Summary

- The circuit elements introduced in this chapter are voltage sources, current sources, and resistors:
  - An **ideal voltage source** maintains a prescribed voltage regardless of the current in the source. An **ideal current source** maintains a prescribed current regardless of the voltage across the source. Voltage and current sources are either **independent**, that is, not influenced by any other current or voltage in the circuit, or **dependent**, that is, determined by some other current or voltage in the circuit. (See pages 28 and 29.)
  - A **resistor** constrains its voltage and current to be proportional to each other. The value of the proportional constant relating voltage and current in a resistor is called its **resistance** and is measured in ohms. (See page 32.)
- **Ohm's law** establishes the proportionality of voltage and current in a resistor. Specifically,

$$v = iR$$

if the current flow in the resistor is in the direction of the voltage drop across it, or

$$v = -iR$$

if the current flow in the resistor is in the direction of the voltage rise across it. (See page 32.)

- By combining the equation for power, $p = vi$, with Ohm's law, we can determine the power absorbed by a resistor:

$$p = i^2R = v^2/R.$$

(See pages 33–34.)

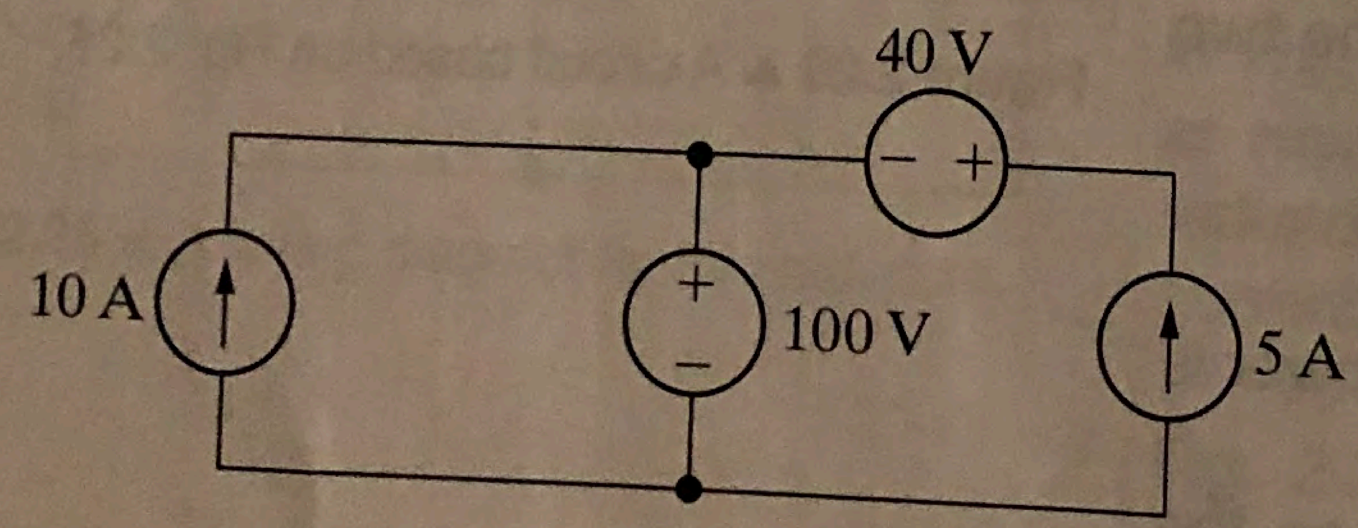
- Circuits have nodes and closed paths. A **node** is a point where two or more circuit elements join. When just two elements connect to form a node, they are said to be **in series**. A **closed path** is a loop traced through connecting elements, starting and ending at the same node and encountering intermediate nodes only once each. (See pages 39–40.)
- The voltages and currents of interconnected circuit elements obey Kirchhoff's laws:
  - **Kirchhoff's current law** states that the algebraic sum of all the currents at any node in a circuit equals zero. (See page 39.)
  - **Kirchhoff's voltage law** states that the algebraic sum of all the voltages around any closed path in a circuit equals zero. (See page 40.)
- A circuit is solved when the voltage across and the current in every element have been determined. By combining an understanding of independent and dependent sources, Ohm's law, and Kirchhoff's laws, we can solve many simple circuits.

Problems

Section 2.1

2.1 If the interconnection in Fig. P2.1 is valid, find the power developed by the current sources. If the interconnection is not valid, explain why.

Figure P2.1



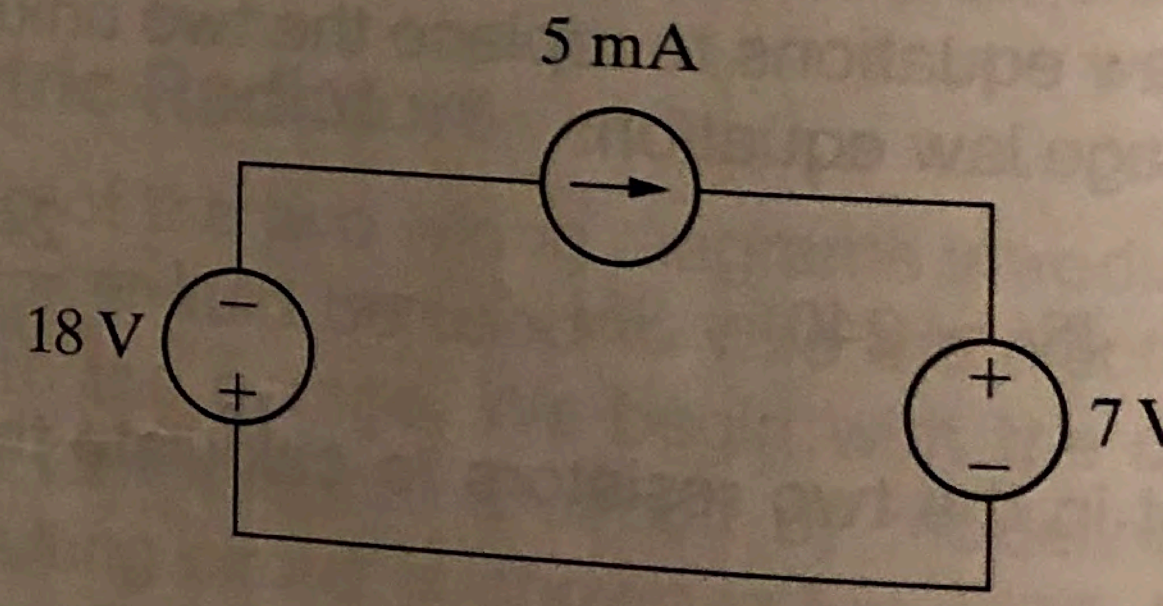
2.2 a) Is the interconnection of ideal sources in the circuit in Fig. P2.2 valid? Explain.

b) Identify which sources are developing power and which sources are absorbing power.

c) Verify that the total power developed in the circuit equals the total power absorbed.

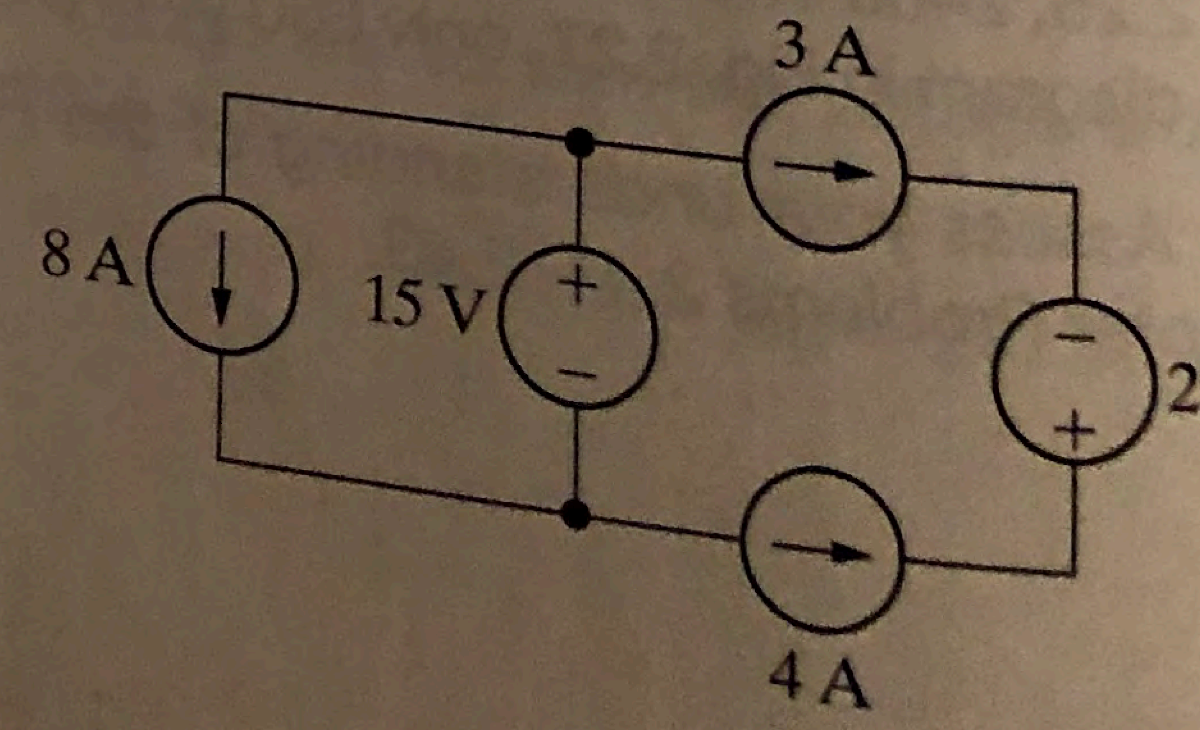
d) Repeat (a)–(c), reversing the polarity of the 18 V source.

Figure P2.2



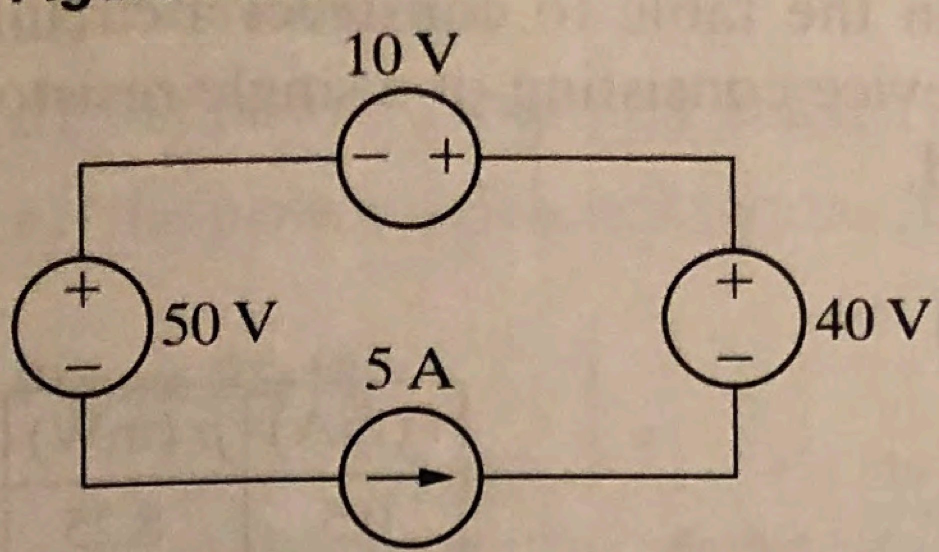
2.3 If the interconnection in Fig. P2.3 is valid, find the total power developed by the voltage sources. If the interconnection is not valid, explain why.

