EXERCISES

2.1 Units and Scales

1. Convert the following to engineering notation:
(*a*) 1.2×10^{-5} s (*b*) 750 mJ
(*c*) 1130 Ω (*d*) 3,500,000,000 bits
(*e*) 0.0065 μm (*f*) 13,560,000 Hz
(*g*) 0.039 nA (*h*) 49,000 Ω
(*i*) 1.173×10^{-5} μA

2. Convert the following to engineering notation:
(*a*) 1,000,000 W (*b*) 12.35 mm
(*c*) 47,000 W (*d*) 0.00546 A
(*e*) 0.033 mJ (*f*) 5.33×10^{-6} mW
(*g*) 0.000000001 s (*h*) 5555 kW
(*i*) 32,000,000,000 pm

3. Convert the following to SI units. Be sure to use engineering notation, and retain four significant digits.
(*a*) 400 hp (*b*) 12 ft (*c*) 2.54 cm
(*d*) 67 Btu (*e*) 285.4×10^{-15} s

4. A certain 15 V dry-cell battery, completely discharged, requires a current of 100 mA for 3 hr to completely recharge. What is the energy storage capacity of the battery, assuming the voltage does not depend on its charge status?

5. A zippy little electric car is equipped with a 175 hp motor.
(*a*) How many kW are required to run the motor if we assume 100 percent efficiency in converting electrical power to mechanical power?
(*b*) How much energy (in J) is expended if the motor is run continuously for 3 hours?
(*c*) If a single lead-acid battery has a 430-kilowatthour storage capacity, how many batteries are required for part (*b*)?

6. A KrF excimer laser generates 400 mJ laser pulses 20 ns in duration.
(*a*) What is the peak instantaneous power of the laser?
(*b*) If only 20 pulses can be generated per second, what is the average power output of the laser?

7. An amplified titanium:sapphire laser generates 1 mJ laser pulses 75 fs in duration.
(*a*) What is the peak instantaneous power of the laser?
(*b*) If only 100 pulses can be generated per second, what is the average power output of the laser?

8. The power supplied by a certain battery is a constant 6 W over the first 5 min, zero for the following 2 min, a value that increases linearly from zero to 10 W during the next 10 min, and a power that decreases linearly from 10 W to zero in the following 7 min. (*a*) What is the total energy in joules expended during this 24 min interval? (*b*) What is the average power in Btu/h during this time?

9. A new type of battery delivers 10 W of power for 8 hr without voltage or current fluctuation. After 8 hr, however, the power output drops linearly from 10 W to 0 in only 5 min. (*a*) What is the energy storage capacity of the battery? (*b*) How much energy is delivered during the last 5 min of the discharge cycle?

2.2 Charge, Current, Voltage, and Power

10. The total charge accumulated by a certain device is given as a function of time by $q = 18t^2 - 2t^4$ (in SI units). (*a*) What total charge is accumulated

at $t = 2$ s? (*b*) What is the maximum charge accumulated in the interval $0 \le t \le 3$ s, and when does it occur? (*c*) At what rate is charge being accumulated at $t = 0.8$ s? (*d*) Sketch curves of q versus t and i versus t in the interval $0 \le t \le 3$ s.

11. The current $i_1(t)$ shown in Fig. 2.6*c* is given as $-2 + 3e^{-5t}$ A for $t < 0$, and $-2 + 3e^{3t}$ A for $t > 0$. Find (*a*) $i_1(-0.2)$; (*b*) $i_1(0.2)$; (*c*) those instants at which $i_1 = 0$; (*d*) the total charge that has passed from left to right along the conductor in the interval $-0.8 < t < 0.1$ s.

12. The waveform shown in Fig. 2.28 has a period of 10 s. (*a*) What is the average value of the current over one period? (*b*) How much charge is transferred in the interval $1 < t < 12$ s? (*c*) If $q(0) = 0$, sketch $q(t)$, $0 < t < 16$ s.

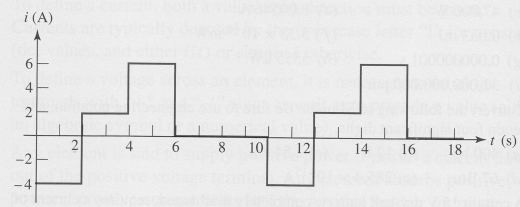


FIGURE 2.28

13. Consider a path with discrete points *A*, *B*, *C*, *D*, and *E*. It takes 2 pJ to move an electron from *A* to *B* or from *B* to *C*. It takes 3 pJ to move a proton from *C* to *D*. It takes no energy to move an electron from *D* to *E*.
    (*a*) What is the potential difference (in volts) between *A* and *B*? (Assume + reference at *B*.)
    (*b*) What is the potential difference (in volts) between *D* and *E*? (Assume + reference at *E*.)
    (*c*) What is the potential difference (in volts) between *C* and *D*? (Assume + reference at *D*.)
    (*d*) What is the potential difference (in volts) between *D* and *B*? (Assume + reference at *D*.)

14. An unmarked box is found in the back corner of a laboratory. It has two wires protruding from it, an orange wire and a purple wire. A voltmeter is connected to the two wires with the + reference on the purple wire. A voltage of −2.86 V is measured in this fashion. What would the voltage reading be if the voltmeter connections were reversed?

15. Determine the power being absorbed by each of the circuit elements shown in Fig. 2.29.

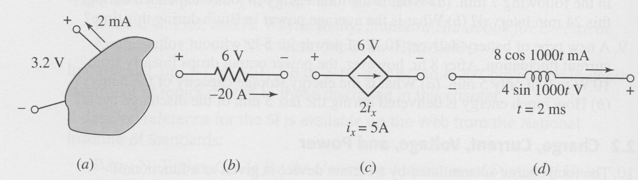
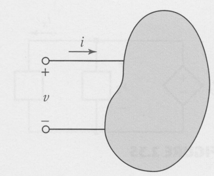


FIGURE 2.29

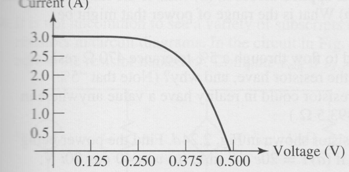
16. Let $i = 3te^{-100t}$ mA and $v = (0.006 - 0.6t)e^{-100t}$ V for the circuit element of Fig. 2.30. (*a*) What power is being absorbed by the circuit element at $t = 5$ ms? (*b*) How much energy is delivered to the element in the interval $0 < t < \infty$?

17. In Fig. 2.30, let $i = 3e^{-100t}$ A. Find the power being absorbed by the circuit element at $t = 8$ ms if v equals (*a*) $40i$; (*b*) $0.2\, di/dt$; (*c*) $30 \int_0^t i\, dt + 20$ V.



