PROBLEMS

P 3-1 For the circuit shown in Figure P 3-1, find i using the current divider principle and determine the power absorbed by the 12-Ω resistor.
Answer: 0.3 A, 0.48 W

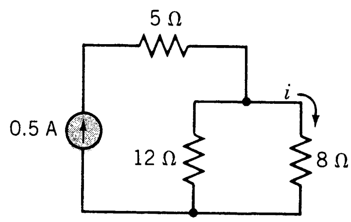

Figure P 3-1

P 3-2 Find i using current division if $I_0 = 6$ mA in the circuit shown in Figure P 3-2.

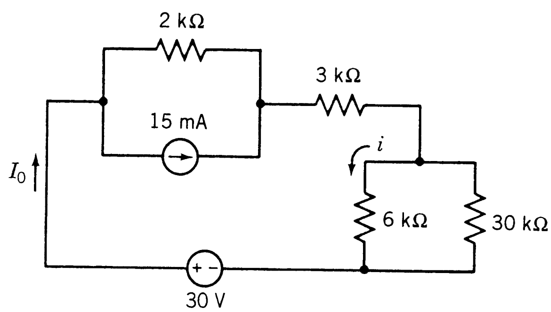

Figure P 3-2

P 3-3 Find i and i_1 using appropriate circuit reductions and the current divider principle for the circuit of Figure P 3-3.
Answer: $i = 2$ A, $i_1 = -3/4$ A

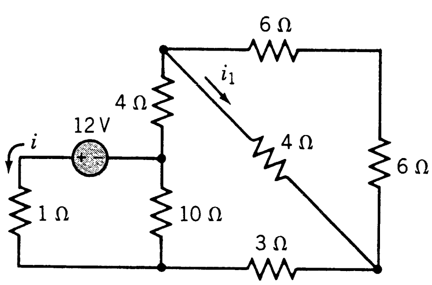

Figure P 3-3

P 3-4 Find i using appropriate circuit reductions and the current divider principle for the circuit of Figure P 3-4.

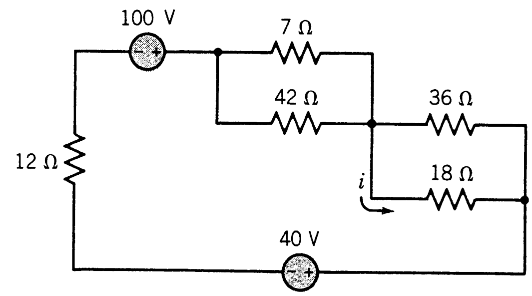

Figure P 3-4

P 3-5 Find i and $R_{eq\,a\text{-}b}$ if $v_{ab} = 40$ V in the circuit of Figure P 3-5.
Answer: $R_{eq\,a\text{-}b} = 8\ \Omega$, $i = 5/6$ A

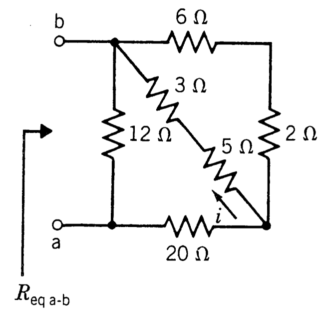

Figure P 3-5

P 3-6 Find R_{eq}, i, and v if $v_{ab} = 12$ V for the circuit of Figure P 3-6.

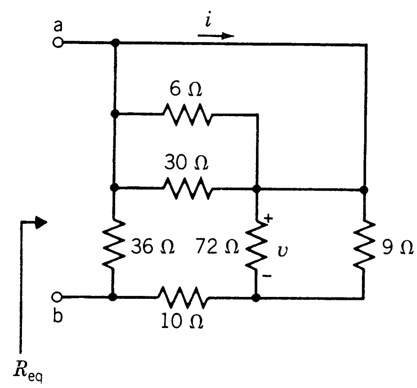

Figure P 3-6

P 3-7 Find i and the power absorbed by the 12-kΩ resistor for the circuit of Figure P 3-7.
Answer: $i = 2$ mA, $p = 16/3$ mW

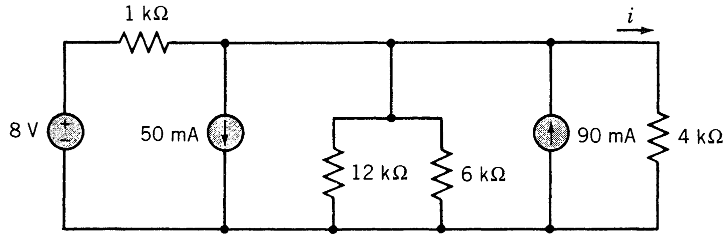

Figure P 3-7

P 3-8 If $v_1 = 12$ V, find i_s and v for the circuit of Figure P 3-8.

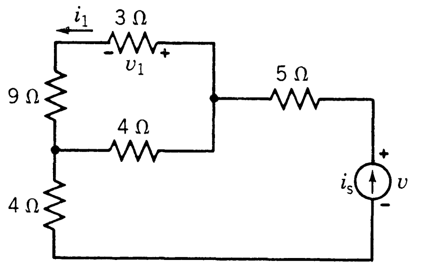

Figure P 3-8

P 3-9 If $v = 2$ V, find the resistance R of the circuit shown in Figure P 3-9.
Answer: $R = 2\ \Omega$

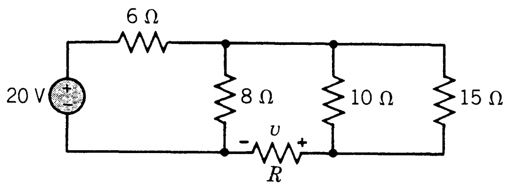

Figure P 3-9

P 3-10 Find the power supplied by the current source and the power absorbed by the 900-Ω resistor in parallel with the current source of Figure P 3-10. All resistances are in ohms.