Figure P2.3



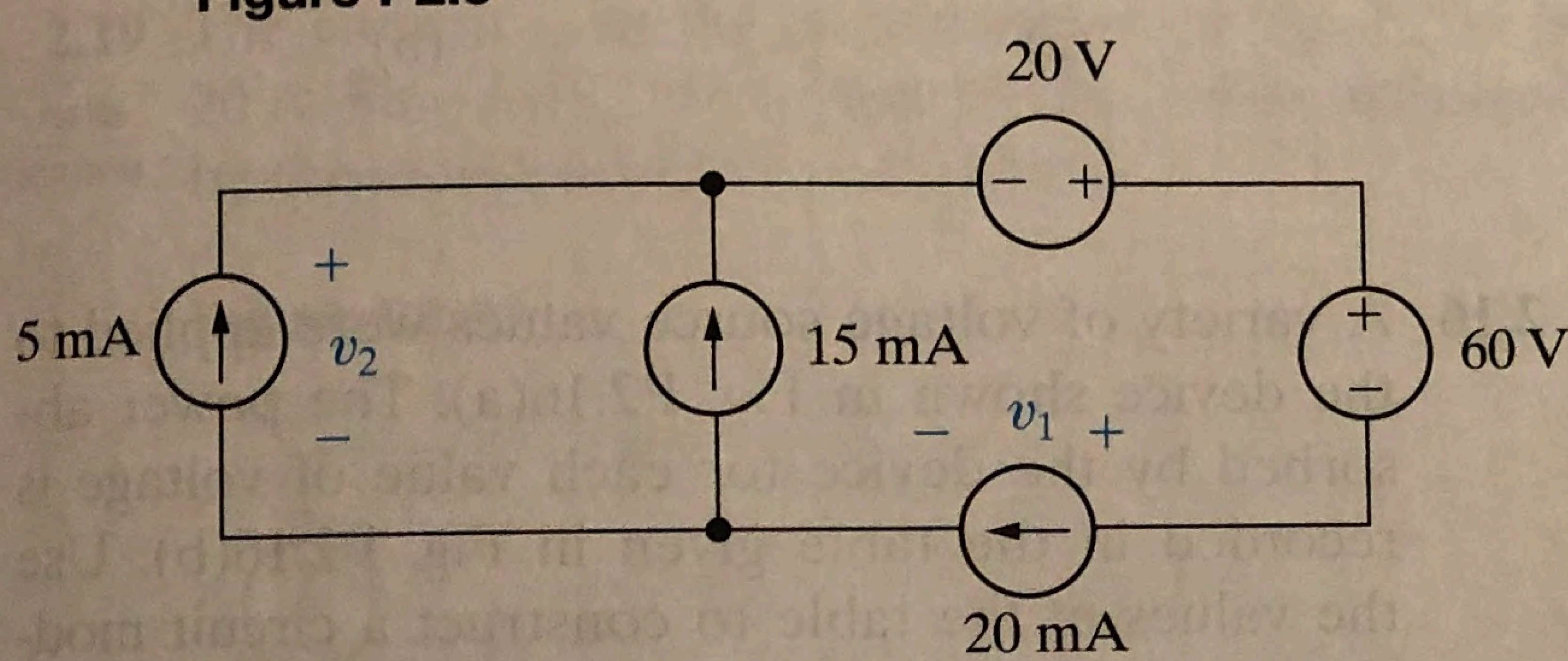
2.4 If the interconnection in Fig. P2.4 is valid, find the total power developed in the circuit. If the interconnection is not valid, explain why.

Figure P2.4



2.5 The interconnection of ideal sources can lead to an indeterminate solution. With this thought in mind, explain why the solutions for v_1 and v_2 in the circuit in Fig. P2.5 are not unique.

Figure P2.5



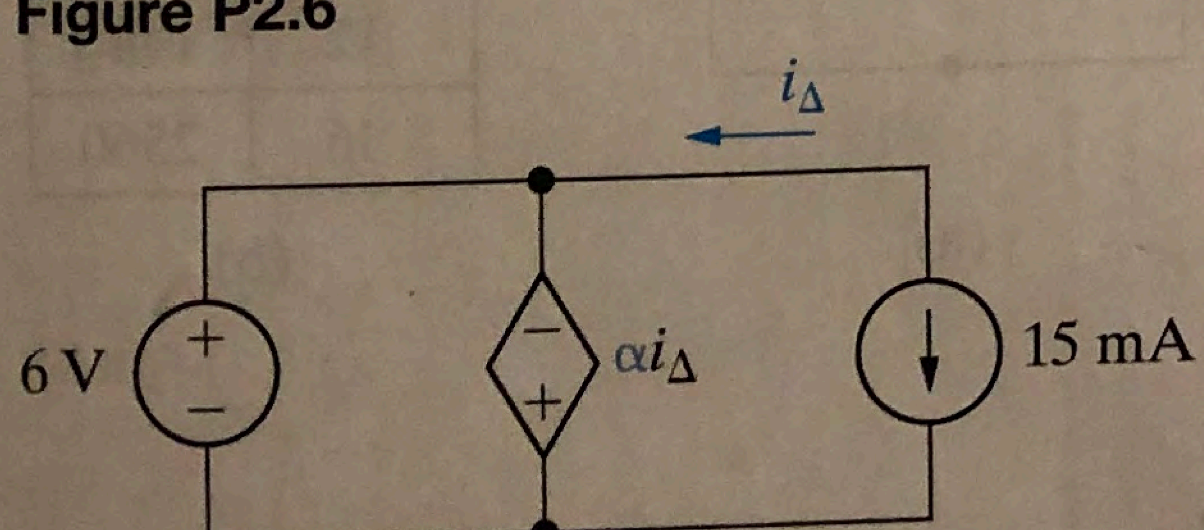
2.6 Consider the interconnection shown in Fig. P2.6.

a) What value of α is required to make this a valid interconnection?

b) For this value of α, find the power associated with the current source.

c) Is the current source supplying or absorbing power?

Figure P2.6

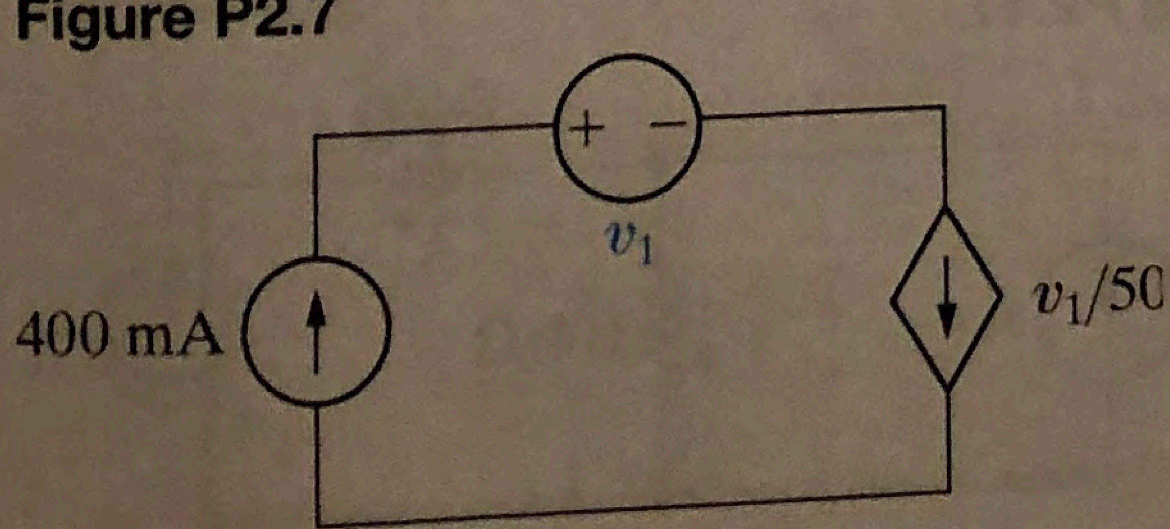


2.7 Consider the interconnection shown in Fig. P2.7.

a) What value of v_1 is required to make this a valid interconnection?

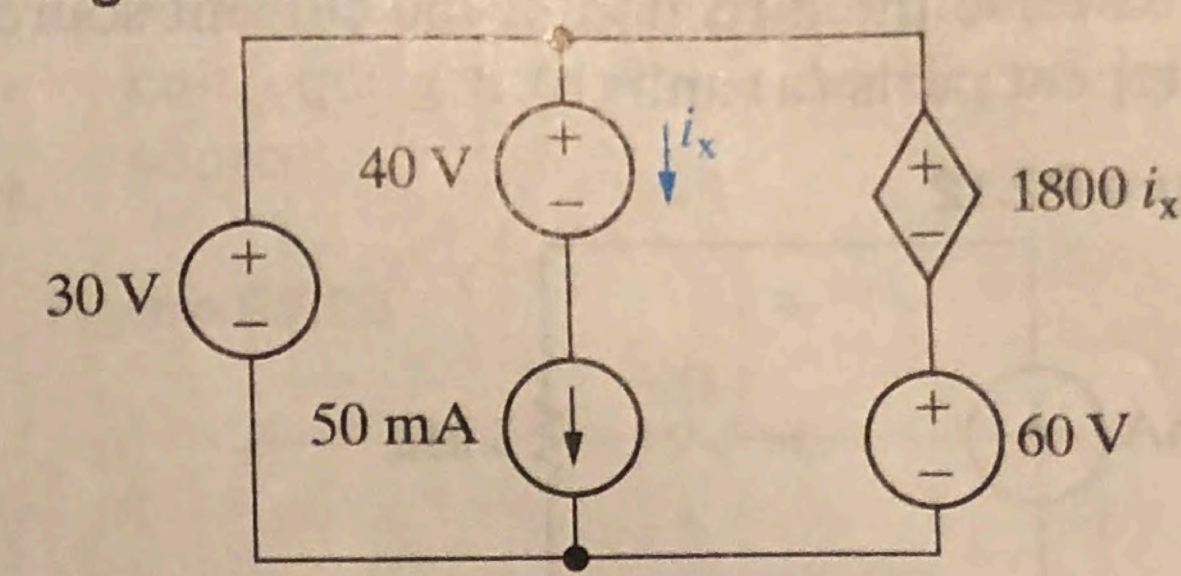
b) For this value of v_1, find the power associated with the voltage source.

Figure P2.7



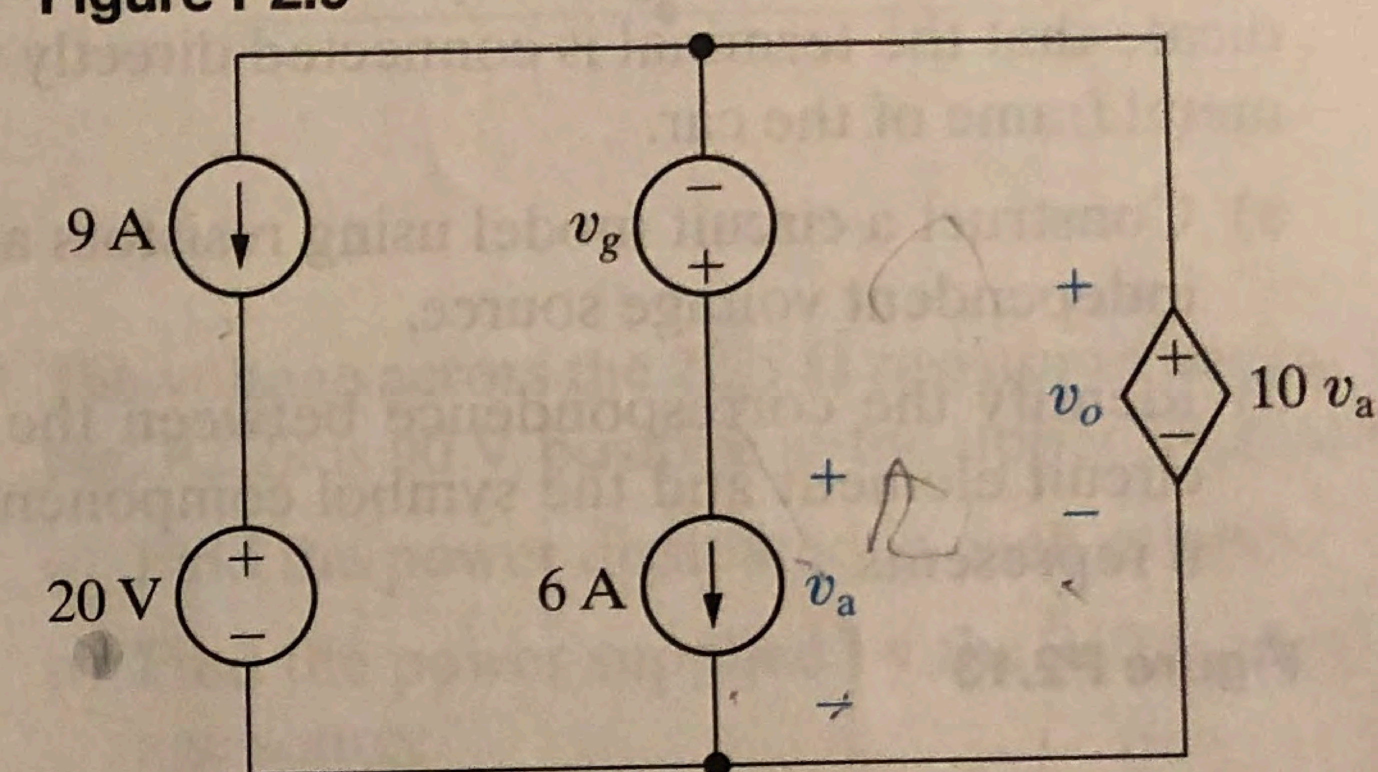
2.8 If the interconnection in Fig. P2.8 is valid, find the total power developed in the circuit. If the interconnection is not valid, explain why.