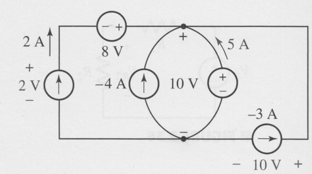
■ **FIGURE 2.30**

18. The current-voltage characteristic of a silicon solar cell exposed to direct sunlight at noon in Florida during midsummer is given in Fig. 2.31. It is obtained by placing different-sized resistors across the two terminals of the device and measuring the resulting currents and voltages.
    (*a*) What is the value of the short-circuit current?
    (*b*) What is the value of the voltage at open circuit?
    (*c*) Estimate the maximum power that can be obtained from the device.



■ **FIGURE 2.31**

19. The current flowing into a certain circuit is monitored carefully over time. All voltages quoted assume the positive reference terminal is the top of the two circuit terminals. It is observed that for the first two hours, a current of 1 mA flows into the top terminal, while a voltage of +5 V is measured. Over the next 30 minutes, no current flows in or out. Then, for two hours, a current of 1 mA flows out of the top terminal, with a voltage of +2 V measured. After that, no current flows in or out again. Assuming the circuit had no energy initially stored, answer the following:
    (*a*) How much power was delivered to the circuit during each of the three intervals?
    (*b*) How much energy was supplied to the circuit during the first two hours of observation?
    (*c*) How much energy remains in the circuit now?

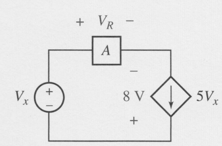


■ **FIGURE 2.32**

2.3 Voltage and Current Sources

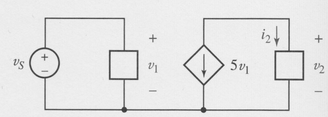
20. Determine which of the five sources in Fig. 2.32 are being charged (absorbing positive power), and show that the algebraic sum of the five absorbed power values is zero.

21. Refer to the circuit of Fig. 2.32. Multiply each current and voltage by 4, and determine which of the five sources are acting as sources of energy (i.e., supplying positive power to other elements).



■ **FIGURE 2.33**

22. In the simple circuit shown in Fig. 2.33, the same current flows through each element. If $V_x = 1$ V and $V_R = 9$ V, compute:
    (*a*) the power absorbed by element *A*;
    (*b*) the power supplied by each of the two sources.
    (*c*) Does the total power supplied equal the total power absorbed? Is your finding reasonable? Why (or why not)?



■ **FIGURE 2.34**

23. For the circuit in Fig. 2.34, if $v_2 = 1000i_2$ and $i_2 = 5$ mA, determine v_S.

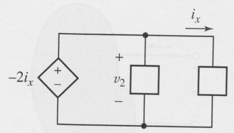


FIGURE 2.35

24. For the circuit of Fig. 2.35, if $i_x = -1$ mA, calculate the voltage v_2.
25. A simple circuit is formed using a 12 V lead-acid battery and an automobile headlight. If the battery delivers a total energy of 460.8 watt-hours over an 8-hour discharge period,
    (*a*) how much power is delivered to the headlight?
    (*b*) what is the current flowing through the bulb? (Assume the battery voltage remains constant while discharging.)
26. A fuse must be selected for a certain application. You may choose from fuses rated to "blow" when the current exceeds 1.5 A, 3 A, 4.5 A, or 5 A. If the supply voltage is 110 V and the maximum allowable power dissipation is 500 W, which fuse should be chosen, and why?

2.4 Ohm's Law

27. A 10% tolerance 1 kΩ resistor may in fact have a value anywhere in the range of 900 to 1100 Ω. If 5.0 V is applied across it, (*a*) what is the range of currents that might be measured? (*b*) What is the range of power that might be measured?
28. A current of 2 mA is forced to flow through a 5% tolerance 470 Ω resistor. What power rating should the resistor have, and why? (Note that "5% tolerance" means that the resistor could in reality have a value anywhere in the range of 446.5 Ω and 493.5 Ω.)
29. Let $R = 1200\ \Omega$ for the resistor shown in Fig. 2.24*d*. Find the power being absorbed by R at $t = 0.1$ s if (*a*) $i = 20e^{-12t}$ mA; (*b*) $v = 40 \cos 20t$ V; (*c*) $vi = 8t^{1.5}$ VA.
30. A certain voltage is +10 V for 20 ms and −10 V for the succeeding 20 ms and continues oscillating back and forth between these two values at 20 ms intervals. The voltage is present across a 50 Ω resistor. Over any 40 ms interval find (*a*) the maximum value of the voltage; (*b*) the average value of the voltage; (*c*) the average value of the resistor current; (*d*) the maximum value of the absorbed power; (*e*) the average value of the absorbed power.

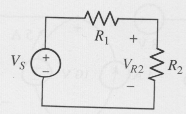


FIGURE 2.36

31. In the circuit in Fig. 2.36, the same current must flow through all three components as a result of conservation laws. Using the fact that the total power supplied equals the total power absorbed, show that the voltage across resistor R_2 is given by:

$$V_{R_2} = V_S \frac{R_2}{R_1 + R_2}$$

32. The following experimental measurements were made on a two-terminal device by setting the voltage using a variable power supply and measuring the resulting current flow into one of the terminals.

Voltage (V)	Current (mA)
−1.5	−3.19
−0.3	−0.638
0.0	1.01×10^{-8}
1.2	2.55
2.5	5.32

(*a*) Plot the current vs. voltage characteristic.
(*b*) Compute the effective conductance and resistance of the device.
(*c*) On a different graph, plot the current vs. voltage characteristic if the device resistance is increased by a factor of 3.

33. For each of the circuits in Fig. 2.37, find the current I and compute the power absorbed by the resistor.

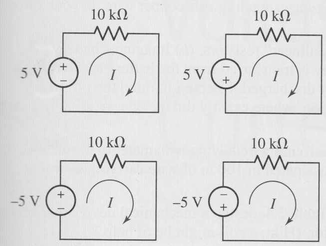


FIGURE 2.37

34. It is not uncommon to see a variety of subscripts on voltages, currents, and resistors in circuit diagrams. In the circuit in Fig. 2.38, the voltage v_π appears across the resistor named r_π. Compute v_{out} if $v_s = 0.01 \cos 1000t$ V.

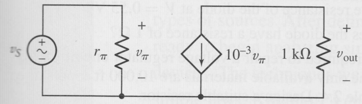


FIGURE 2.38

35. The circuit of Fig. 2.38 is constructed so that $v_S = 2 \sin 5t$ V, and $r_\pi = 80\ \Omega$. Calculate v_{out} at $t = 0$ and $t = 314$ ms.

36. A length of 18 AWG solid copper wire is run along the side of a road to connect a sensor to a central computer system. If the wire is known to have a resistance of 53 Ω, what is the total length of the wire? (Assume the temperature is ~20°C.)