P 3-11 For the circuit of Figure P 3-11, find i, v, and the power absorbed by the unknown circuit element if the power supplied by the 16-V source is 8 watts.
Answer: $v = 8$ V, $i = -1/6$ A, $p = -4/3$ W

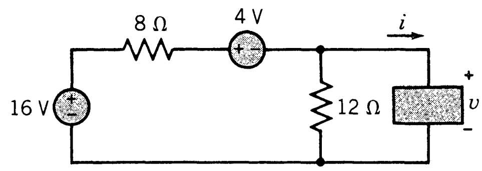

Figure P 3-11

P 3-12 For the circuit shown in Figure P 3-12, find the power absorbed by each element and show that the total circuit neither absorbs nor dissipates energy.

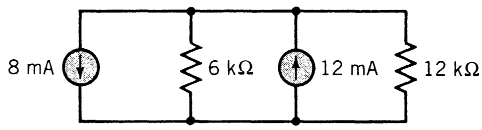

Figure P 3-12

P 3-13 Find i in the circuit in Figure P 3-13.
Answer $i = -1$ mA

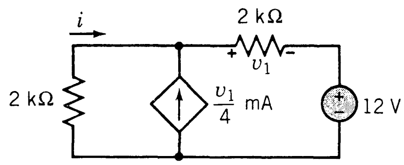

Figure P 3-13

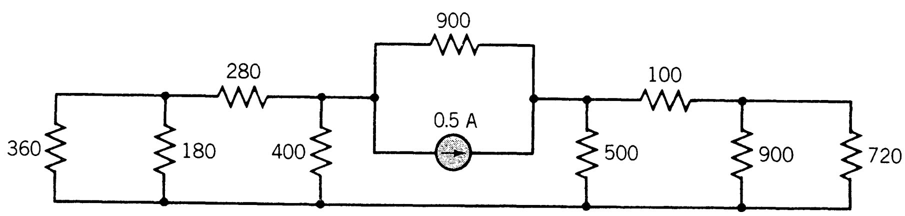

Figure P 3-10

P 3-14 Find the power absorbed by the 600-Ω resistor in Figure P 3-14.

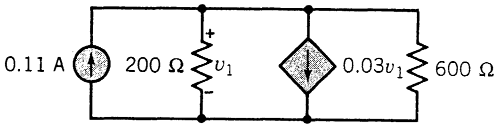

Figure P 3-14

P 3-15 A solar photovoltaic panel may be represented by the model shown in Figure P 3-15, where R_L is the load resistor. The source current is 2 A and $v_{ab} = 40$ V. Find R_1 when $R_2 = 10\ \Omega$ and $R_L = 30\ \Omega$.

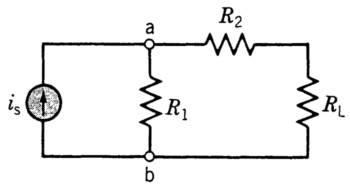

Figure P 3-15

P 3-16 Find i and the power absorbed by each element shown in Figure P 3-16.

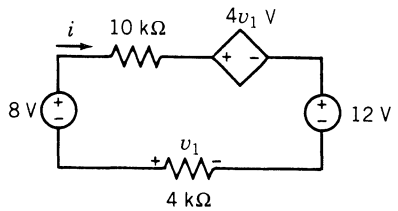

Figure P 3-16

P 3-17 Find v_1 and v in the circuit shown in Figure P 3-17.
Answer: $v_1 = 4$ V, $v = 15$ V

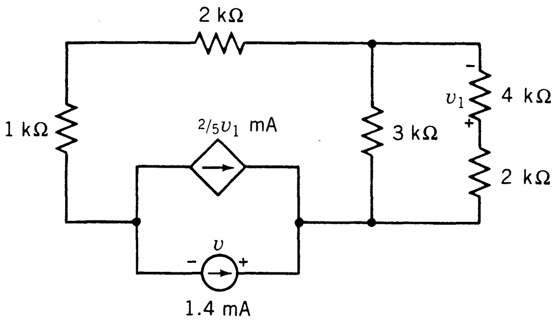

Figure P 3-17

P 3-18 Find the load resistance R_L if $v = 0.06$ V in the circuit of Figure P 3-18. This circuit is a model of a transistor amplifier with a load R_L.

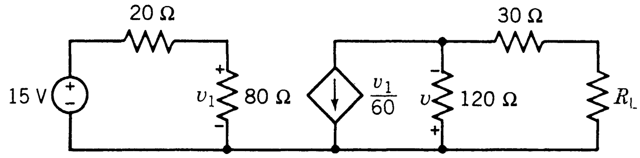

Figure P 3-18

P 3-19 For the circuit of Figure P 3-19, find v_1 and the power absorbed by each element.
Answer: $v_1 = 3$ V

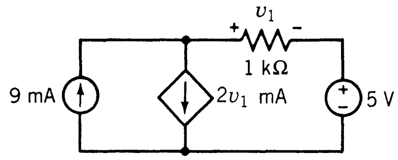

Figure P 3-19

P 3-20 Find v_a and i in the circuit shown in Figure P 3-20.

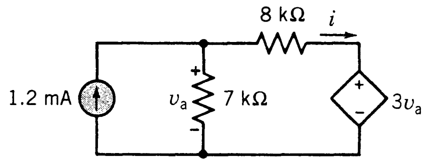

Figure P 3-20

P 3-21 Find i for the circuit of Figure P 3-21. Note that the units of the conductances are siemens (S).
Answer: $i = 1.6$ A

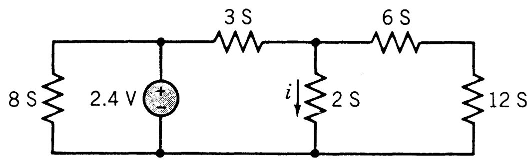

Figure P 3-21

P 3-22 Find v_x and the power absorbed by the conductance of 5 mS, for the circuit shown in Figure P 3-22. The dependant source units are mA/V.