Figure P2.8



2.9 Find the total power developed in the circuit in Fig. P2.9 if $v_o = 5$ V.

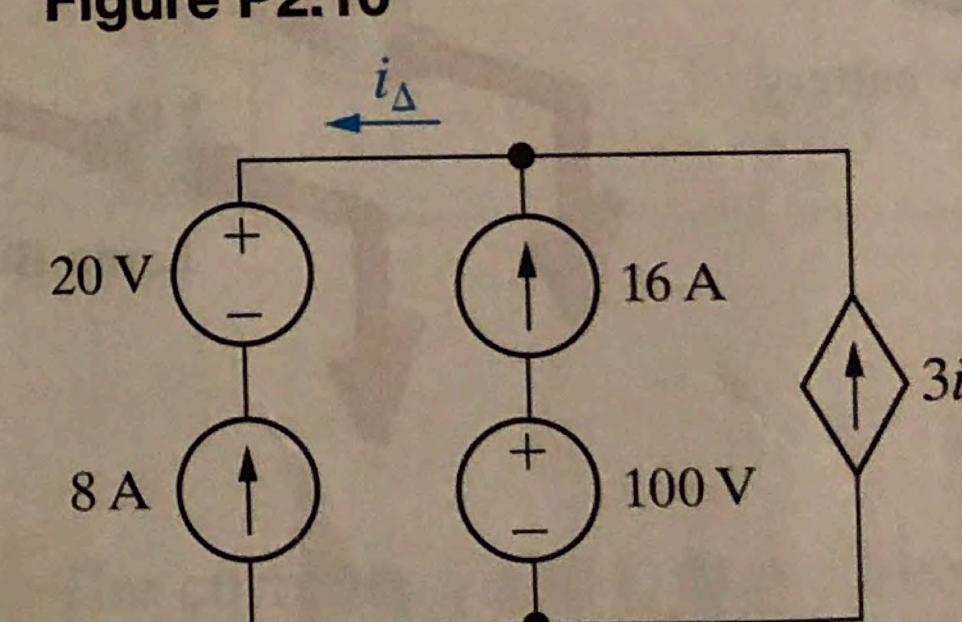
Figure P2.9



2.10 a) Is the interconnection in Fig. P2.10 valid? Explain.

b) Can you find the total energy developed in the circuit? Explain.

Figure P2.10



Sections 2.2–2.3

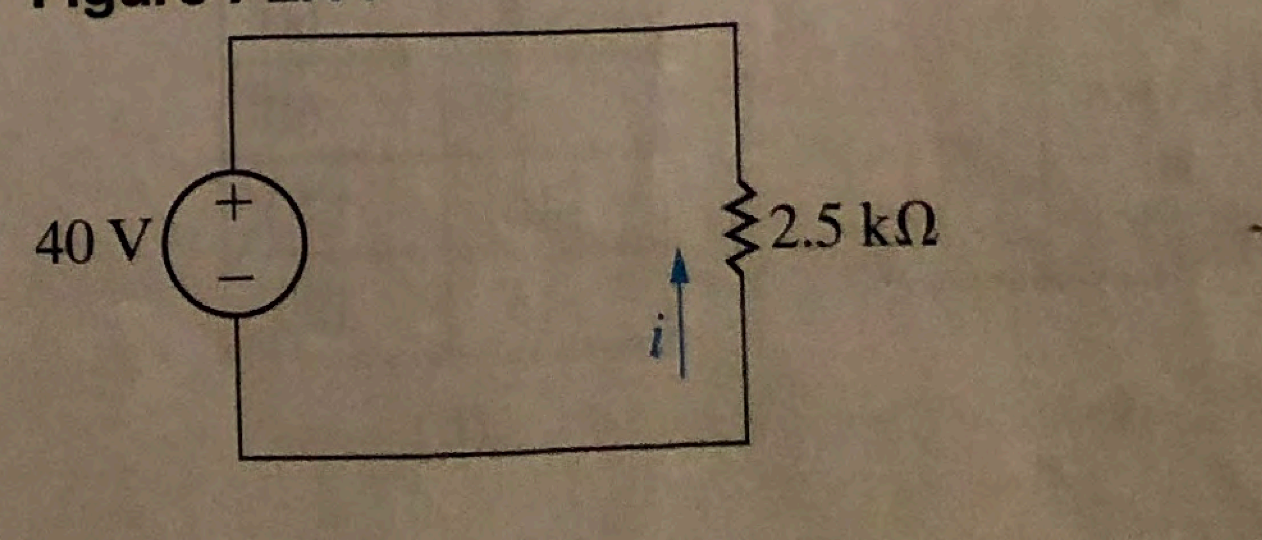
2.11 For the circuit shown in Fig. P2.11

a) Find i.

b) Find the power supplied by the voltage source.

c) Reverse the polarity of the voltage source and repeat parts (a) and (b).

Figure P2.11



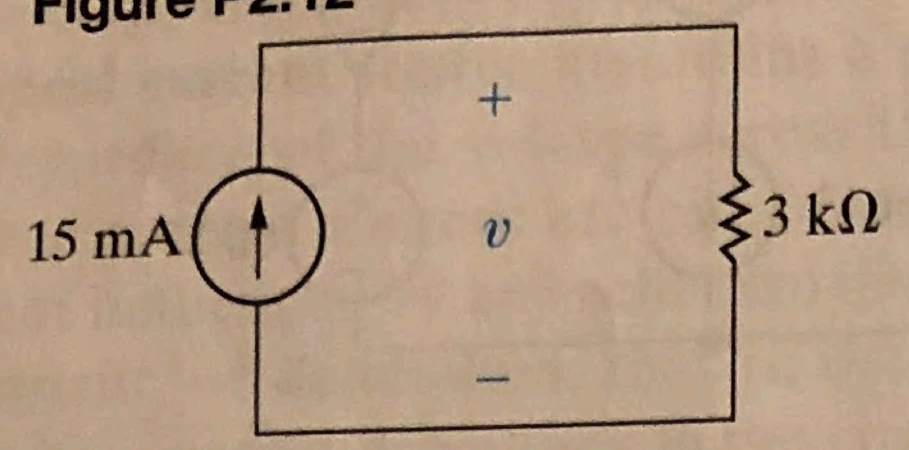
2.12 For the circuit shown in Fig. P2.12

a) Find v.

b) Find the power absorbed by the resistor.

c) Reverse the direction of the current source and repeat parts (a) and (b).

Figure P2.12

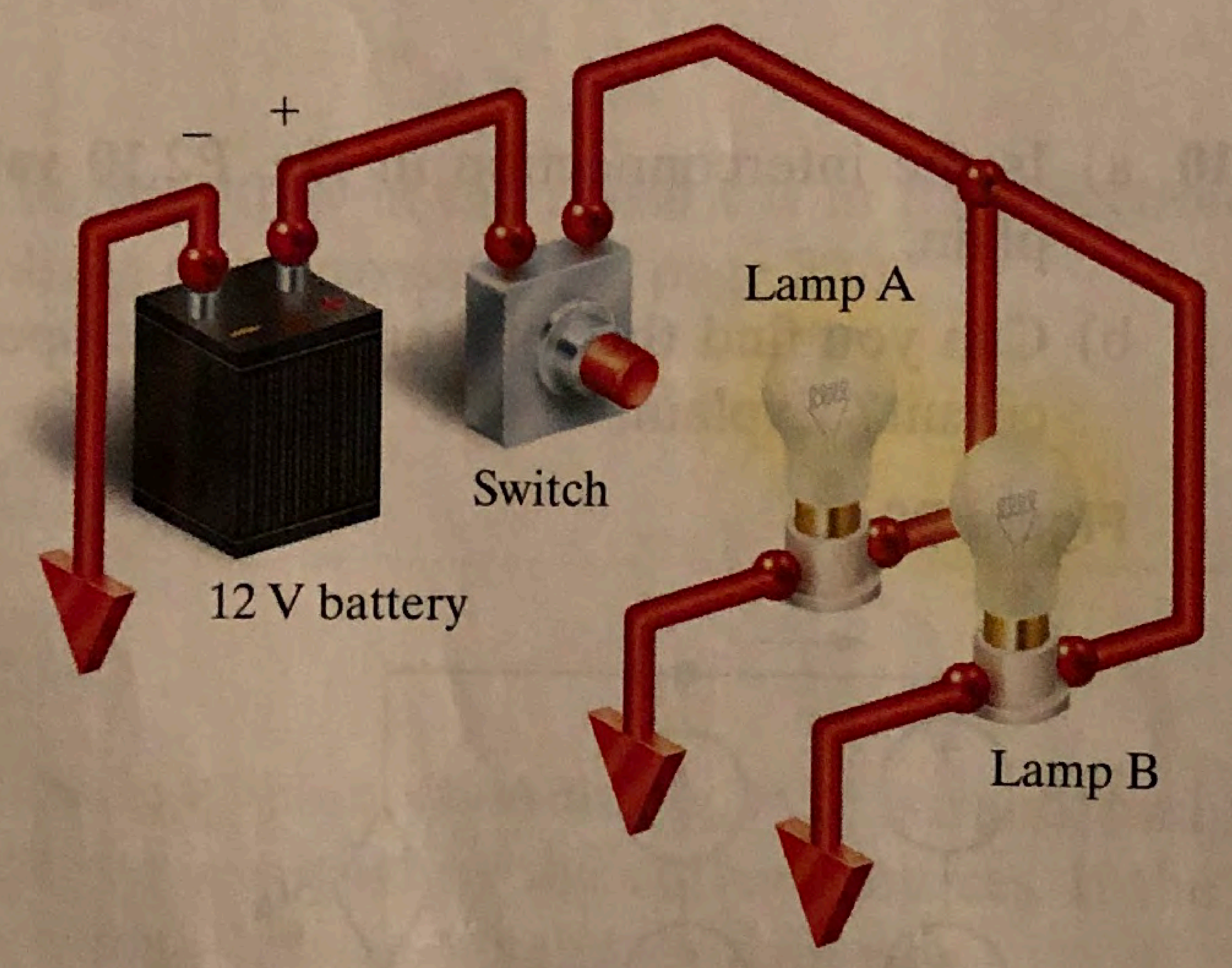


2.13 A pair of automotive headlamps is connected to a 12 V battery via the arrangement shown in Fig. P2.13. In the figure, the triangular symbol ▼ is used to indicate that the terminal is connected directly to the metal frame of the car.

a) Construct a circuit model using resistors and an independent voltage source.

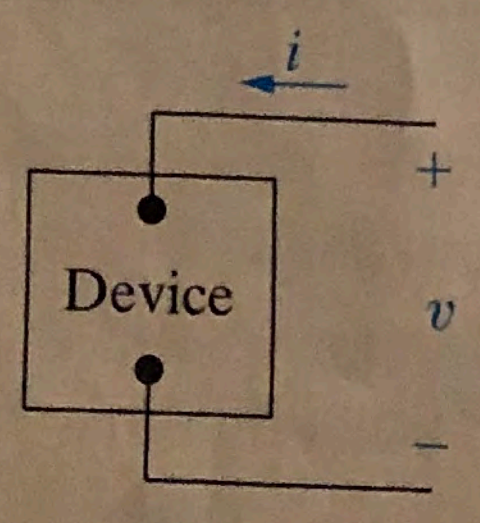
b) Identify the correspondence between the ideal circuit element and the symbol component that it represents.

Figure P2.13



2.14 The terminal voltage and terminal current were measured on the device shown in Fig. P2.14(a). The values of v and i are given in the table of Fig. P2.14(b). Use the values in the table to construct a circuit model for the device consisting of a single resistor from Appendix H.

Figure P2.14



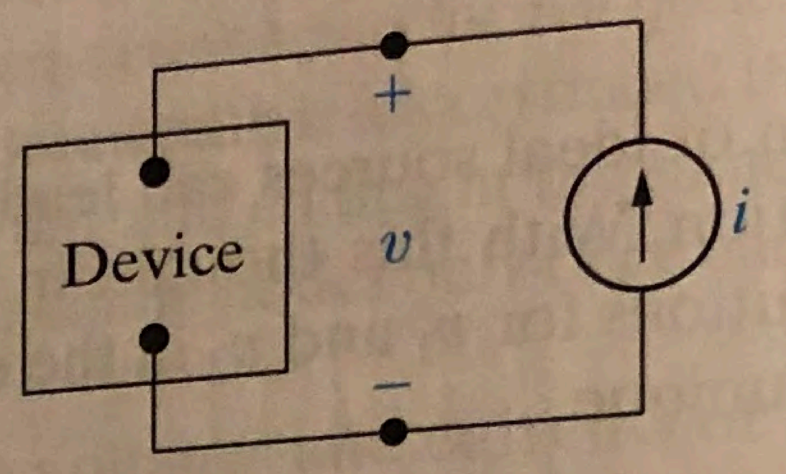
(a)

i (mA)	v (V)
−10	−120
−5	−60
5	60
10	120
15	180

(b)

2.15 A variety of current source values were applied to the device shown in Fig. P2.15(a). The power absorbed by the device for each value of current is recorded in the table given in Fig. P2.15(b). Use the values in the table to construct a circuit model for the device consisting of a single resistor from Appendix H.