37. You're stranded on a desert island, and the air temperature is 108°F. After realizing that your transmitter is not working, you trace the problem to a broken 470 Ω resistor. Fortunately, you notice that a large spool of 28 AWG solid copper wire also washed ashore. How many feet of wire will you require to use as a replacement for the 470 Ω resistor? Note that because the island is in the tropics, it is a little balmier than the 20°C used to quote the wire resistance in Table 2.4. You may use the following relationship[5] to correct the values in Table 2.4:

$$\frac{R_2}{R_1} = \frac{234.5 + T_2}{234.5 + T_1}$$

where T_1 = reference temperature (20°C in this case)
R_1 = resistance at the reference temperature
T_2 = new temperature (in degrees Celsius)
R_2 = resistance at the new temperature.

38. The resistance of a conductor having a length l and a uniform cross-sectional area A is given by $R = l/\sigma A$, where σ (sigma) is the electrical conductivity. If $\sigma = 5.8 \times 10^7$ S/m for copper: (*a*) what is the resistance of a #18 copper wire (diameter = 1.024 mm) that is 50 ft long? (*b*) If a circuit board has a copper-foil conducting ribbon 33 μm thick and 0.5 mm wide that can carry 3 A safely at 50°C, find the resistance of a 15 cm length of this ribbon and the power delivered to it by the 3 A current.

(5) D. G. Fink and H. W. Beaty, *Standard Handbook for Electrical Engineers*, 13th ed. New York: McGraw-Hill, 1993, p. 2–9.

39. Table 2.3 lists several types of copper wire standards, with a resistivity of approximately 1.7 $\mu\Omega \cdot$ cm. Use the information in Table 2.4 for 28 AWG wire to extract the resistivity of the corresponding soft copper wire. Is your value consistent with Table 2.3?

40. (*a*) List three examples of "nonlinear" resistors. (*b*) Imagine a battery connected to a resistor. Energy is transferred from the battery to the resistor until the battery is completely discharged. Keeping in mind the physical principle of energy conservation, where exactly did the energy initially stored in the battery go?

41. If B33 copper is used to make round wire having a diameter of 1 mm, how much power would be dissipated in 100 m of wire carrying a current of 1.5 A?

D 42. Based on the information in Table 2.4, design a mechanical device that acts as a continuously variable resistor. (Hint: a coil might be of help.)

43. The diode, a very common two-terminal nonlinear device, can be modeled using the following current-voltage relationship:

$$I = 10^{-9}(e^{39V} - 1)$$

(*a*) Sketch the current-voltage characteristic for $V = -0.7$ to 0.7 V.

(*b*) What is the effective resistance of the diode at $V = 0.55$ V?

(*c*) At what current does the diode have a resistance of 1 Ω?

D 44. A resistance of 10 Ω is required to repair a voltage regulator circuit for a portable application. The only available materials are 10,000 ft spools of each wire gauge listed in Table 2.4. Design a suitable resistor.

D 45. The resistivity of "*n*-type" crystalline silicon is given by $\rho = 1/qN_D\mu_n$, where q, the charge per electron, is 1.602×10^{-19} C, N_D = the number of phosphorus impurity atoms per cm^3, and μ_n = the electron mobility (in units of cm^2 V^{-1}s^{-1}). The mobility and impurity concentration are related by Fig. 2.39. Assuming a 6 in–diameter silicon wafer 250 μm thick, design a 100 Ω resistor by specifying a phosphorus concentration in the range of $10^{15} \le N_D \le 10^{18}$ atoms/cm^3, and a suitable device geometry.

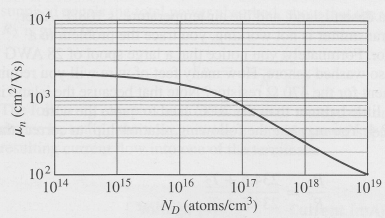


FIGURE 2.39

- Voltage division allows us to calculate what fraction of the total voltage across a series string of resistors is dropped across any one resistor (or group of resistors).
- Current division allows us to calculate what fraction of the total current into a parallel string of resistors flows through any one of the resistors.

READING FURTHER

A discussion of the principles of conservation of energy and conservation of charge, as well as Kirchhoff's laws, can be found in

R. Feynman, R. B. Leighton, and M. L. Sands, *The Feynman Lectures on Physics.* Reading, Mass.: Addison-Wesley, 1989, pp. 4-1, 4-7, and 25-9.

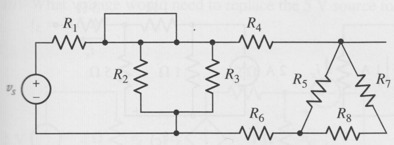
A very detailed discussion of grounding practices consistent with the 1996 National Electrical Code® can be found in

J. F. McPartland and B. J. McPartland, *McGraw-Hill's National Electrical Code® Handbook,* 22nd ed. New York: McGraw-Hill, 1996, pp. 337–485.

EXERCISES

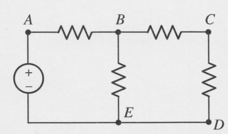
3.1 Nodes, Paths, Loops, and Branches

1. Redraw the circuit of Fig. 3.42, consolidating nodes into the minimum number possible.



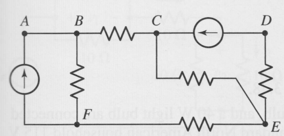
■ **FIGURE 3.42**

2. In the circuit of Fig. 3.42, count the number of (*a*) nodes; (*b*) branches.
3. In Fig. 3.43,
   (*a*) How many nodes are there?
   (*b*) How many branches are there?
   (*c*) If we move from *A* to *B* to *E* to *D* to *C* to *B*, have we formed a path? A loop?



■ **FIGURE 3.43**

4. In Fig. 3.44,
   (*a*) How many nodes are there?
   (*b*) How many branches are there?
   (*c*) If we move from *B* to *F* to *E* to *C*, have we formed a path? A loop?

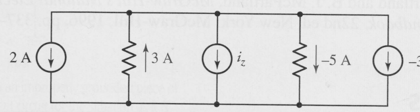


■ **FIGURE 3.44**

5. Referring to the circuit depicted in Fig. 3.43,
   (*a*) If a second wire is connected between points *E* and *D* of the circuit, how many nodes does the new circuit have?
   (*b*) If a resistor is added to the circuit so that one terminal is connected to point *C* and the other terminal is left floating, how many nodes does the new circuit have?
   (*c*) Which of the following represent loops?
      (*i*) Moving from *A* to *B* to *C* to *D* to *E* to *A*.
      (*ii*) Moving from *B* to *E* to *A*.
      (*iii*) Moving from *B* to *C* to *D* to *E* to *B*.
      (*iv*) Moving from *A* to *B* to *C*.
      (*v*) Moving from *A* to *B* to *C* to *B* to *A*.