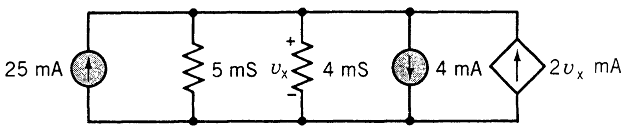

Figure P 3-22

P 3-23 For the circuit shown in Figure P 3-23, find $R_{eq\,a-b}$ and $R_{eq\,c-d}$. Also determine the voltage v_{cd} when $v_{ab} = 20$ V.
Answer: $R_{eq\,c-d} = 6\ \Omega$

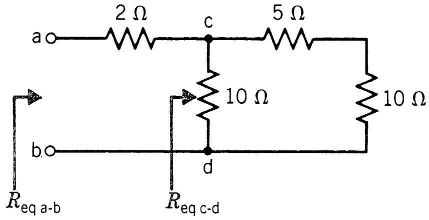

Figure P 3-23

P 3-24 Find the R_{eq} at terminals a–b in Figure P 3-24. Also determine i, i_1, and i_2.

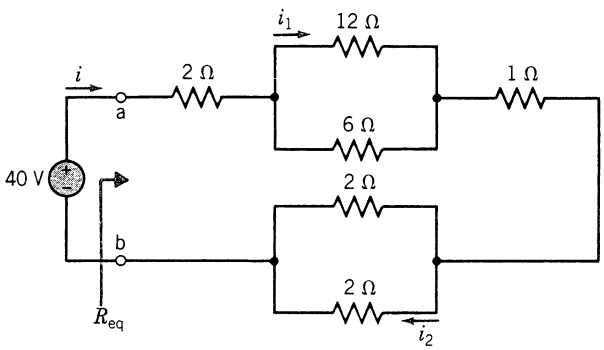

Figure P 3-24

P 3-25 For the circuit of Figure P 3-25, given that $R_{eq} = 9\ \Omega$, find R.
Answer: $R = 15\ \Omega$

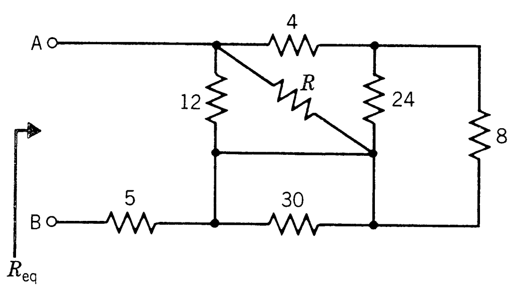

Figure P 3-25

P 3-26 Electric streetcar railways have been used for about 100 years. An electric railway was established by Werner Siemens from Charlottenbourg to Spandau in Berlin in 1885, as shown in Figure P 3-26*a*. This railway may be represented by the electric circuit shown in Figure P 3-26*b*. Find the power delivered to the motor R_L by the central power source.

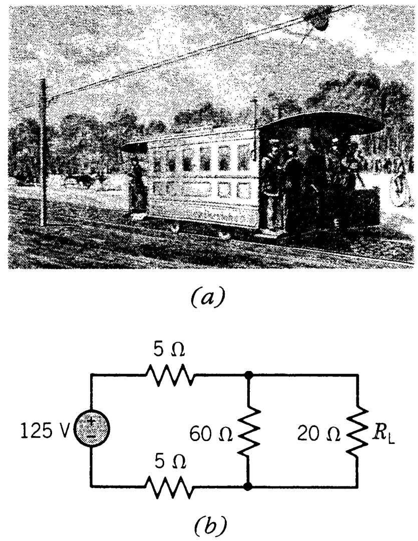

Figure P 3-26 *(a)* The electric street railway in Berlin in 1885. Courtesy of Burndy Library. *(b)* Circuit model of the railway, where $R_L = 20\ \Omega$.

P 3-27 Most of us are familiar with the effects of a mild electric shock. The effects of a severe shock can be devastating and often fatal. Shock results when current is passed through the body. A person can be modeled as a network of resistances. Consider the model circuit shown in Figure P 3-27. Determine the voltage developed across the heart and the current flowing through the heart of the person when he or she firmly grasps one end of a voltage source whose other end is connected to the floor. The heart is represented by R_h. The floor has resistance to current flow equal to R_f, and the person is standing barefoot on the floor. This type of accident might occur at a swimming pool or boat dock. The upper-body resistance R_U and lower-body resistance R_L vary from person to person.

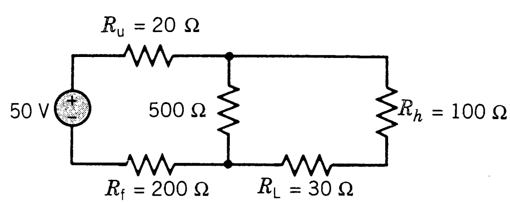

Figure P 3-27 The resistance of the heart. $R_h = 10\ \Omega$.

