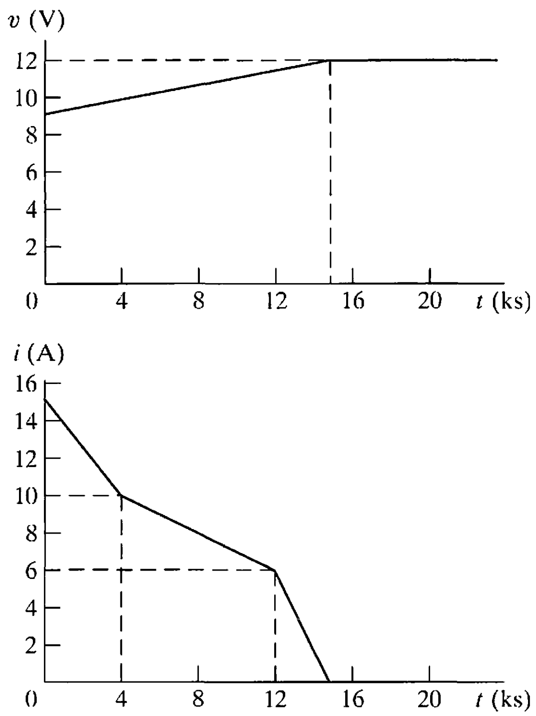
d) Find the average value of p in the interval $0 \le t \le 15.625$ ms.

1.24 The voltage and current at the terminals of an automobile battery during a charge cycle are shown in Fig. P1.24.
PSPICE
MULTISIM

a) Calculate the total charge transferred to the battery.

b) Calculate the total energy transferred to the battery.

Figure P1.24



1.25 The voltage and current at the terminals of the circuit element in Fig. 1.5 are zero for $t < 0$ and $t > 40$ s. In the interval between 0 and 40 s the expressions are
PSPICE
MULTISIM

$$v = t(1 - 0.025t) \text{ V}, \quad 0 < t < 40 \text{ s};$$

$$i = 4 - 0.2t \text{ A}, \quad 0 < t < 40 \text{ s}.$$

a) At what instant of time is the power being delivered to the circuit element maximum?

b) What is the power at the time found in part (a)?

c) At what instant of time is the power being extracted from the circuit element maximum?

d) What is the power at the time found in part (c)?

e) Calculate the net energy delivered to the circuit at 0, 10, 20, 30 and 40 s.

1.26 The numerical values for the currents and voltages in the circuit in Fig. P1.26 are given in Table P1.26. Find the total power developed in the circuit.

Figure P1.26

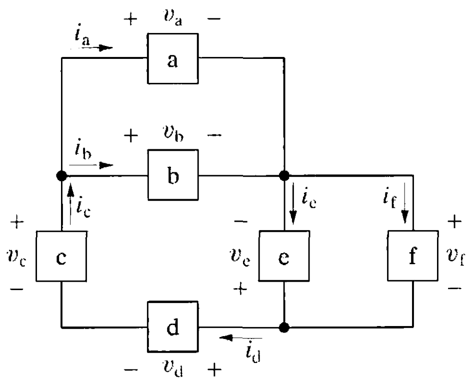


TABLE P1.26

Element	Voltage (kV)	Current (mA)
a	150	0.6
b	150	−1.4
c	100	−0.8
d	250	−0.8
e	300	−2.0
f	−300	1.2

1.27 The numerical values of the voltages and currents in the interconnection seen in Fig. P1.27 are given in Table P1.27. Does the interconnection satisfy the power check?

Figure P1.27

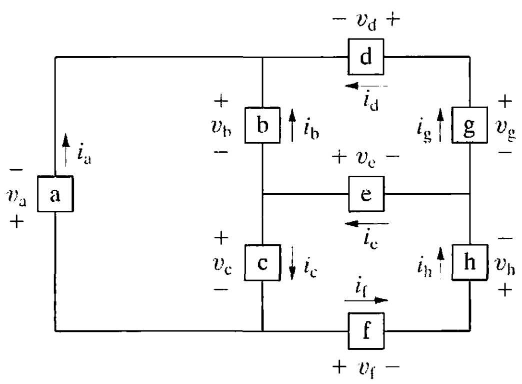


TABLE P1.27

Element	Voltage (V)	Current (mA)
a	990	−22.5
b	600	−30
c	300	60
d	105	52.5
e	−120	30
f	165	82.5
g	585	52.5
h	−585	82.5

1.28 Assume you are an engineer in charge of a project and one of your subordinate engineers reports that the interconnection in Fig. P1.28 does not pass the power check. The data for the interconnection are given in Table P1.28.

a) Is the subordinate correct? Explain your answer.

b) If the subordinate is correct, can you find the error in the data?