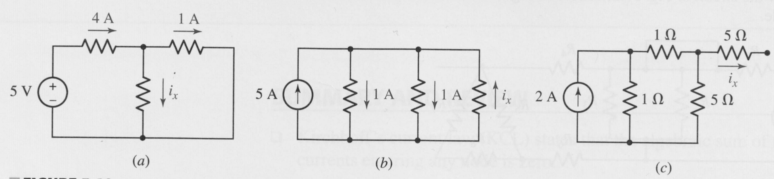
3.2 Kirchhoff's Current Law

6. (*a*) Determine the current labeled i_z in the circuit shown in Fig. 3.45. (*b*) If the resistor carrying 3 A has a value of 1 Ω, what is the value of the resistor carrying −5 A?



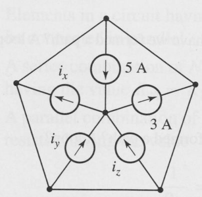
■ **FIGURE 3.45**

7. Find i_x in each of the circuits in Fig. 3.46.



■ **FIGURE 3.46**

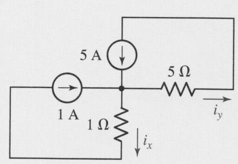
8. Referring to Fig. 3.47,
   (*a*) Find i_x if $i_y = 2$ A and $i_z = 0$ A. (*b*) Find i_y if $i_x = 2$ A and $i_z = 2\,i_y$.
   (*c*) Find i_z if $i_x = i_y = i_z$.



■ **FIGURE 3.47**

9. Find i_x and i_y in the circuit of Fig. 3.48.

10. A 100 W light bulb, a 60 W light bulb, and a 40 W light bulb are connected in parallel to each other and to a standard North American household 115 V supply. Compute the current flowing through each light bulb and the total current delivered by the voltage supply.



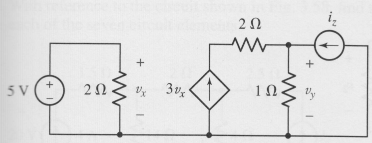
■ **FIGURE 3.48**

11. The digital multimeter (DMM) is a device commonly used to measure voltages. It is equipped with two leads (usually red for the positive reference and black for the negative reference) and an LCD display. Let's suppose a DMM is connected to the circuit of Fig. 3.46*b* with the positive lead at the top node and the negative lead on the bottom node. Using KCL, explain why we would ideally want a DMM used in this way to have an infinite resistance as opposed to zero resistance.

12. A local restaurant has a neon sign constructed from 12 separate bulbs; when a bulb fails, it appears as an infinite resistance and cannot conduct current. In wiring the sign, the manufacturer offers two options (Fig. 3.49). From what you've learned about KCL, which one should the restaurant owner select? Explain.

■ **FIGURE 3.49**

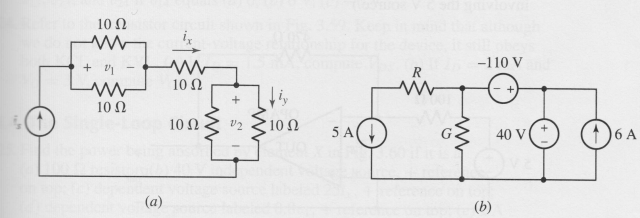
13. In the circuit of Fig. 3.50,
(*a*) Calculate v_y if $i_z = -3$ A.
(*b*) What voltage would need to replace the 5 V source to obtain $v_y = -6$ V if $i_z = 0.5$ A?



■ **FIGURE 3.50**

14. Referring to the circuit in Fig. 3.51*a*,
(*a*) If $i_x = 5$ A, find v_1 and i_y. (*b*) If $v_1 = 3$ V, find i_x and i_y.
(*c*) What value of i_s will lead to $v_1 \neq v_2$?

15. Find *R* and *G* in the circuit of Fig. 3.51*b* if the 5 A source is supplying 100 W and the 40 V source is supplying 500 W.



■ **FIGURE 3.51**

3.3 Kirchhoff's Voltage Law

16. In the circuits of Fig. 3.52*a* and *b*, determine the current labeled *i*.

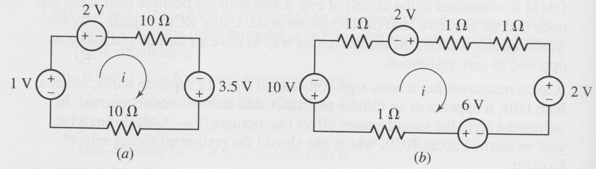


FIGURE 3.52

17. Calculate the value of *i* in each circuit of Fig. 3.53.

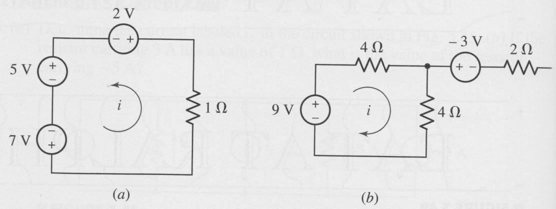


FIGURE 3.53

18. Consider the simple circuit shown in Fig. 3.54. Using KVL, derive the expressions

$$v_1 = v_s \frac{R_1}{R_1 + R_2} \quad \text{and} \quad v_2 = v_s \frac{R_2}{R_1 + R_2}$$

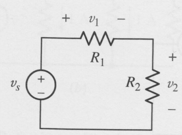


FIGURE 3.54

19. The circuit shown in Fig. 3.55 includes a device known as an op amp. This device has two unusual properties in the circuit shown: (1) $V_d = 0$ V, and (2) no current can flow into either input terminal (marked "−" and "+" inside the symbol), but it *can* flow through the output terminal (marked "OUT"). This seemingly impossible situation—in direct conflict with KCL—is a result of power leads to the device that are not included in the symbol. Based on this information, calculate V_{out}. (Hint: two KVL equations are required, both involving the 5 V source.)

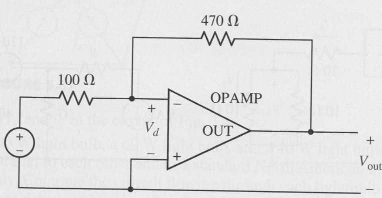
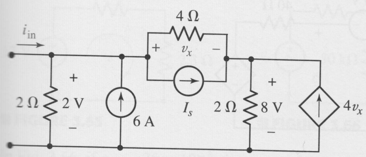


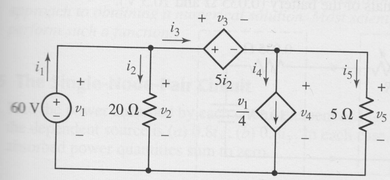
FIGURE 3.55

20. Use Ohm's and Kirchhoff's laws on the circuit of Fig. 3.56 to find (*a*) v_x; (*b*) i_{in}; (*c*) I_s; (*d*) the power provided by the dependent source.