***P 3-28** For the circuit of Figure P 3-28, find R_{eq} at terminals a–b and the current i if $v_{ab} = 14$ V.

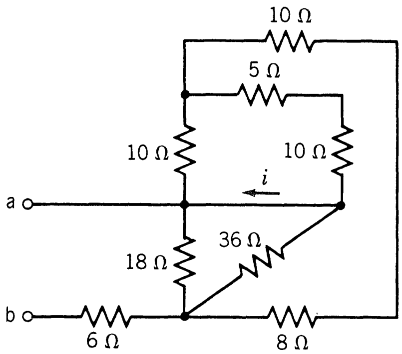

Figure P 3-28

***P 3-29** Find i_1 in the circuit shown in Figure P 3-29.

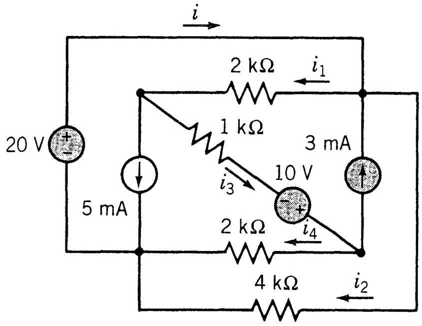

Figure P 3-29

***P 3-30** Find i in the circuit shown in Figure P 3-30.

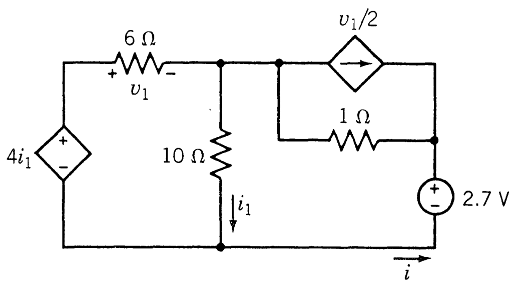

Figure P 3-30

***P 3-31** For the circuit of Figure P 3-31, find $R_{eq\,a\text{-}b}$. Hint: Note the symmetry of the circuit.

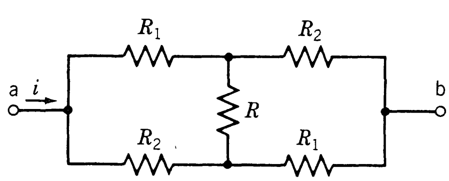

Figure P 3-31

P 3-32 An electric heater is connected to a constant 250-V source and absorbs 1000 W. Subsequently, this heater is connected to a constant 210-V source. What power does it absorb from the 210-V source? What is the resistance of the heater?

P 3-33 A model of a common-emitter transistor amplifier is shown in Figure P 3-33. Find the voltage v_o when $v_s = 1$ mV.
Answer: $v_o = 4$ V

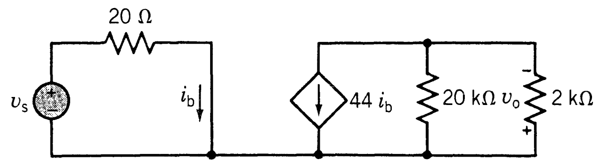

Figure P 3-33 Model of a transistor amplifier.

P 3-34 For the circuit shown in Figure P 3-34:
(a) Find the current i.
(b) Find the voltage v.
(c) Find the power absorbed by the 2-A current source.
(d) Find the power delivered by the 8-V voltage source.

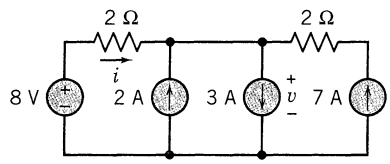

Figure P 3-34

P 3-35 Determine R and the power delivered to the 6-Ω resistor for the circuit shown in Figure P 3-35 when $i = 2$ A.

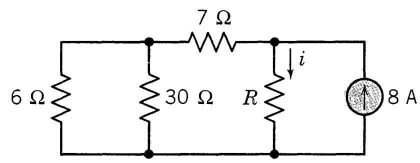

Figure P 3-35

P 3-36 The 10-V source in Figure P 3-36 is known to be delivering 20 W to the circuit. (a) Determine whether the element x is an active or passive element. (b) Determine the power delivered or absorbed by the element x and indicate whether it is delivering or absorbing power.
Answer: $P_x = 4$ W delivered

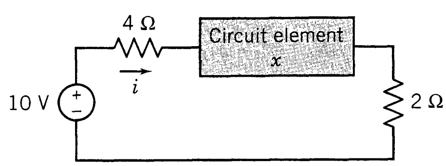

Figure P 3-36

* Note: An asterisk denotes a challenging problem.

ADVANCED PROBLEMS

AP 3-1 The portable lighting equipment for a mine is located 100 meters from its dc supply source. The mine lights use a total of 5 kW and operate at 120 V dc. Determine the required cross-sectional area of the copper wires used to connect the source to the mine lights if we require that the power lost in the copper wires be less than or equal to 5 percent of the power required by the mine lights.

AP 3-2 The current i_2 is 10 A in the circuit shown in Figure AP 3-2. Determine the resistance R.

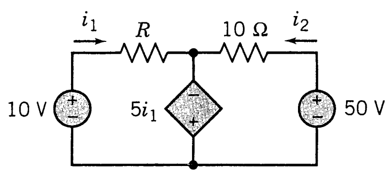

Figure AP 3-2

AP 3-3 Determine the equivalent resistance, R_{xy}, of the circuit shown in Figure AP 3-3.

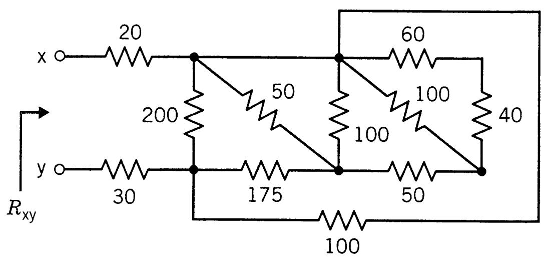

Figure AP 3-3 All resistances in ohms.

AP 3-4 The circuit of 1-ohm resistors shown in Figure AP 3-4 extends to infinity in both directions. Determine the resistance R_{ab} between terminals a and b.

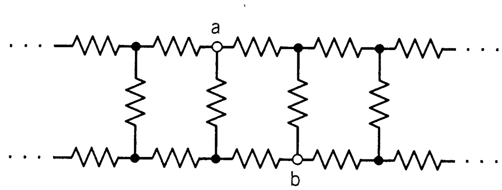

Figure AP 3-4

AP 3-5 The model of an amplifier is shown in Figure AP 3-5. Determine R_i, R_o, and v_o when $R_G = 10$ MΩ, $g = 5$ mS, $R_D = 1$ kΩ, $R_2 = 100$ Ω, and $R_s = 100$ Ω.