Figure P2.15



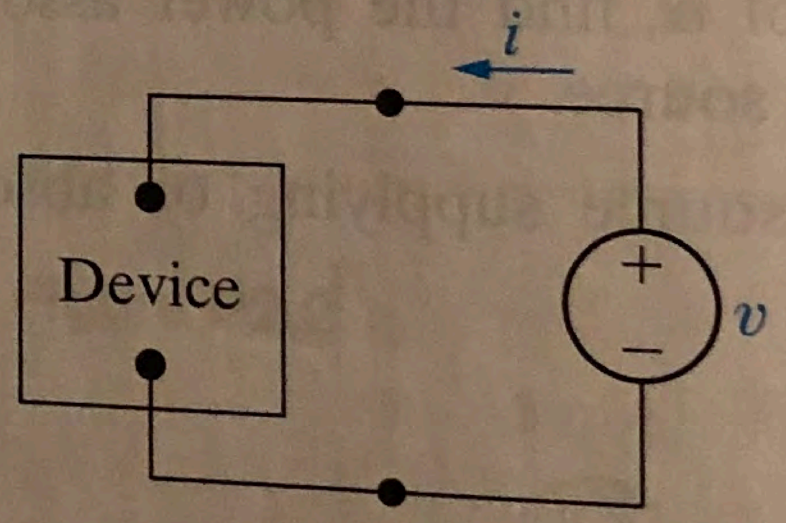
(a)

i (mA)	p (mW)
0.5	8.25
1.0	33.00
1.5	74.25
2.0	132.00
2.5	206.25
3.0	297.00

(b)

2.16 A variety of voltage source values were applied to the device shown in Fig. P2.16(a). The power absorbed by the device for each value of voltage is recorded in the table given in Fig. P2.16(b). Use the values in the table to construct a circuit model for the device consisting of a single resistor from Appendix H.

Figure P2.16



(a)

v (V)	p (mW)
−8	640
−4	160
4	160
8	640
12	1440
16	2560

(b)

Section 2.4

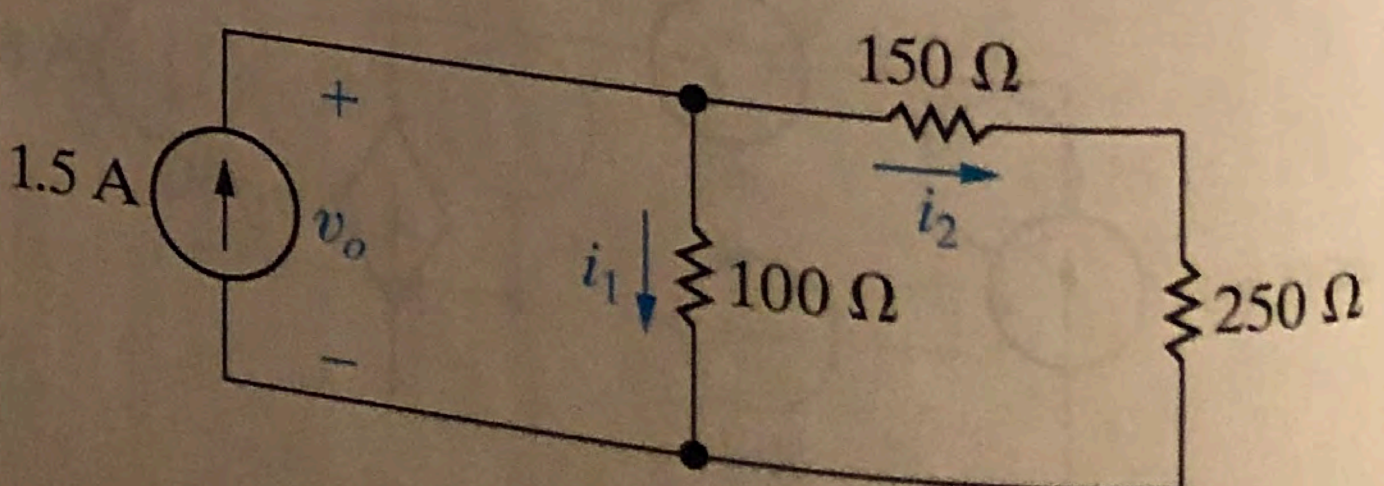
2.17 PSPICE MULTISIM

a) Find the currents i_1 and i_2 in the circuit in Fig. P2.17.

b) Find the voltage v_o.

c) Verify that the total power developed equals the total power dissipated.

Figure P2.17



2.18 Given the circuit shown in Fig. P2.18, find

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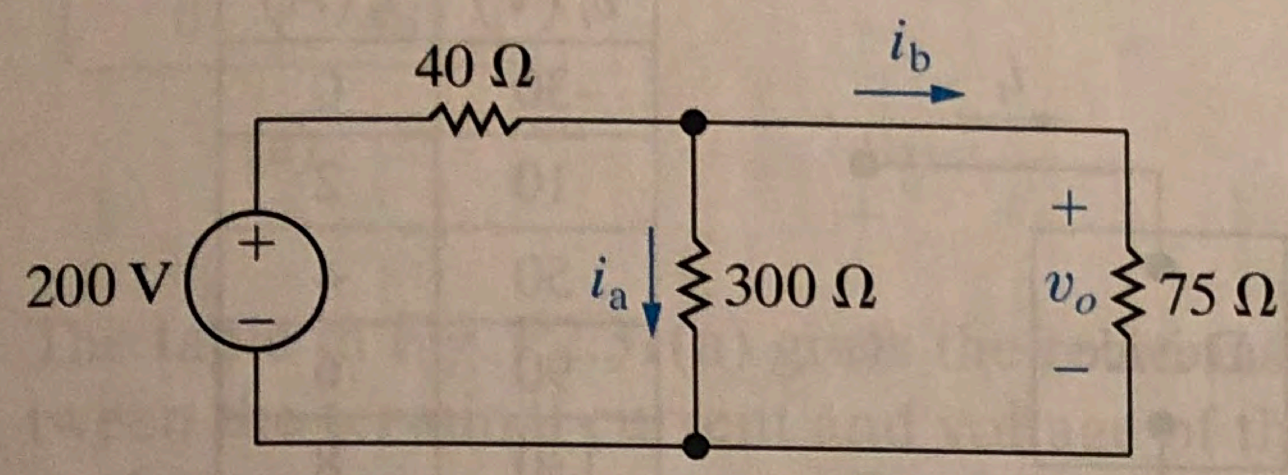
a) the value of i_a,
b) the value of i_b,
c) the value of v_o,
d) the power dissipated in each resistor,
e) the power delivered by the 200 V source.

Figure P2.18



2.19 The current i_a in the circuit shown in Fig. P2.19 is 20 A. Find (a) i_o; (b) i_g; and (c) the power delivered by the independent current source.

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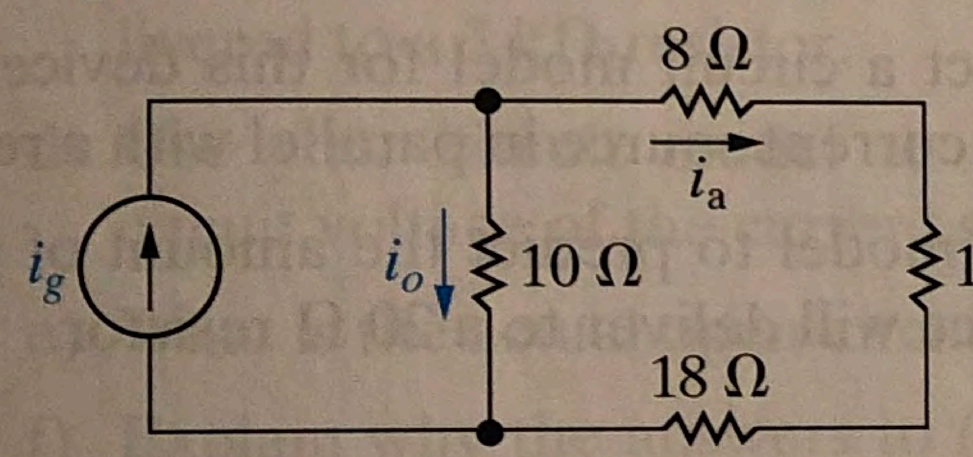
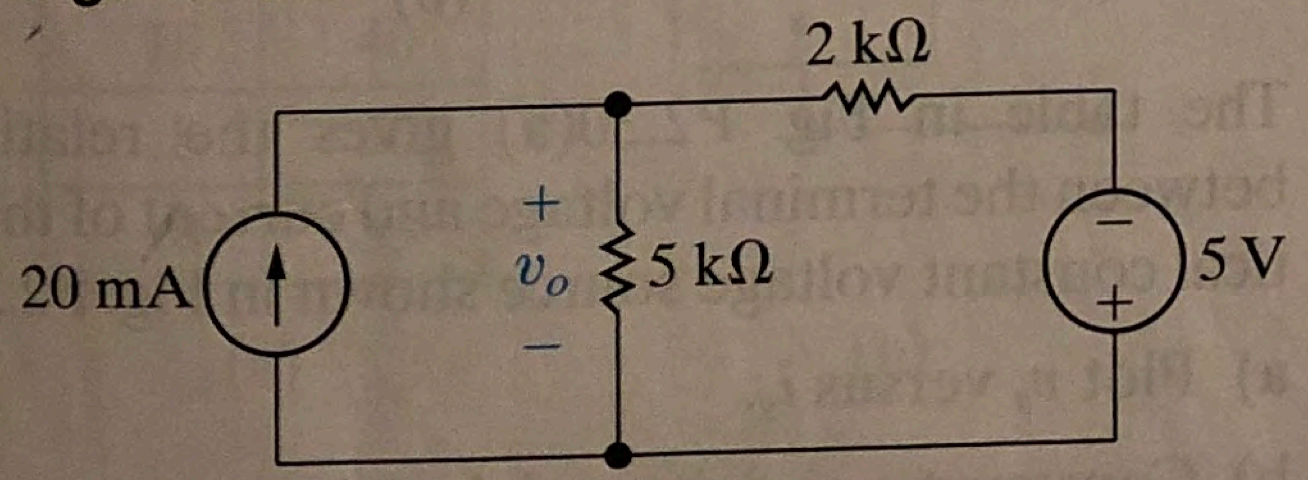
Figure P2.19



2.20 Consider the circuit shown in Fig. P2.20.

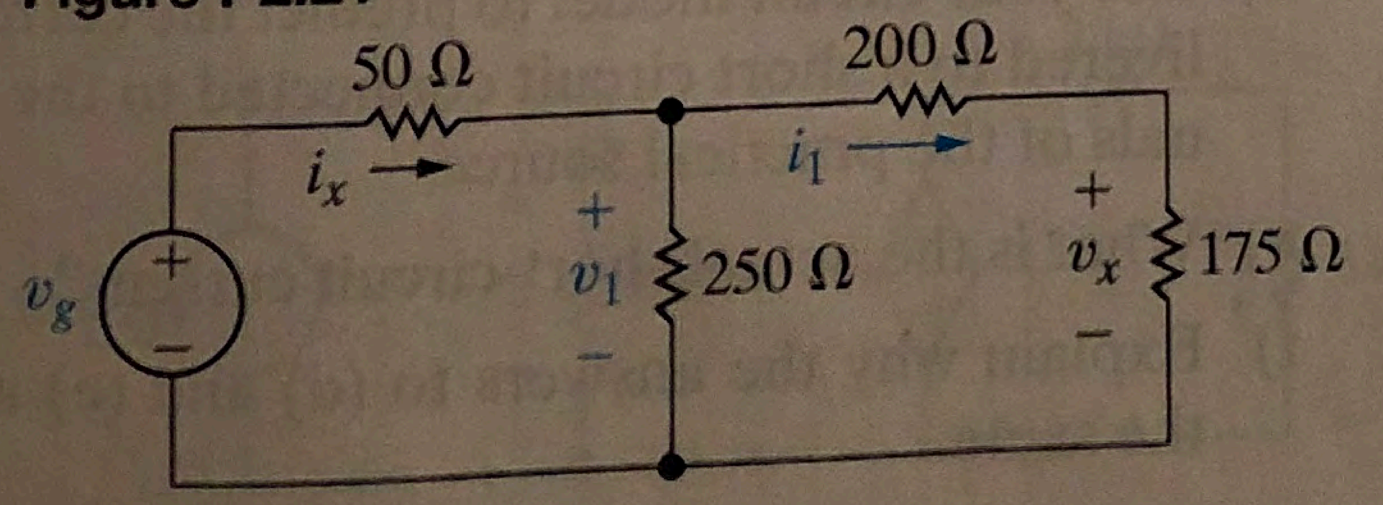
a) Find v_o using Kirchoff's laws and Ohm's law.
b) Test the solution for v_o by verifying that the total power supplied equals the total power absorbed.

Figure P2.20



2.21 The current i_x in the circuit shown in Fig. P2.21 is 50 mA, and the voltage v_x is 3.5 V. Find (a) i_1; (b) v_1; (c) v_g; and (d) the power supplied by the voltage source.