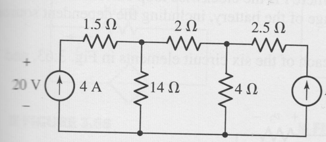
■ **FIGURE 3.56**

21. (*a*) Use Kirchhoff's and Ohm's laws in a step-by-step procedure to evaluate all the currents and voltages in the circuit of Fig. 3.57. (*b*) Calculate the power absorbed by each of the five circuit elements and show that the sum is zero.



■ **FIGURE 3.57**

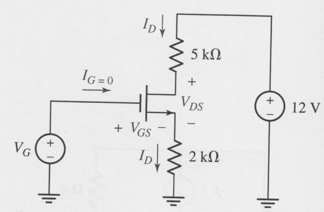
22. With reference to the circuit shown in Fig. 3.58, find the power absorbed by each of the seven circuit elements.



■ **FIGURE 3.58**

23. A certain circuit contains six elements and four nodes, numbered 1, 2, 3, and 4. Each circuit element is connected between a different pair of nodes. The voltage v_{12} (+ reference at first-named node) is 12 V, and $v_{34} = -8$ V. Find v_{13}, v_{23}, and v_{24} if v_{14} equals (*a*) 0; (*b*) 6 V; (*c*) −6 V.

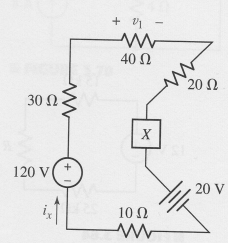
24. Refer to the transistor circuit shown in Fig. 3.59. Keep in mind that although we do not know the current-voltage relationship for the device, it still obeys both KCL and KVL. (*a*) If $I_D = 1.5$ mA, compute V_{DS}. (*b*) If $I_D = 2$ mA and $V_G = 3$ V, compute V_{GS}.



■ **FIGURE 3.59**

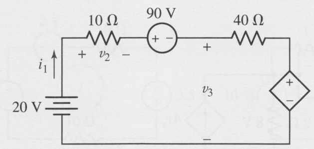
3.4 The Single-Loop Circuit

25. Find the power being absorbed by element X in Fig. 3.60 if it is a (*a*) 100 Ω resistor; (*b*) 40 V independent voltage source, + reference on top; (*c*) dependent voltage source labeled $25i_x$, + reference on top; (*d*) dependent voltage source labeled $0.8v_1$, + reference on top; (*e*) 2 A independent current source, arrow directed upward.



■ **FIGURE 3.60**

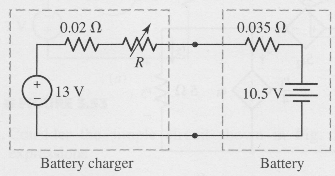
26. Find i_1 in the circuit of Fig. 3.61 if the dependent voltage source is labeled: (*a*) $2v_2$; (*b*) $1.5v_3$; (*c*) $-15i_1$.



■ **FIGURE 3.61**

27. Refer to the circuit of Fig. 3.61 and label the dependent source $1.8v_3$. Find v_3 if (*a*) the 90 V source generates 180 W; (*b*) the 90 V source absorbs 180 W; (*c*) the dependent source generates 100 W; (*d*) the dependent source absorbs 100 W of power.

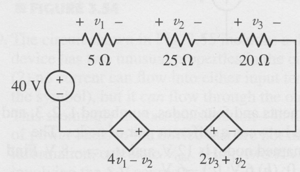
28. For the battery charger modeled by the circuit of Fig. 3.62, find the value of the adjustable resistor *R* so that: (*a*) a charging current of 4 A flows; (*b*) a power of 25 W is delivered to the battery (0.035 Ω and 10.5 V); (*c*) a voltage of 11 V is present at the terminals of the battery (0.035 Ω and 10.5 V).



■ **FIGURE 3.62**

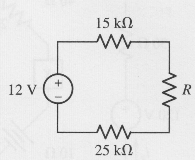
29. The circuit of Fig. 3.62 is modified by installing a dependent voltage source in series with the battery. Break the top wire, place the + reference at the right and let the control be $0.05i$, where *i* is the clockwise loop current. Find this current and the terminal voltage of the battery, including the dependent source, if $R = 0.5\ \Omega$.

30. Find the power absorbed by each of the six circuit elements in Fig. 3.63, and show that they sum to zero.



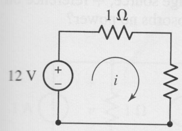
■ **FIGURE 3.63**

31. For the circuit of Fig. 3.64,
    (*a*) Determine the resistance *R* that will result in the 25 kΩ resistor absorbing 2 mW.
    (*b*) Determine the resistance *R* that results in the 12 V source delivering 3.6 mW to the circuit.
    (*c*) Replace the resistor *R* with a voltage source such that no power is absorbed by either resistor; draw the circuit, indicating the voltage polarity of the new source.

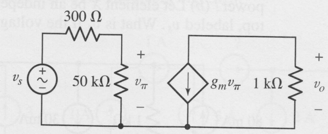


■ **FIGURE 3.64**

32. Referring to Table 2.4, if the bottom wire segment in the circuit of Fig. 3.65 is 22 AWG solid copper and 3000 ft long, compute the current i.



■ FIGURE 3.65



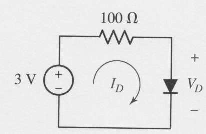
■ FIGURE 3.66

33. In Fig. 3.66, if $g_m = 25 \times 10^{-3}$ siemens and $v_s = 10 \cos 5t$ mV, find $v_o(t)$.

34. Kirchhoff's laws apply whether or not Ohm's law applies to a particular element. The *I-V* characteristic of a diode, for example, is given by

$$I_D = I_S\,(e^{V_D/V_T} - 1)$$

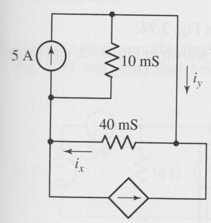
where $V_T = 27$ mV at room temperature and I_S can vary from 10^{-12} to 10^{-3} A. In the circuit of Fig. 3.67, use KVL/KCL to obtain V_D if $I_S = 3\ \mu$A. (*Note: This problem results in a transcendental equation, requiring an iterative approach to obtaining a numerical solution. Most scientific calculators will perform such a function.*)



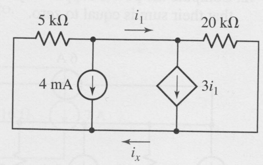
■ FIGURE 3.67

3.5 The Single-Node-Pair Circuit

35. Find the power absorbed by each circuit element of Fig. 3.68 if the control for the dependent source is (*a*) $0.8i_x$; (*b*) $0.8i_y$. In each case, demonstrate that the absorbed power quantities sum to zero.