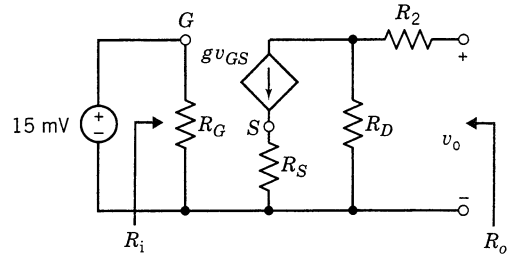

Figure AP 3-5 Amplifier circuit.

AP 3-6 Determine R_{eq} for the circuit shown in Figure AP 3-6 in the form of a continued fraction as

$$R_1 + \cfrac{1}{G_2 + \cdots}$$

Calculate R_{eq} when $R_1 = 1$ Ω and $G_2 = 1/2$ S.

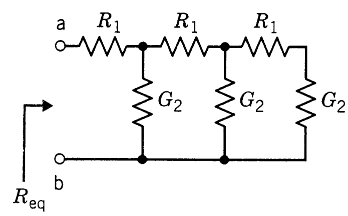

Figure AP 3-6

AP 3-7 The source $v_s = 240$ volts is connected to three equal resistors as shown in Figure AP 3-7. Determine R when the voltage source delivers 1920 watts to the resistors.

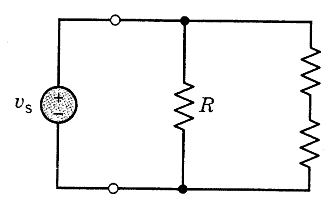

Figure AP 3-7

DESIGN PROBLEMS

DP 3-1 A circuit is used to supply energy to a heater as shown in Figure DP 3-1. It is desired to supply 3.53 mW to the heater. Determine an appropriate voltage source v_s and a resistance R_1.

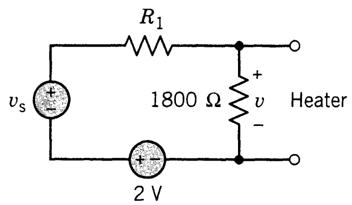

Figure DP 3-1 A heater circuit.

DP 3-2 A circuit is shown in Figure DP 3-2 with an unspecified resistance R. Select R so that the equivalent resistance looking into terminals a–b is 1 Ω.

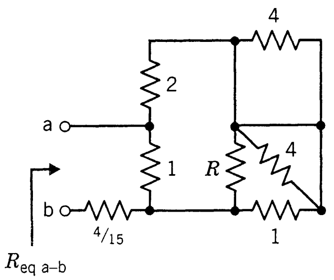

Figure DP 3-2 All resistances in ohms.

DP 3-3 A circuit is shown in Figure DP 3-3 with an unspecified current source constant. Select the constant g so that the voltage $v = 16$ V.

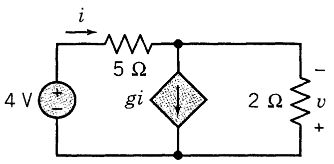

Figure DP 3-3

DP 3-4 A phonograph pickup, stereo amplifier, and speaker are shown in Figure DP 3-4*a* and redrawn as a circuit model as shown in DP 3-4*b*. Determine the resistance R so that the voltage v across the load is 16 V. Determine the power delivered to the speaker.

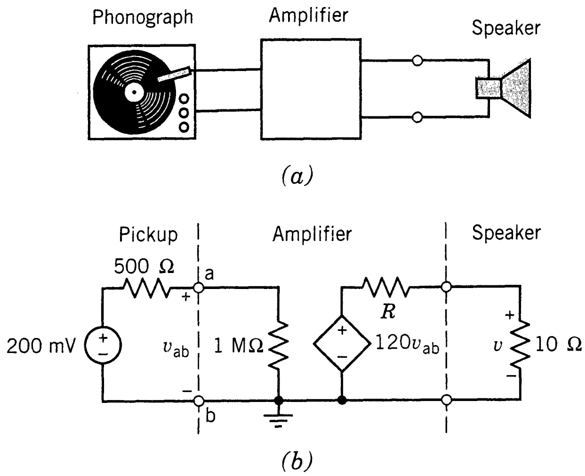

Figure DP 3-4 A phonograph stereo system.

DP 3-5 A Christmas tree light set is required that will operate from a 6-V battery on a tree in a city park. The heavy-duty battery can provide 9 A for the 4-hour period of operation each night. Design a parallel set of lights (select the maximum number of lights) when the resistance of each bulb is 12 Ω.

DP 3-6 A circuit with a subcircuit box is shown in Figure DP 3-6. The subcircuit is known to absorb 150 W prior to $t = 5$ s. After the switch is opened at $t = 5$ s, the power absorbed by the box is 65 W. Calculate a suitable value for R and specify your model for the subcircuit.

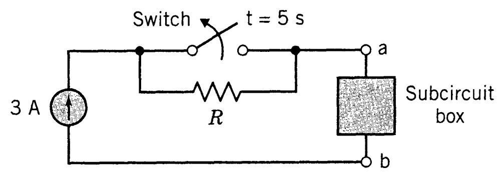

Figure DP 3-6

DP 3-7 A designer requires the circuit of Figure DP 3-7 to exhibit a resistance R_{eq} at terminals a–b of 24 Ω. Select a suitable value for g and R when $1 \le g \le 5$.

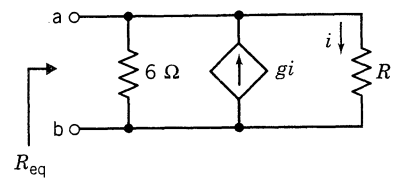

Figure DP 3-7

TERMS AND CONCEPTS

Dual Circuits Circuits such that the set of transforms that converts one circuit into another also converts the second circuit into the first.

Efficiency of Power Transfer Ratio of the power delivered to the load to the power supplied by the source.

Equivalent Circuit Arrangement of circuit elements that is equivalent to a more complex arrangement of elements. A circuit that exhibits identical characteristics (behavior) to another circuit at identical terminals.

Maximum Power Transfer Theorem The maximum power delivered by a circuit represented by its Thévenin equivalent is attained when the load resistor R_L is equal to the Thévenin resistance R_t.