Figure P2.21



2.22 The current i_o in the circuit in Fig. P2.22 is 2 A.

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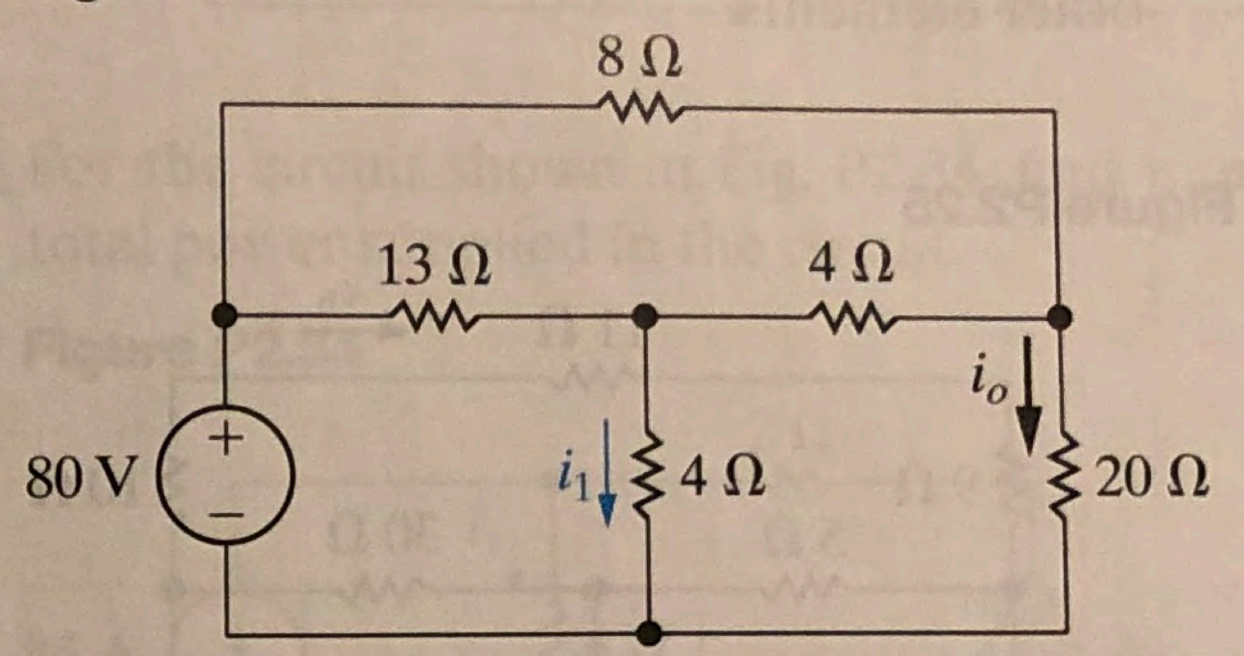
a) Find i_1.
b) Find the power dissipated in each resistor.
c) Verify that the total power dissipated in the circuit equals the power developed by the 80 V source.

Figure P2.22



2.23 The voltage across the 22.5 Ω resistor in the circuit in Fig. P2.23 is 90 V, positive at the upper terminal.

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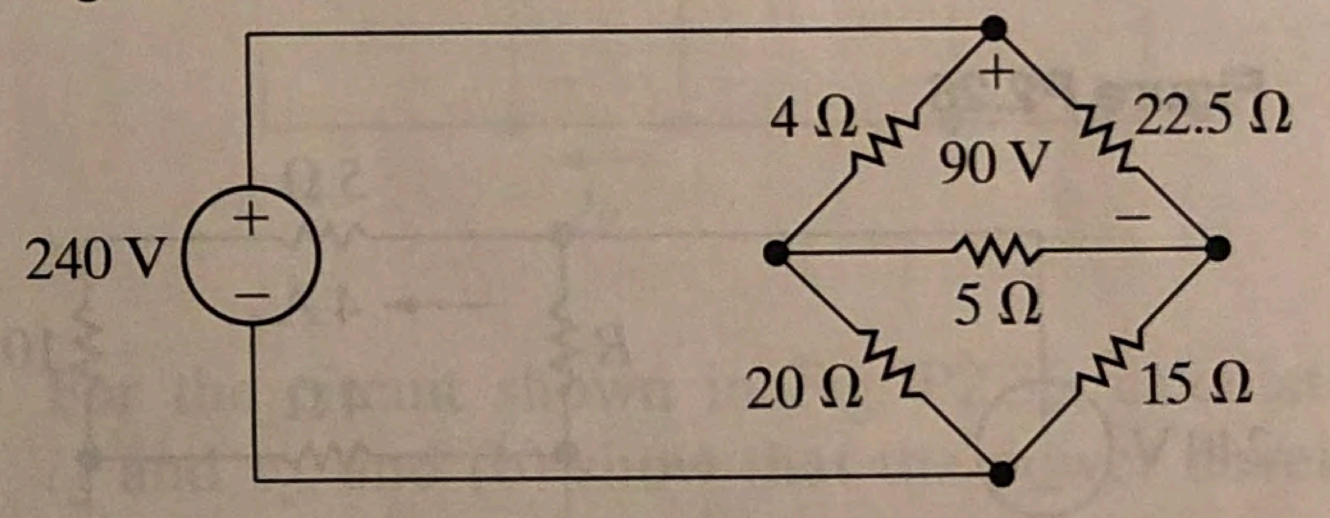
a) Find the power dissipated in each resistor.
b) Find the power supplied by the 240 V ideal voltage source.
c) Verify that the power supplied equals the total power dissipated.

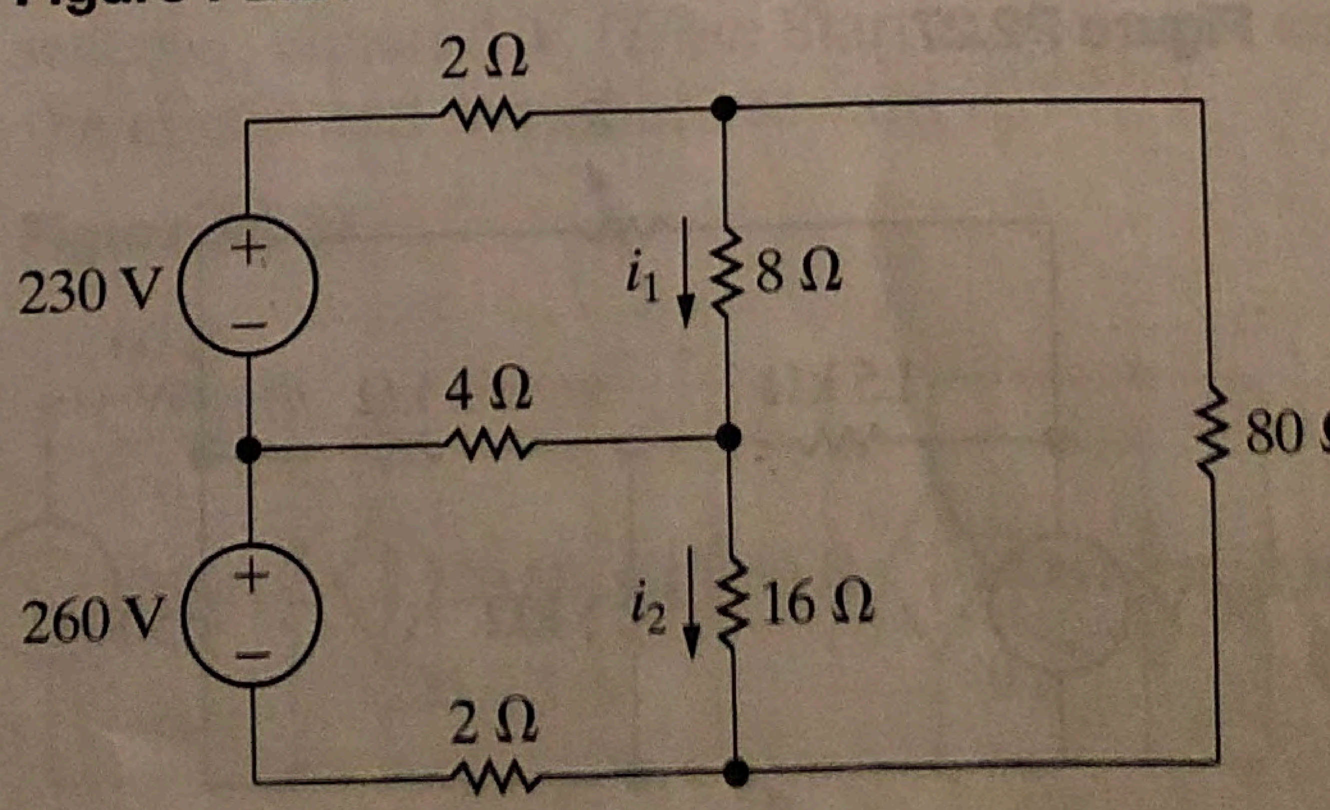
Figure P2.23



2.24 The currents i_1 and i_2 in the circuit in Fig. P2.24 are 20 A and 15 A, respectively.

a) Find the power supplied by each voltage source.
b) Show that the total power supplied equals the total power dissipated in the resistors.

Figure P2.24



2.25 The currents i_a and i_b in the circuit in Fig. P2.25 are 4 A and -2 A, respectively.
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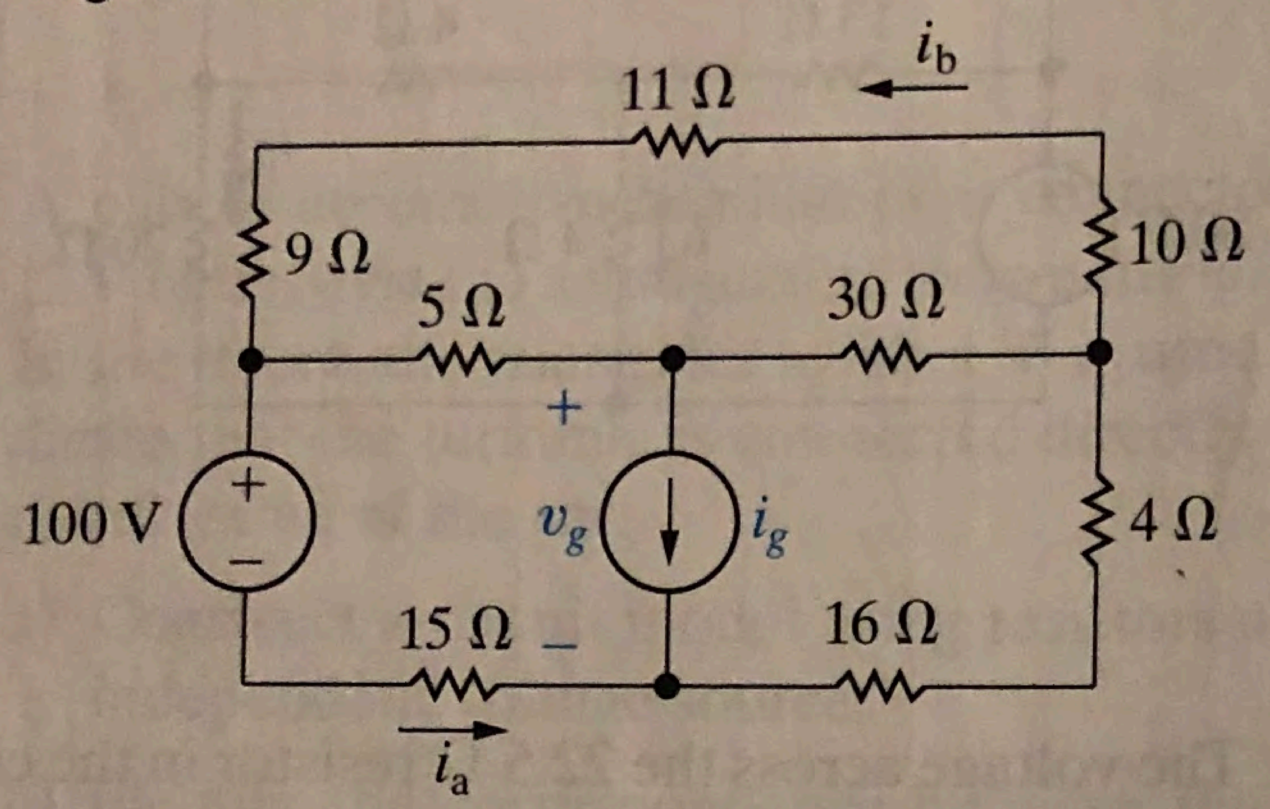
a) Find i_g.

b) Find the power dissipated in each resistor.

c) Find v_g.

d) Show that the power delivered by the current source is equal to the power absorbed by all the other elements.