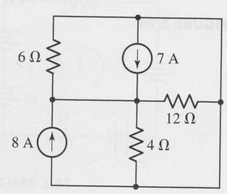
■ FIGURE 3.68



■ FIGURE 3.69

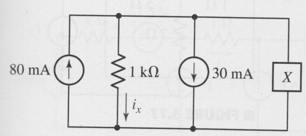
36. Find i_x in the circuit of Fig. 3.69.

37. Find the power absorbed by each element in the single-node-pair circuit of Fig. 3.70, and show that the sum is equal to zero.



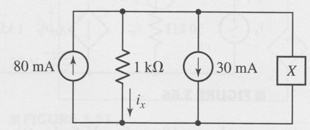
■ FIGURE 3.70

38. Find the power absorbed by element X in the circuit of Fig. 3.71 if it is a (*a*) 4 kΩ resistor; (*b*) 20 mA independent current source, reference arrow downward; (*c*) dependent current source, reference arrow downward, labeled $2i_x$; (*d*) 60 V independent voltage source, + reference at top.



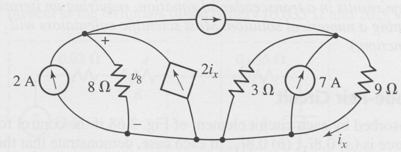
■ FIGURE 3.71

39. (*a*) Let element X in Fig. 3.72 be an independent current source, arrow directed upward, labeled i_s. What is i_s if none of the four circuit elements absorbs any power? (*b*) Let element X be an independent voltage source, + reference on top, labeled v_s. What is v_s if the voltage source absorbs no power?



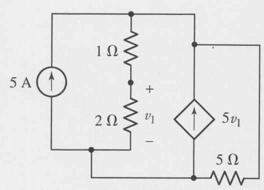
■ **FIGURE 3.72**

40. (*a*) Apply the techniques of single-node-pair analysis to the upper right node in Fig. 3.73 and find i_x. (*b*) Now work with the upper left node and find v_8. (*c*) How much power is the 5 A source generating?



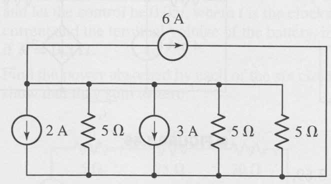
■ **FIGURE 3.73**

41. Find the power absorbed by the 5 Ω resistor in Fig. 3.74.



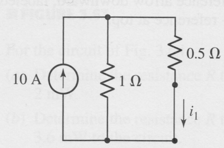
■ **FIGURE 3.74**

42. Compute the power supplied by each element shown in Fig. 3.75, and show that their sum is equal to zero.

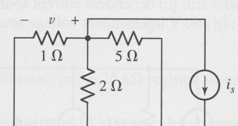


■ **FIGURE 3.75**

43. Referring to Table 2.4, how many miles of 28 AWG solid copper wire is required for the labelled wire segment of Fig. 3.76 to obtain $i_1 = 5$ A?



■ **FIGURE 3.76**

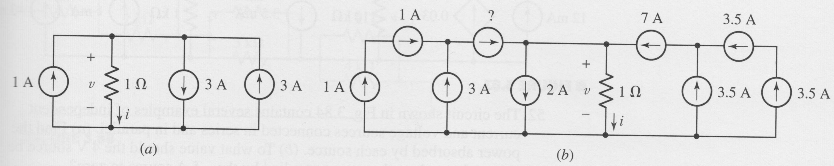


■ **FIGURE 3.77**

44. In the circuit of Fig. 3.77, if $v = 6$ V, find i_s.

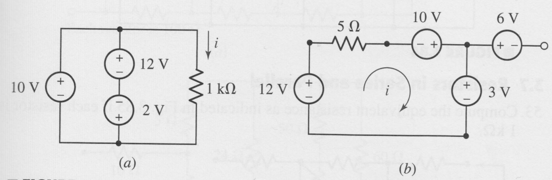
3.6 Series and Parallel Connected Sources

45. Using combinations of sources, compute i for both circuits in Fig. 3.78.



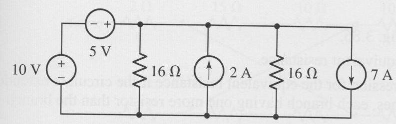
■ **FIGURE 3.78**

46. Compute v for each of the circuits in Fig. 3.78 by first combining sources.
47. Compute the current labeled i in each of the circuits in Fig. 3.79.



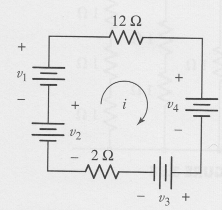
■ **FIGURE 3.79**

48. Compute the power absorbed by each element of the circuit shown in Fig. 3.80, and verify that their sum is zero.



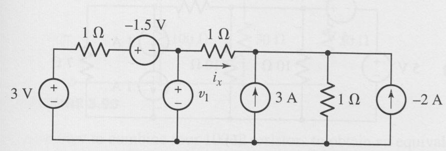
■ **FIGURE 3.80**

49. For the circuit in Fig. 3.81, compute i if:
   (a) $v_1 = v_2 = 10$ V and $v_3 = v_4 = 6$ V.
   (b) $v_1 = v_3 = 3$ V and $v_2 = v_4 = 2.5$ V.
   (c) $v_1 = -3$ V, $v_2 = 1.5$ V, $v_3 = -0.5$ V, and $v_4 = 0$ V.



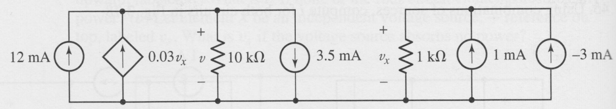
■ **FIGURE 3.81**

50. In the circuit of Fig. 3.82, choose v_1 to obtain a current i_x of 2 A.



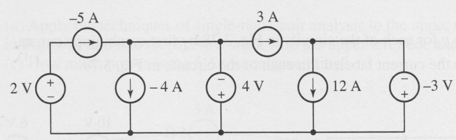
■ **FIGURE 3.82**

51. Find the voltage v in the circuit of Fig. 3.83.



■ **FIGURE 3.83**

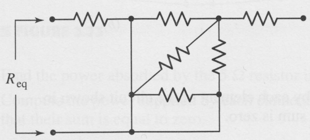
52. The circuit shown in Fig. 3.84 contains several examples of independent current and voltage sources connected in series and in parallel. (*a*) Find the power absorbed by each source. (*b*) To what value should the 4 V source be changed to reduce the power supplied by the −5 A source to zero?