Norton's Theorem For a linear circuit, divide it into two parts, A and B. For circuit A, determine its short-circuit current at its terminals. The equivalent circuit of A is a current source i_{sc} in parallel with a resistance R_n, where R_n is the resistance calculated with all its independent sources deactivated.

Source Transformation Transformation of one source into another while retaining the terminal characteristics. A voltage source may be transformed to a current source and vice versa.

Superposition Theorem For a linear circuit containing independent sources, the voltage across (or the current through) any element may be obtained by adding algebraically all the individual voltages (or currents) caused by each independent source acting alone with all other sources set to zero.

Thévenin's Theorem Divide a circuit into two parts, A and B, connected at a pair of terminals. Determine v_{oc} as the open-circuit voltage of A with B disconnected. Then the equivalent circuit of A is a source voltage v_{oc} in series with R_t, where R_t is the resistance seen at the terminals of circuit A when all the independent sources are deactivated.

REFERENCE Chapter 5

Edelson, Edward, "Solar Cell Update", Popular Science, June 1992, pp. 95–99.

PROBLEMS

P 5-1 For the circuit of Figure P 5-1, find the current i and the power absorbed by the resistor R_L when $R_L = 2$ ohms by using successive source transformations.
Answer: $i = 2$ A
$p = 8$ W

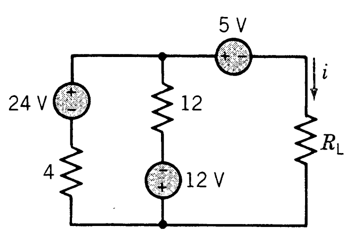

Figure P 5-1 All resistances are in ohms.

P 5-2 Consider the circuit of Figure P 5-2. Find i_a by simplifying the circuit (using source transformations) to a single-loop circuit so that you need to write only one KVL equation to find i_a.

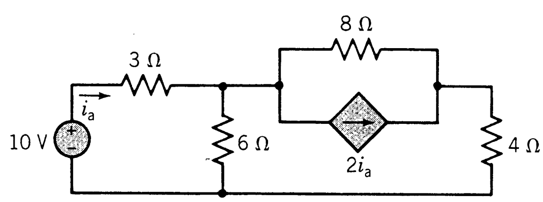

Figure P 5-2

P 5-3 Use source transformations to find the voltage v across the 1-amp current source for the circuit shown in Figure P 5-3.
Answer: $v = 3$ volts

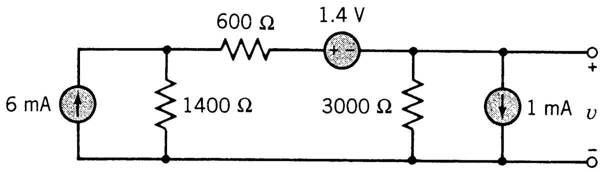

Figure P 5-3

P 5-4 Find v_0 using source transformations if $i = 5/2$ A in the circuit shown in Figure P 5-4.

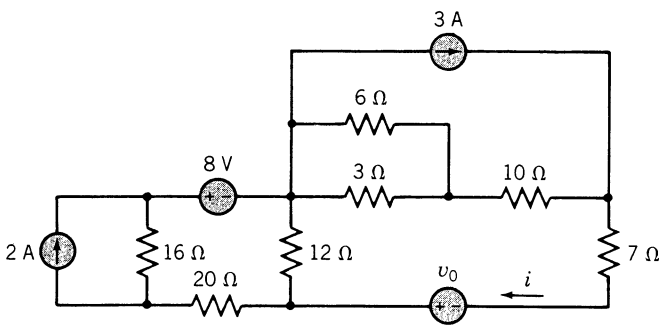

Figure P 5-4

P 5-5 Use superposition to find v for the circuit shown in Figure P 5-5.
Answer: $v = -6$ volts

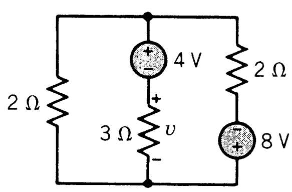

Figure P 5-5

P 5-6 Use superposition to find v for the circuit of Figure P 5-6.

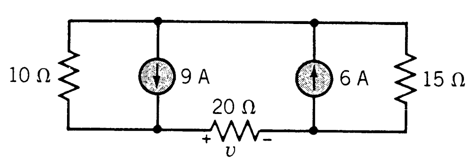

Figure P 5-6

P 5-7 Use superposition to find i for the circuit of Figure P 5-7.
Answer: $i = -2$ mA

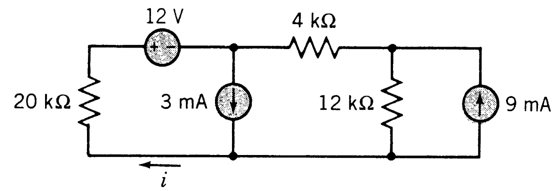

Figure P 5-7

P 5-8 Use superposition to find v_x for the circuit of Figure P 5-8.

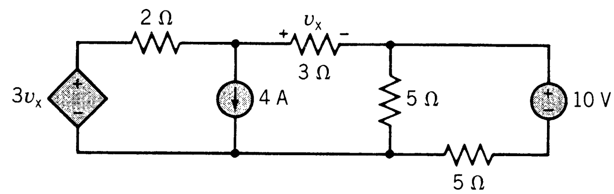

Figure P 5-8

P 5-9 Use superposition to find i for the circuit of Figure P 5-9.
Answer: $i = 3.5$ mA.

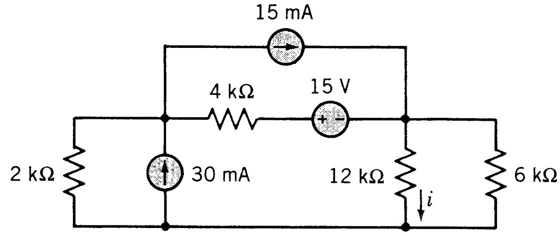

Figure P 5-9

P 5-10 Find the Thévenin equivalent circuit for the circuit of Figure P 5-10.