Figure P2.25



2.26 For the circuit shown in Fig. P2.26, find (a) R and (b) the power supplied by the 240 V source.
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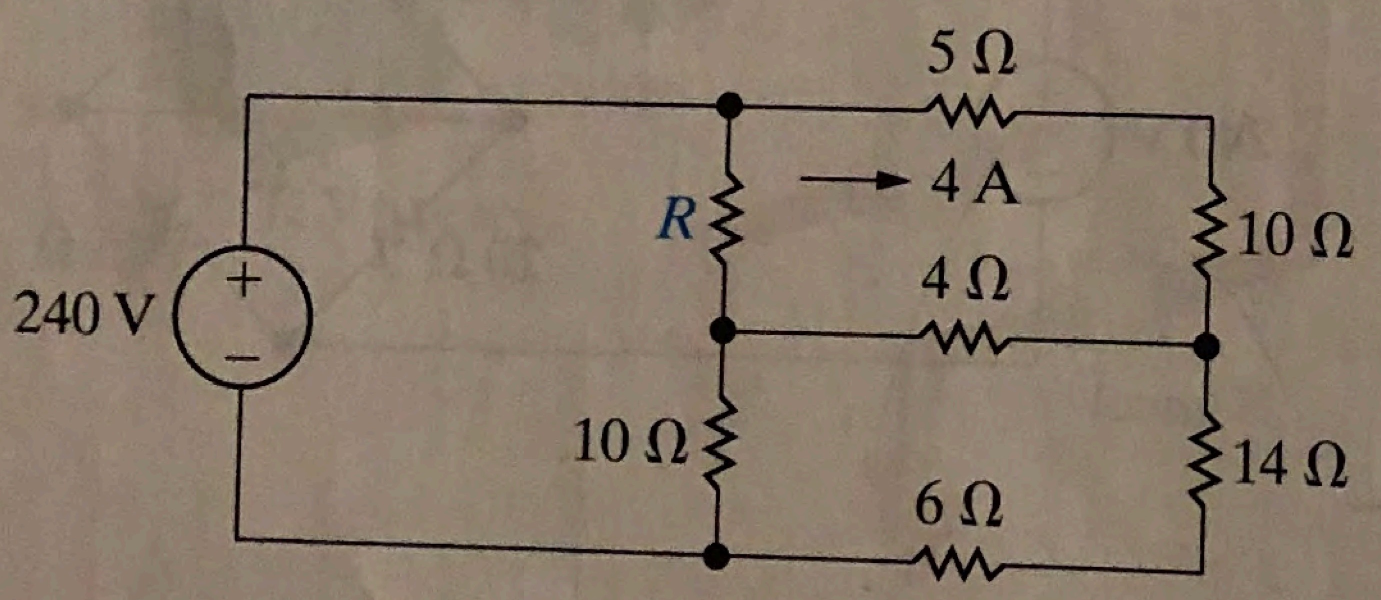
Figure P2.26



2.27 The variable resistor R in the circuit in Fig. P2.27 is adjusted until i_o equals 10 mA. Find the value of R.
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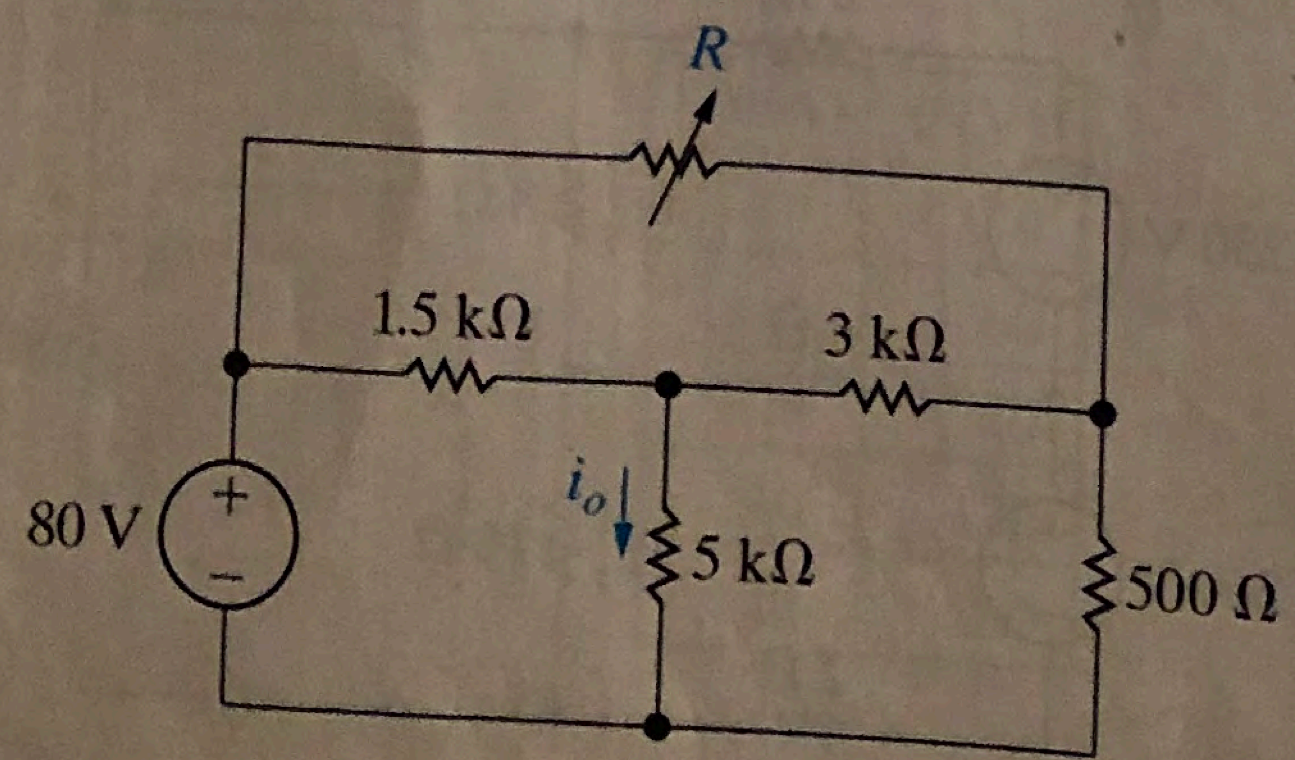
Figure P2.27

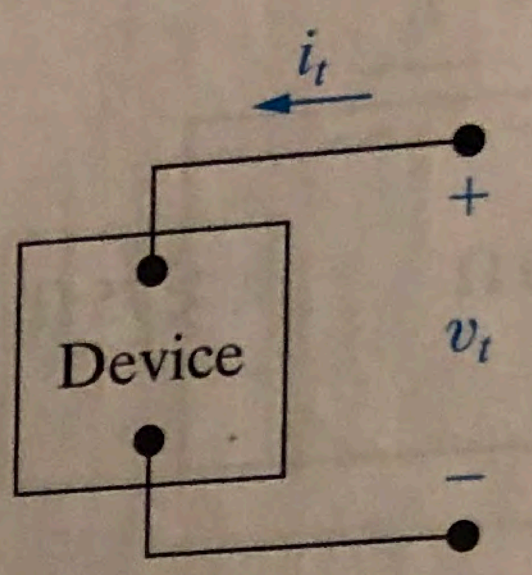


2.28 The voltage and current were measured at the terminals of the device shown in Fig. P2.28(a). The results are tabulated in Fig. P2.28(b).

a) Construct a circuit model for this device using an ideal voltage source in series with a resistor.

b) Use the model to predict the i_t the amount of power the device will deliver to a 40 Ω resistor.

Figure P2.28



(a)

v_t (V)	i_t (A)
−30	0
10	2
50	4
90	6
130	8

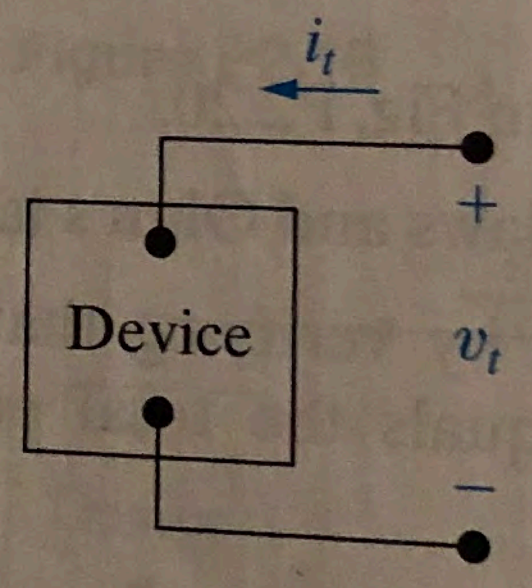
(b)

2.29 The voltage and current were measured at the terminals of the device shown in Fig. P2.29(a). The results are tabulated in Fig. P2.29(b).

a) Construct a circuit model for this device using an ideal current source in parallel with a resistor.

b) Use the model to predict the amount of power the device will deliver to a 20 Ω resistor.

Figure P2.29



(a)

v_t (V)	i_t (A)
50	0
65	3
80	6
95	9
110	12

(b)

2.30 The table in Fig. P2.30(a) gives the relationship between the terminal voltage and current of the practical constant voltage source shown in Fig. P2.30(b).

a) Plot v_s versus i_s.

b) Construct a circuit model of the practical source that is valid for $0 \leq i_s \leq 24$ mA, based on the equation of the line plotted in (a). (Use an ideal voltage source in series with an ideal resistor.)

c) Use your circuit model to predict the current delivered to a 1 kΩ resistor connected to the terminals of the practical source.

d) Use your circuit model to predict the current delivered to a short circuit connected to the terminals of the practical source.

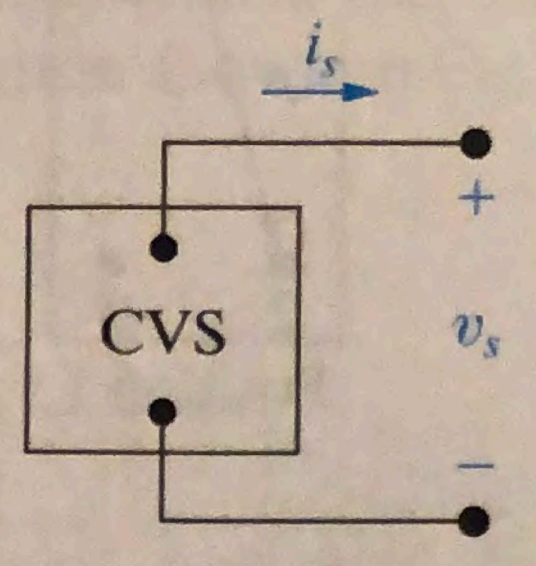
e) What is the actual short-circuit current?

f) Explain why the answers to (d) and (e) are not the same.

Figure P2.30

v_s (V)	i_s (mA)
24	0
22	8
20	16
18	24
15	32
10	40
0	48

(a)



(b)

2.31 The table in Fig. P2.31(a) gives the relationship between the terminal current and voltage of the practical constant current source shown in Fig. P2.31(b).

a) Plot i_s versus v_s.

b) Construct a circuit model of this current source that is valid for $0 \leq v_s \leq 30$ V, based on the equation of the line plotted in (a).

c) Use your circuit model to predict the current delivered to a 3 kΩ resistor.

d) Use your circuit model to predict the open-circuit voltage of the current source.

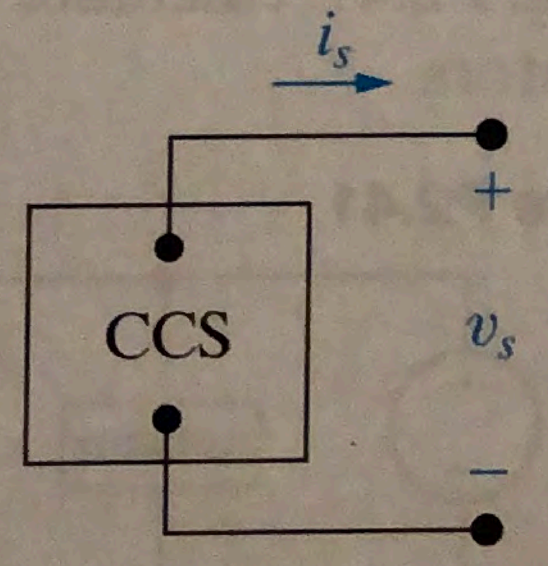
e) What is the actual open-circuit voltage?

f) Explain why the answers to (d) and (e) are not the same.

Figure P2.31

i_s (mA)	v_s (V)
40	0
35	10
30	20
25	30
18	40
8	50
0	55

(a)



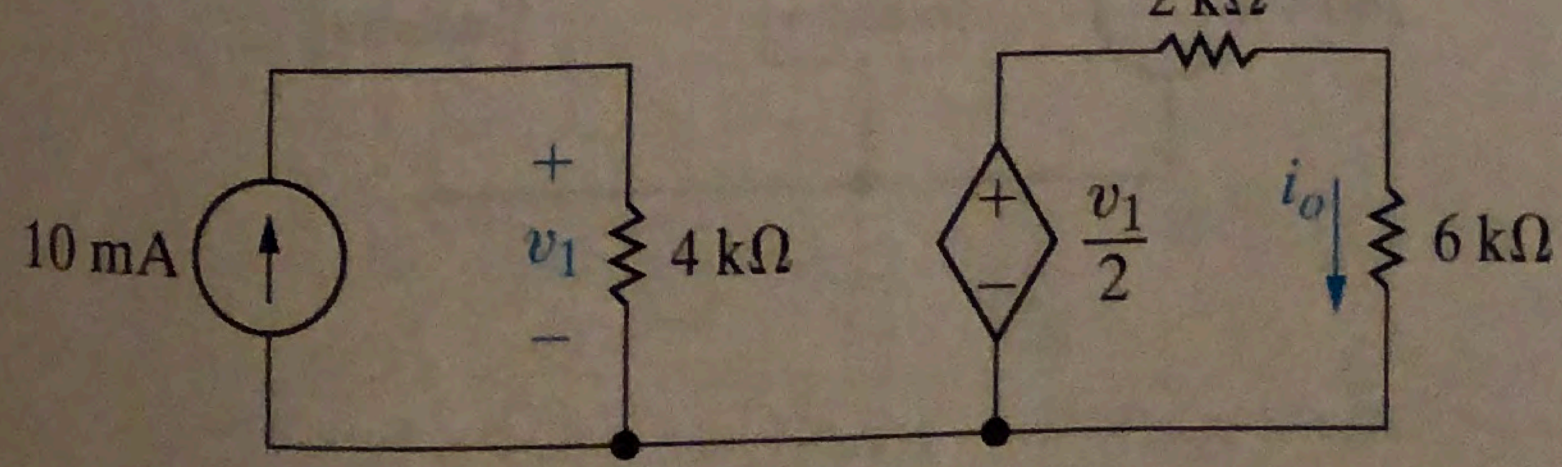
(b)

2.32 Consider the circuit shown in Fig. P2.32.

a) Find i_o.