■ **FIGURE 3.84**

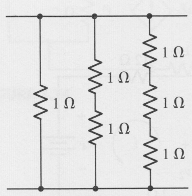
3.7 Resistors in Series and Parallel

53. Compute the equivalent resistance as indicated in Fig. 3.85 if each resistor is 1 kΩ.



■ **FIGURE 3.85**

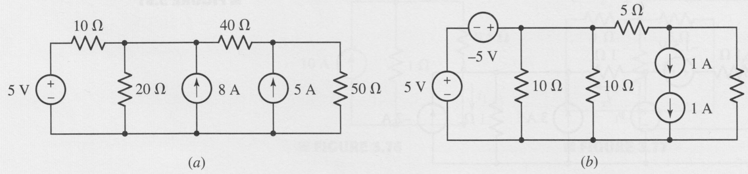
54. For the circuit in Fig. 3.86,
   (*a*) Compute the equivalent resistance.
   (*b*) Derive an expression for the equivalent resistance if the circuit is extended using N branches, each branch having one more resistor than the branch to its left.



■ **FIGURE 3.86**

55. Given three 10 kΩ resistors, three 47 kΩ resistors, and three 1 kΩ resistors, find a combination (not all resistors need to be used) that yields:
   (*a*) 5 kΩ
   (*b*) 57,333 Ω
   (*c*) 29.5 kΩ

56. Simplify the networks in Fig. 3.87 using resistor and source combinations.



■ **FIGURE 3.87**

57. Compute the equivalent resistance of the circuit in Fig. 3.88.

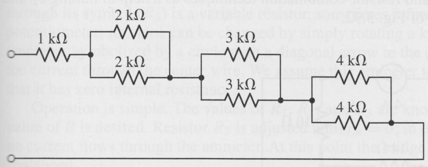


FIGURE 3.88

58. Find R_{eq} for each of the resistive networks shown in Fig. 3.89.

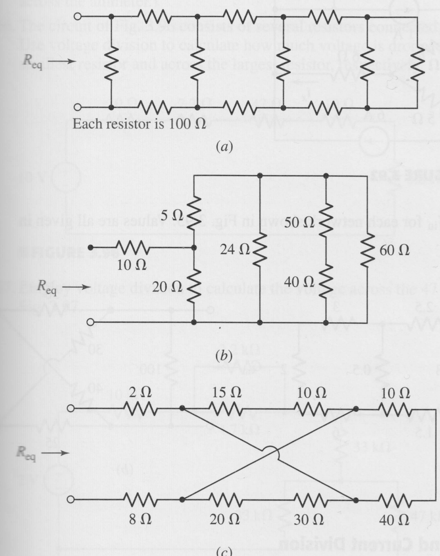


FIGURE 3.89

59. In the network shown in Fig. 3.90: (*a*) let $R = 80\ \Omega$ and find R_{eq}; (*b*) find R if $R_{eq} = 80\ \Omega$; (*c*) find R if $R = R_{eq}$.

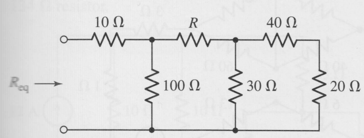
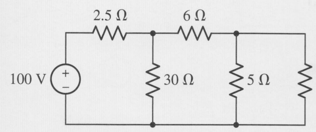


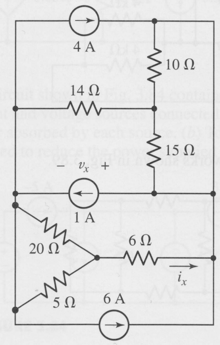
FIGURE 3.90

60. Show how to combine four 100 Ω resistors to obtain an equivalent resistance of (*a*) 25 Ω; (*b*) 60 Ω; (*c*) 40 Ω.

61. Find the power absorbed by each of the resistors in the circuit of Fig. 3.91.
62. Use source- and resistor-combination techniques as a help in finding v_x and i_x in the circuit of Fig. 3.92.

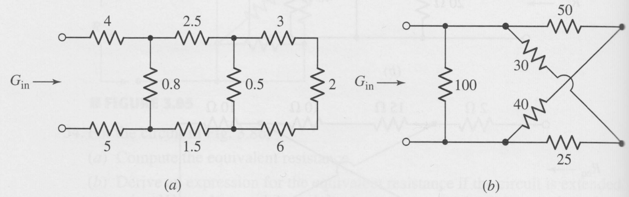


■ **FIGURE 3.91**



■ **FIGURE 3.92**

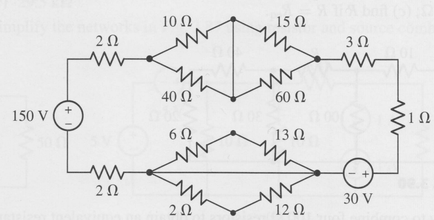
63. Determine G_{in} for each network shown in Fig. 3.93. Values are all given in millisiemens.



■ **FIGURE 3.93**

3.8 Voltage and Current Division

64. Use both resistance and source combinations, as well as current division, in the circuit of Fig. 3.94 to find the power absorbed by the 1 Ω, 10 Ω, and 13 Ω resistors.

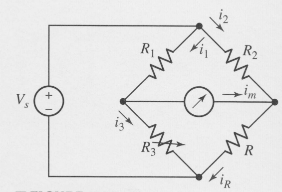


■ **FIGURE 3.94**

65. The ***Wheatstone bridge*** (Fig. 3.95) is one of the most well-known electrical circuits and is used in resistance measurement. The resistor with an arrow through its symbol (R_3) is a variable resistor, sometimes referred to as a potentiometer; its value can be changed by simply rotating a knob. The ammeter, symbolized by a circle with a diagonal arrow in the center, measures the current through the center wire. We assume this ammeter to be ideal, so that it has zero internal resistance.

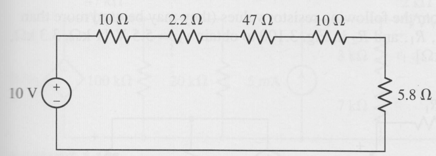
Operation is simple. The values of R_1, R_2, and R_3 are known, and the value of R is desired. Resistor R_3 is adjusted until $i_m = 0$; in other words, until no current flows through the ammeter. At this point the bridge is said to be "balanced."

Using KCL and KVL, show that $R = \frac{R_2}{R_1} R_3$. (Hints: The value of V_s is irrelevant; with $i_m = 0$, $i_1 = i_3$ and $i_2 = i_R$; and there is no voltage dropped across the ammeter.)



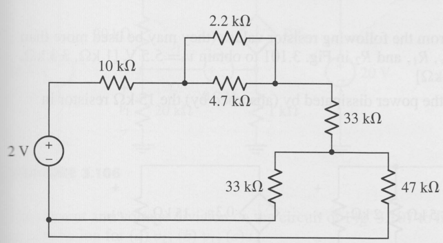
■ **FIGURE 3.95**

66. The circuit of Fig. 3.96 consists of several resistors connected in a series string. Use voltage division to calculate how much voltage is dropped across the smallest resistor and across the largest resistor, respectively.