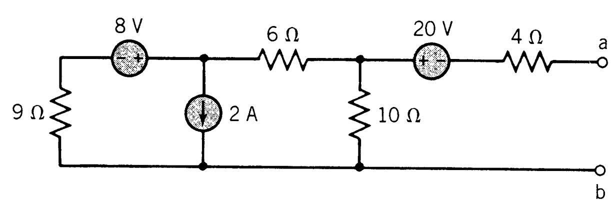

Figure P 5-10

Answer: $R_t = 10\ \Omega$
$v_{oc} = -24$ V

P 5-11 Find the Thévenin equivalent circuit for the circuit of Figure P 5-11.

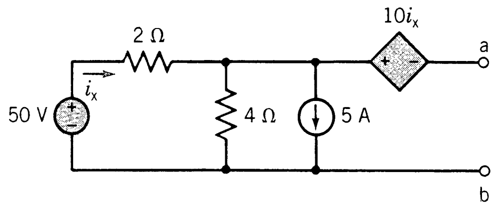

Figure P 5-11

P 5-12 Find R_t for the circuit of Figure P 5-12.
Answer: $R_t = 3\ \Omega$

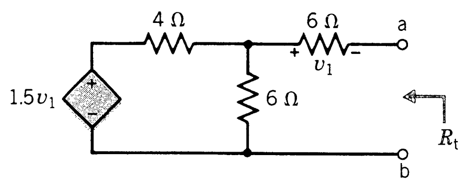

Figure P 5-12

P 5-13 Find the Thévenin resistance for the circuit shown in Figure P 5-13.

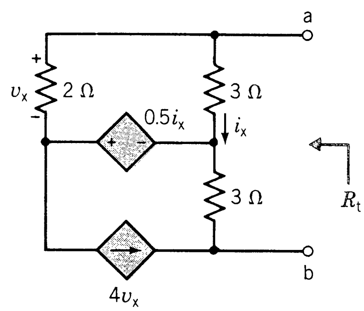

Figure P 5-13

P 5-14 Find the Thévenin equivalent circuit for the circuit shown in Figure P 5-14.
Answer: $R_t = 3\ \Omega$
$v_{oc} = 3$ V

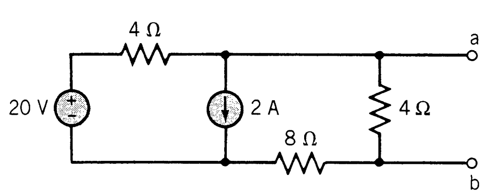

Figure P 5-14

P 5-15 Find the Norton equivalent circuit for the circuit shown in Figure P 5-15.
Answer: $R_t = -1\ \Omega$
$i_{sc} = -15$ A

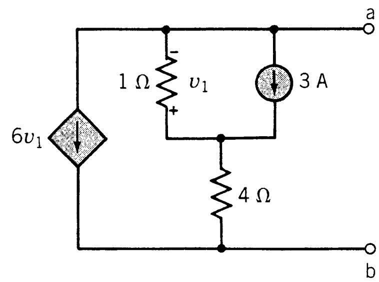

Figure P 5-15

P 5-16 (a) Find the Norton equivalent circuit for the circuit shown in Figure P 5-16.
(b) If a resistor R is connected between terminals a–b, what is the maximum power that it could absorb?

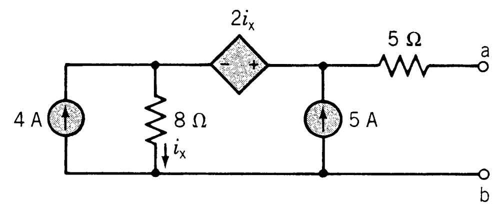

Figure P 5-16

P 5-17 Consider the circuit shown in Figure P 5-17. Find and draw the Thévenin and Norton equivalent circuits. Express everything in terms of α, R, and I_o.
Answer: $R_t = R/(\alpha R - 1)$
$i_{sc} = I_o$
$v_{oc} = RI_o/(1 - \alpha R)$

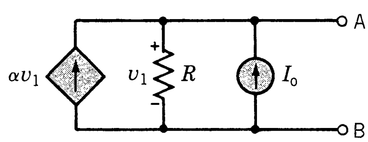

Figure P 5-17

P 5-18 Find the Norton equivalent circuit for the circuit shown in Figure P 5-18.

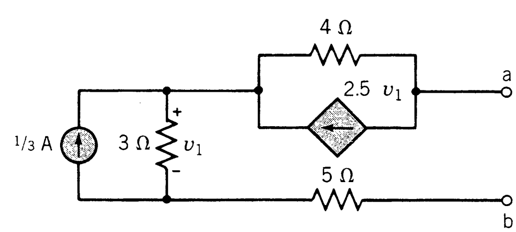

Figure P 5-18

P 5-19 Find R_t between terminals a–b and draw the Norton equivalent for the circuit shown in Figure P 5-19. Current i_x has units of mA.
Answer: $R_t = 3\ \text{k}\Omega$
$i_{sc} = 1$ mA

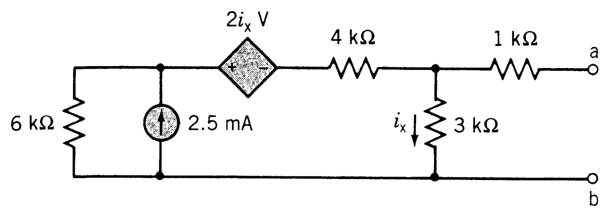

Figure P 5-19

P 5-20 Find the Norton equivalent circuit between terminals a–b for $R = 0$ for the circuit shown in Figure P 5-20.