Figure P1.28

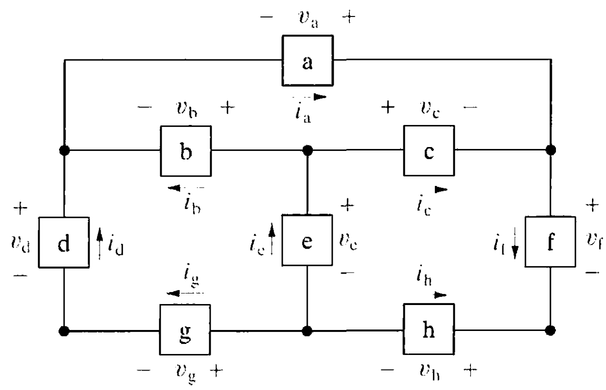


TABLE P1.28

Element	Voltage (V)	Current (A)
a	46.16	6.0
b	14.16	4.72
c	−32.0	−6.4
d	22.0	1.28
e	33.6	1.68
f	66.0	−0.4
g	2.56	1.28
h	−0.4	0.4

1.29 a) The circuit shown in Fig. P1.29 identifies voltage polarities and current directions to be used in calculating power for each component. Using only the voltage polarities and current directions, predict which components supply power and which components absorb power, using the passive sign convention.

b) The numerical values of the currents and voltages for each element are given in Table P1.29. How much total power is absorbed and how much is delivered in this circuit?

c) Based on the computations in part (b), identify the components that supply power and those that absorb power. Why are these answers different from the ones in part (a)?

Figure P1.29

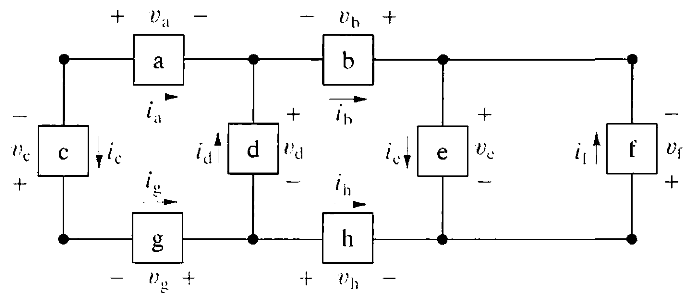


TABLE P1.29

Element	Voltage (V)	Current (mA)
a	5	2
b	1	3
c	7	−2
d	−9	1
e	−20	5
f	20	2
g	−3	−2
h	−12	−3

1.30 One method of checking calculations involving interconnected circuit elements is to see that the total power delivered equals the total power absorbed (conservation-of-energy principle). With this thought in mind, check the interconnection in Fig. P1.30 and state whether it satisfies this power check. The current and voltage values for each element are given in Table P1.30.

Figure P1.30

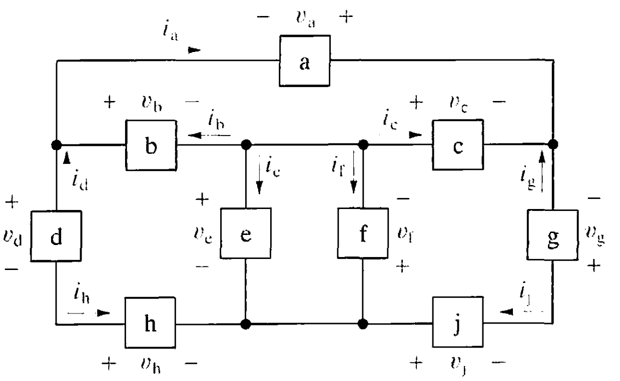


TABLE P1.30

Element	Voltage (V)	Current (mA)
a	1.6	80
b	2.6	60
c	−4.2	−50
d	1.2	20
e	1.8	30
f	−1.8	−40
g	−3.6	−30
h	3.2	−20
j	−2.4	30

1.31 Show that the power balances for the circuit shown in Fig. 1.7, using the voltage and current values given in Table 1.4, with the value of the current for component d changed to −1 A.

1.32 Suppose there is no power lost in the wires used to distribute power in a typical home.

a) Create a new model for the power distribution circuit by modifying the circuit shown in Fig 1.7. Use the same names, voltage polarities, and current directions for the components that remain in this modified model.

b) The following voltages and currents are calculated for the components:

$v_a = 120$ V $\quad i_a = -10$ A
$v_b = 120$ V $\quad i_b = 10$ A
$v_f = -120$ V $\quad i_f = 3$ A
$v_g = 120$ V
$v_h = -240$ V $\quad i_h = -7$ A

If the power in this modified model balances, what is the value of the current in component g?

CHAPTER

2

Circuit Elements

CHAPTER CONTENTS

✓CHAPTER OBJECTIVES

1 Understand the symbols for and the behavior of the following ideal basic circuit elements: independent voltage and current sources, dependent voltage and current sources, and resistors.

2 Be able to state Ohm's law, Kirchhoff's current law, and Kirchhoff's voltage law, and be able to use these laws to analyze simple circuits.

3 Know how to calculate the power for each element in a simple circuit and be able to determine whether or not the power balances for the whole circuit.

There are five ideal basic circuit elements: voltage sources, current sources, resistors, inductors, and capacitors. In this chapter we discuss the characteristics of voltage sources, current sources, and resistors. Although this may seem like a small number of elements with which to begin analyzing circuits, many practical systems can be modeled with just sources and resistors. They are also a useful starting point because of their relative simplicity; the mathematical relationships between voltage and current in sources and resistors are algebraic. Thus you will be able to begin learning the basic techniques of circuit analysis with only algebraic manipulations.

We will postpone introducing inductors and capacitors until Chapter 6, because their use requires that you solve integral and differential equations. However, the basic analytical techniques for solving circuits with inductors and capacitors are the same as those introduced in this chapter. So, by the time you need to begin manipulating more difficult equations, you should be very familiar with the methods of writing them.