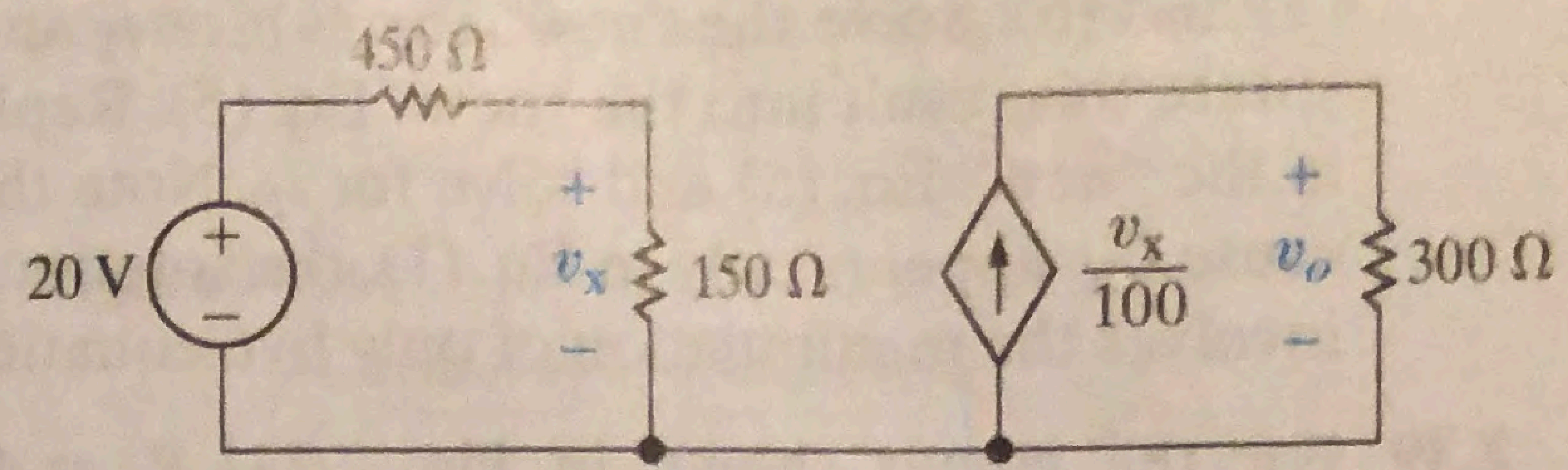
b) Verify the value of i_o by showing that the power generated in the circuit equals the power absorbed in the circuit.

Figure P2.32



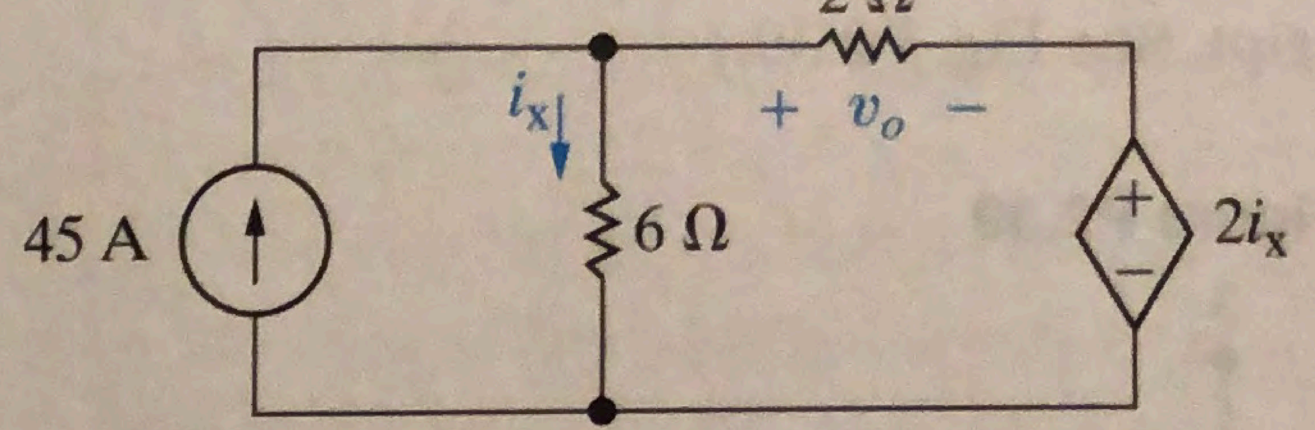
2.33 For the circuit shown in Fig. P2.33, find v_o and the total power absorbed in the circuit.

Figure P2.33



2.34 For the circuit shown in Fig. P2.34, find v_o and the total power supplied in the circuit.

Figure P2.34



2.35 Find (a) i_o, (b) i_1, and (c) i_2 in the circuit in Fig. P2.35.

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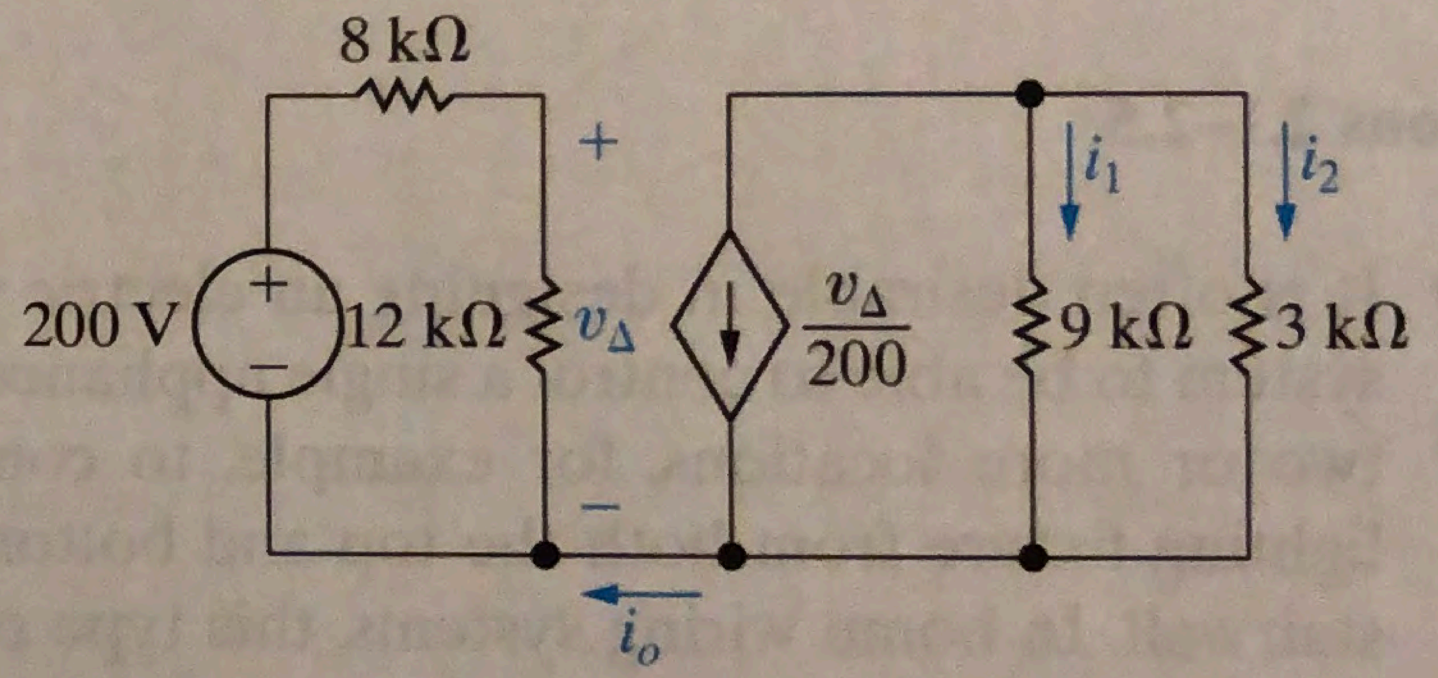
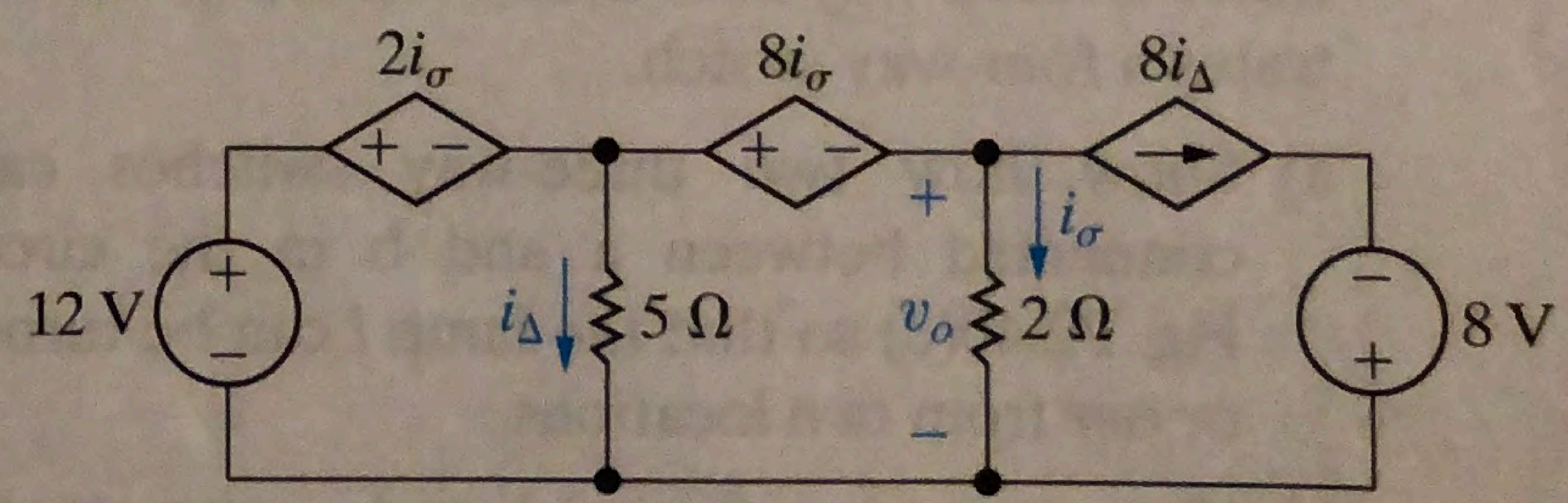
Figure P2.35



2.36 For the circuit shown in Fig. P2.36, calculate (a) i_Δ and v_o, and (b) show that the power developed equals the power absorbed.

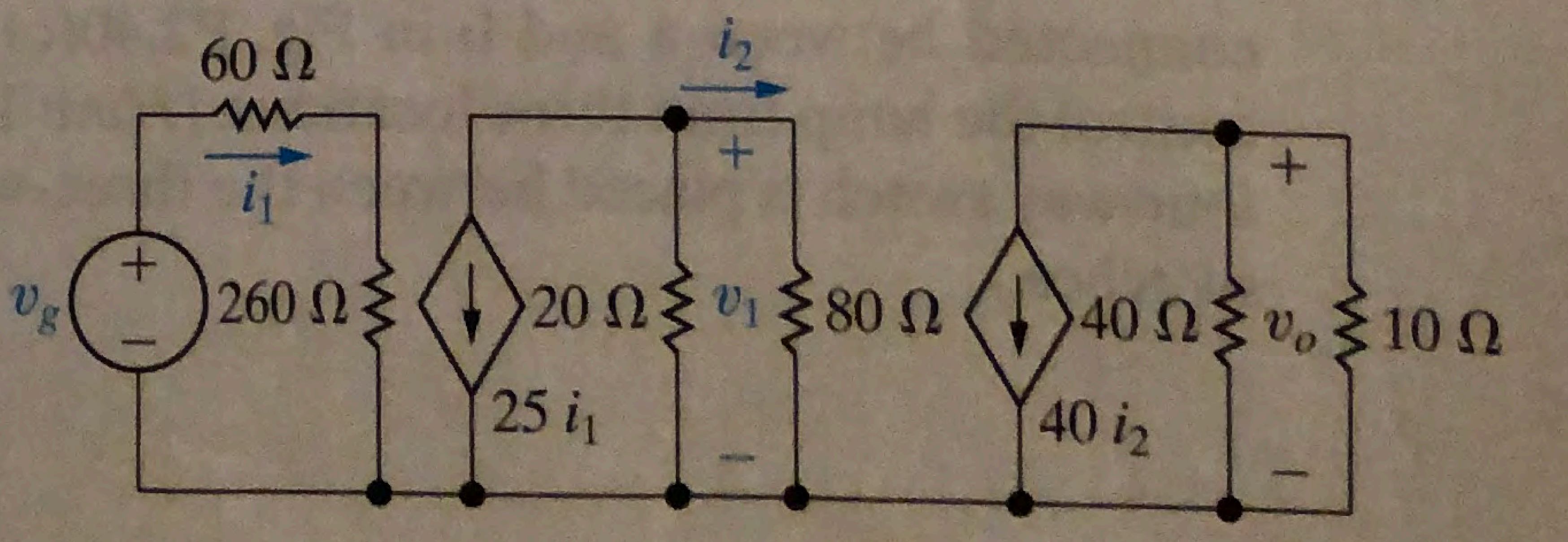
PSPICE
MULTISIM

Figure P2.36



2.37 Find v_1 and v_g in the circuit shown in Fig. P2.37 when v_o equals 5 V. (*Hint:* Start at the right end of the circuit and work back toward v_g.)