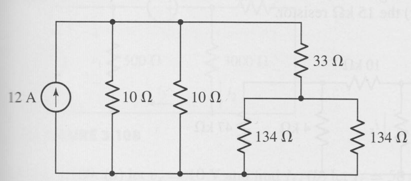
■ **FIGURE 3.96**

67. Employ voltage division to calculate the voltage across the 47 kΩ resistor of Fig. 3.97.



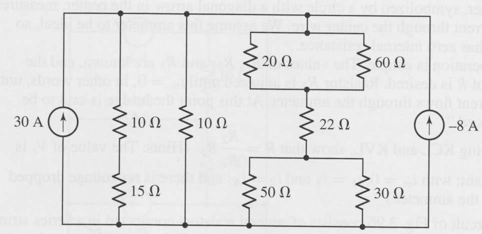
■ **FIGURE 3.97**

68. Referring to the circuit depicted in Fig. 3.98, use current division to calculate the current flowing downward through (*a*) the 33 Ω resistor; (*b*) the rightmost 134 Ω resistor.



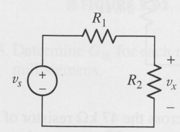
■ **FIGURE 3.98**

69. It appears that despite the large number of components in the circuit of Fig. 3.99, only the voltage across the 15 Ω resistor is of interest. Use current division to assist in calculating the correct value.

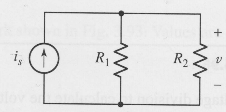


■ **FIGURE 3.99**

D 70. Choosing from the following resistor values (they may be used more than once), set v_s, R_1, and R_2 in Fig. 3.100 to obtain $v_x = 5.5$ V. [1 kΩ, 3.3 kΩ, 4.7 kΩ, 10 kΩ]



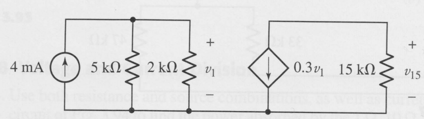
■ **FIGURE 3.100**



■ **FIGURE 3.101**

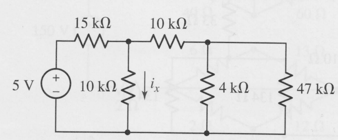
D 71. Choosing from the following resistor values (they may be used more than once), set i_s, R_1, and R_2 in Fig. 3.101 to obtain $v = 5.5$ V. [1 kΩ, 3.3 kΩ, 4.7 kΩ, 10 kΩ]

72. Determine the power dissipated by (absorbed by) the 15 kΩ resistor in Fig. 3.102.



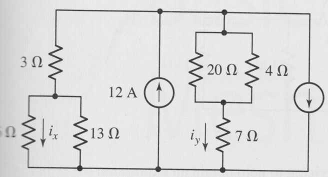
■ **FIGURE 3.102**

73. For the circuit in Fig. 3.103, determine i_x, and compute the power dissipated by (absorbed by) the 15 kΩ resistor.



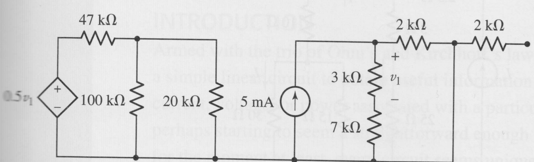
■ **FIGURE 3.103**

74. For the circuit in Fig. 3.104, find i_x, i_y, and the power dissipated by (absorbed by) the 3 Ω resistor.



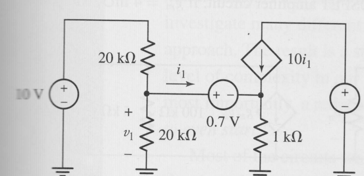
■ FIGURE 3.104

75. What is the power dissipated by (absorbed by) the 47 kΩ resistor in Fig. 3.105?



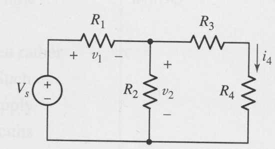
■ FIGURE 3.105

76. Explain why voltage division cannot be used to determine v_1 in Fig. 3.106.



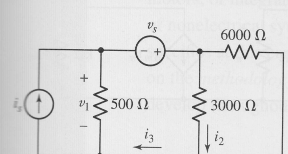
■ FIGURE 3.106

77. Use current and voltage division on the circuit of Fig. 3.107 to find an expression for (*a*) v_2; (*b*) v_1; (*c*) i_4.



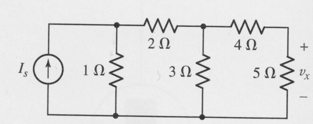
■ FIGURE 3.107

78. With reference to the circuit shown in Fig. 3.108: (*a*) let $v_s = 40$ V, $i_s = 0$, and find v_1; (*b*) let $v_s = 0$, $i_s = 3$ mA, and find i_2 and i_3.



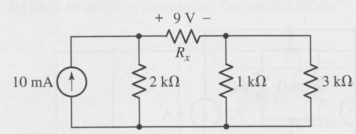
■ FIGURE 3.108

79. In Fig. 3.109: (*a*) let $v_x = 10$ V and find I_s; (*b*) let $I_s = 50$ A and find v_x; (*c*) calculate the ratio v_x/I_s.



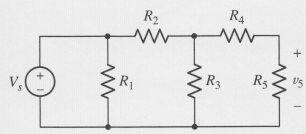
■ FIGURE 3.109

80. Determine how much power is absorbed by R_x in the circuit of Fig. 3.110.



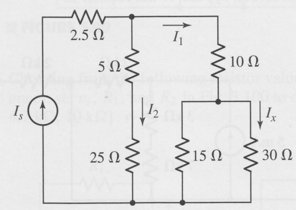
■ **FIGURE 3.110**

81. Use current and voltage division to help obtain an expression for v_5 in Fig. 3.111.



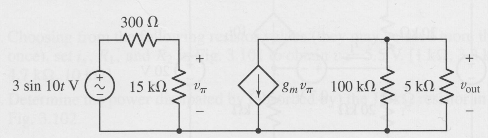
■ **FIGURE 3.111**

82. With reference to the circuit of Fig. 3.112, find (*a*) I_x if $I_1 = 12$ mA; (*b*) I_1 if $I_x = 12$ mA; (*c*) I_x if $I_2 = 15$ mA; (*d*) I_x if $I_s = 60$ mA.



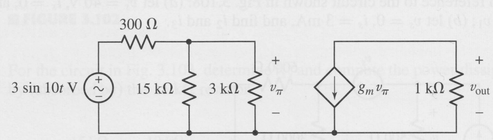
■ **FIGURE 3.112**

83. The circuit in Fig. 3.113 is a commonly used equivalent circuit used to model the ac behavior of a MOSFET amplifier circuit. If $g_m = 4$ m℧, compute v_{out}.



■ **FIGURE 3.113**

84. The circuit in Fig. 3.114 is a commonly used equivalent circuit used to model the ac behavior of a bipolar junction transistor amplifier circuit. If $g_m = 38$ m℧, compute v_{out}.



■ **FIGURE 3.114**