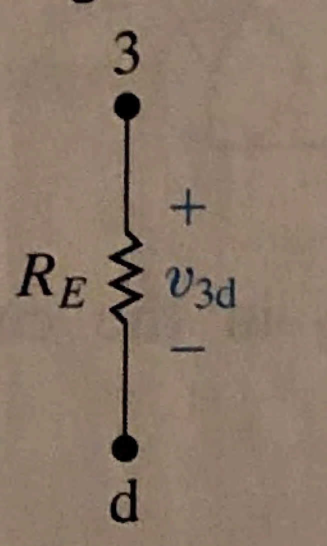
Figure P2.37



2.38 Derive Eq. 2.21. *Hint:* Use Eqs. (3) and (4) from Example 2.12 to express i_E as a function of i_B. Solve Eq. (2) for i_2 and substitute the result into both Eqs. (5) and (6). Solve the "new" Eq. (6) for i_1 and substitute this result into the "new" Eq. (5). Replace i_E in the "new" Eq. (5) and solve for i_B. Note that because i_{CC} appears only in Eq. (1), the solution for i_B involves the manipulation of only five equations.

2.39 PSPICE MULTISIM For the circuit shown in Fig. 2.24, $R_1 = 40\text{ k}\Omega$, $R_2 = 60\text{ k}\Omega$, $R_C = 750\ \Omega$, $R_E = 120\ \Omega$, $V_{CC} = 10$ V, $V_0 = 600$ mV, and $\beta = 49$. Calculate i_B, i_C, i_E, v_{3d}, v_{bd}, i_2, i_1, v_{ab}, i_{CC}, and v_{13}. (*Note:* In the double subscript notation on voltage variables, the first subscript is positive with respect to the second subscript. See Fig. P2.39.)

Figure P2.39



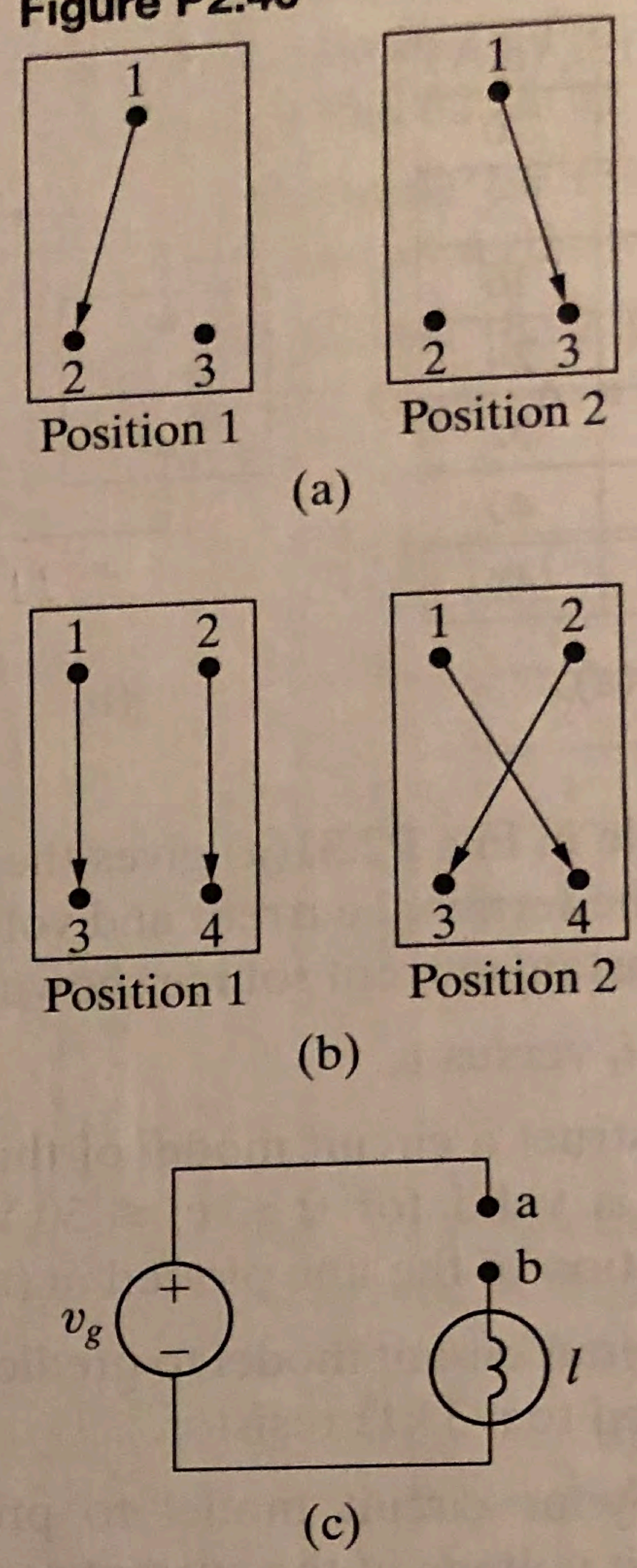
Sections 2.1–2.5

2.40 PSPICE MULTISIM It is often desirable in designing an electric wiring system to be able to control a single appliance from two or more locations, for example, to control a lighting fixture from both the top and bottom of a stairwell. In home wiring systems, this type of control is implemented with three-way and four-way switches. A three-way switch is a three-terminal, two-position switch, and a four-way switch is a four-terminal, two-position switch. The switches are shown schematically in Fig. P2.40(a), which illustrates a three-way switch, and P2.40(b), which illustrates a four-way switch.

a) Show how two three-way switches can be connected between a and b in the circuit in Fig. P2.40(c) so that the lamp l can be turned ON or OFF from two locations.

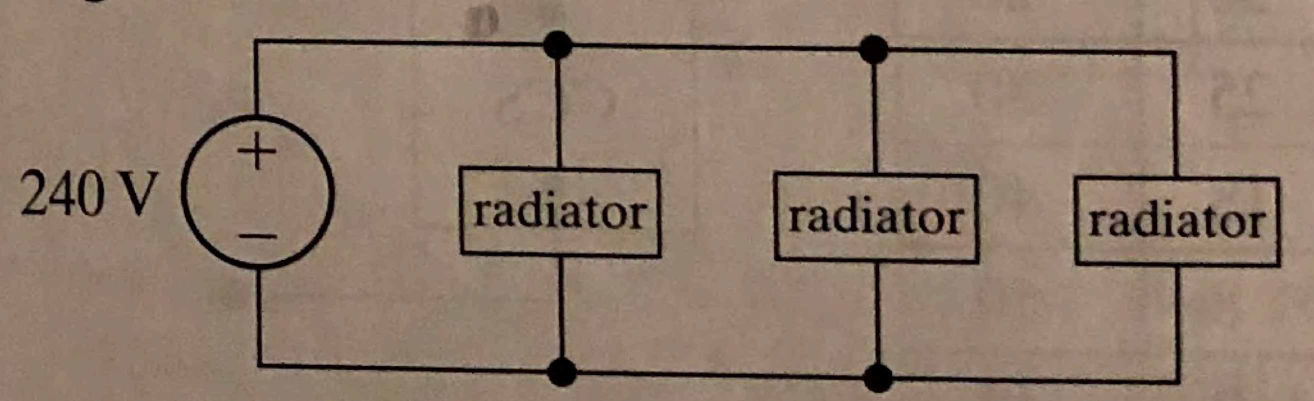
b) If the lamp (appliance) is to be controlled from more than two locations, four-way switches are used in conjunction with two three-way switches. One four-way switch is required for each location in excess of two. Show how one four-way switch plus two three-way switches can be connected between a and b in Fig. P2.40(c) to control the lamp from three locations. (*Hint:* The four-way switch is placed between the three-way switches.)

Figure P2.40



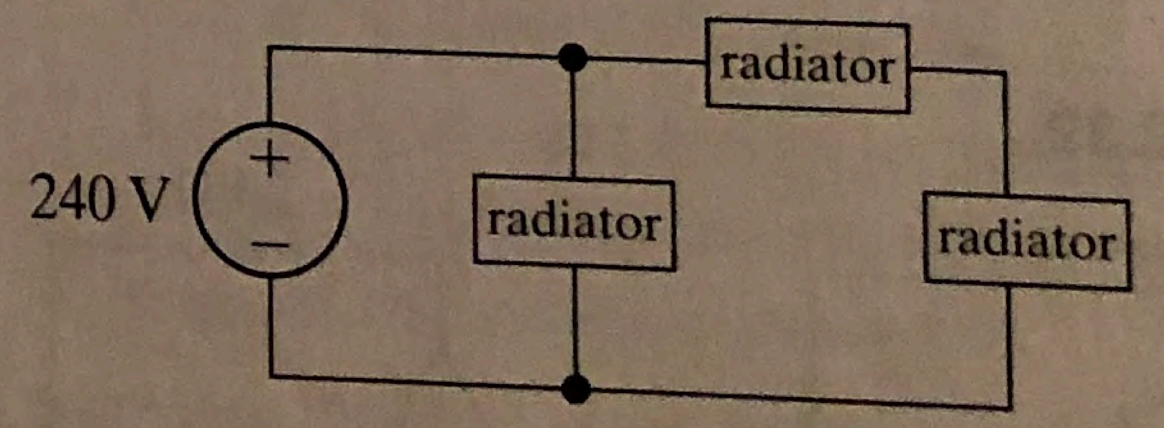
2.41 PRACTICAL PERSPECTIVE Suppose you want to add a third radiator to your garage that is identical to the two radiators you have already installed. All three radiators can be modeled by 48 Ω resistors. Using the wiring diagram shown in Fig. P2.41, calculate the total power for the three radiators.

Figure P2.41



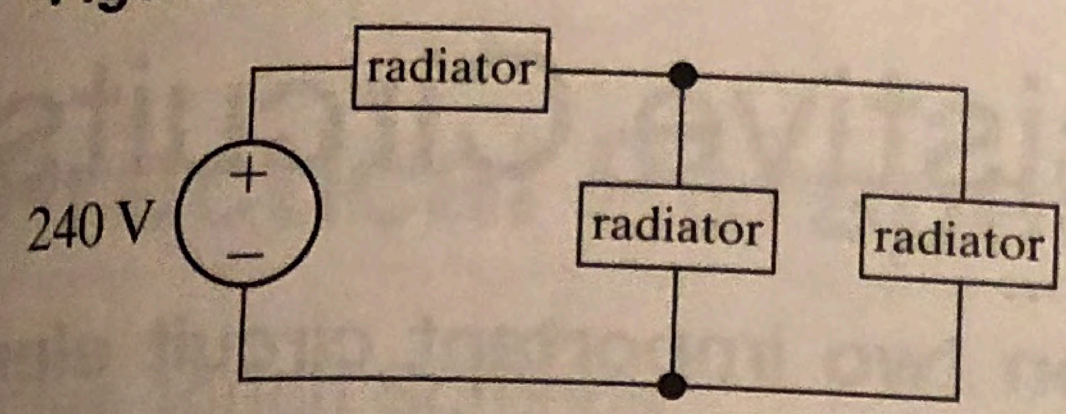
2.42 PRACTICAL PERSPECTIVE Repeat Problem 2.41 using the wiring diagram shown in Fig. P2.42. Compare the total radiator power in this configuration with the total radiator power in the configuration shown in Fig. P2.41.

Figure P2.42



2.43 PRACTICAL PERSPECTIVE Repeat Problem 2.41 using the wiring diagram shown in Fig. P2.43. Compare the total radiator power in this configuration with the total radiator power in the configuration shown in Fig. P2.41.

Figure P2.43



2.44 PRACTICAL PERSPECTIVE Repeat Problem 2.41 using the wiring diagram shown in Fig. P2.44. Compare the total radiator power in this configuration with the total radiator power in the configuration shown in Fig. P2.41.

Figure P2.44