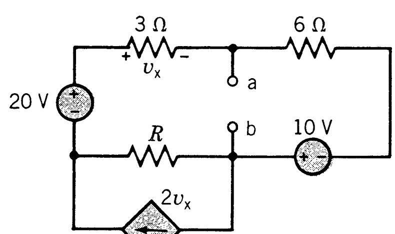

Figure P 5-20

P 5-21 Find the Thévenin equivalent circuit in Problem P5-20 for $R = 1\ \Omega$.
Answer: $R_t = -3\ \Omega$
$v_{oc} = 25$ V

P 5-22 The circuit model for a photovoltaic cell is given in Figure P 5-22. [Edelson, 1992] The current i_s is proportional to the solar insolation (kW/m²). (a) Find the load resistance for maximum power transfer. (b) Find the maximum power transferred when $i_s = 1$ A.

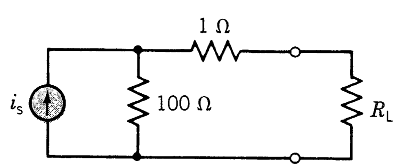

Figure P 5-22

P 5-23 For the circuit in Figure P 5-23 (a) find R such that maximum power is dissipated in R and (b) calculate the value of maximum power.
Answer: $R = 60\ \Omega$
$P_{max} = 54$ mW

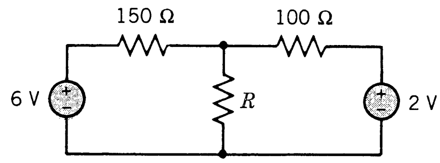

Figure P 5-23

P 5-24 For the circuit in Figure P 5-24, prove that for R_s variable and R_L fixed, the power dissipated in R_L is maximum when $R_s = 0$.

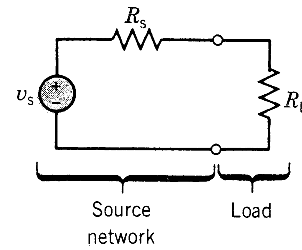

Figure P 5-24

P 5-25 Find the maximum power to the load R_L if the maximum power transfer condition is met for the circuit of Figure P 5-25.
Answer: max $p_L = 0.75$ watt

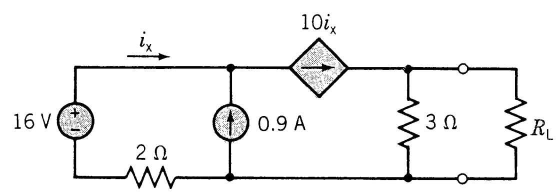

Figure P 5-25

***P 5-26** For the circuit of Figure P 5-26, $R_{bc} = 10^6\ \Omega$, $R_{ce} = 100\ \text{k}\Omega$, $R_{bb} = 100\ \Omega$, $R_{be} = 2\ \text{k}\Omega$, and $g_m = 50$ mA/V. (a) Find R_{in} (open C–E). (b) Find R_{out} (short B–E).
Answer: $R_{in} = 299\ \Omega$

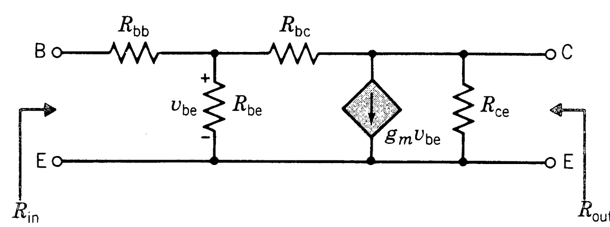

Figure P 5-26

* Note: An asterisk denotes a challenging problem.

***P 5-27** For the circuit shown in Figure P 5-27, find the Thévenin equivalent circuit between points A and B. (R_d and diode are the load.) The diode is a commonly used electronic device.
Answer: $R_t = 4.8\ \text{k}\Omega$
$v_{oc} = 18$ V

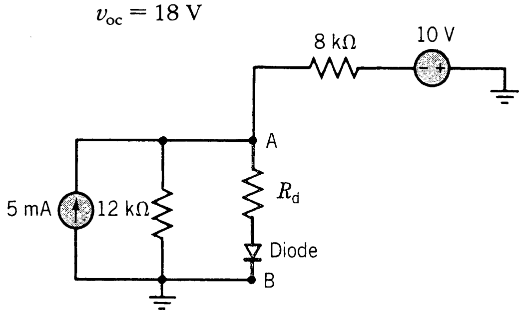

Figure P 5-27

***P 5-28** Using Thévenin's theorem, show that the circuit in Figure P 5-28*a* is equivalent to Figure P 5-28*b* where

$$R_b = \frac{R_1 R_2}{R_1 + R_2}$$

and

$$v = V_{cc} \frac{R_2}{R_1 + R_2}$$

The transistor Q is an electronic device and the base current i_b is negligible.

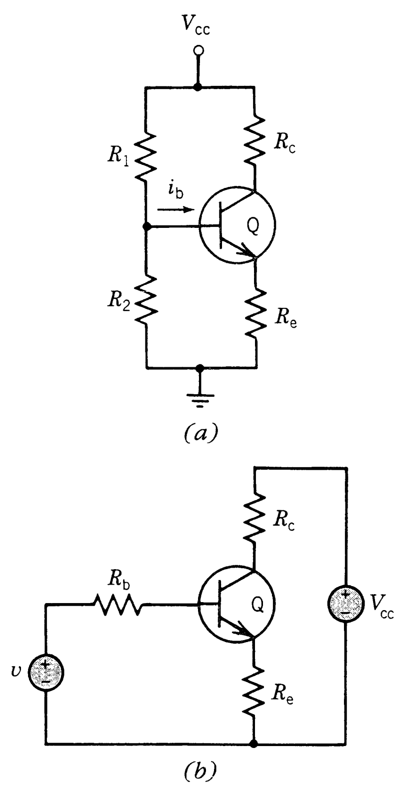

Figure P 5-28

***P 5-29** Consider the circuit of Figure P 5-29. (a) Find R_L such that R_L absorbs maximum power. (b) If maximum $p_L = 54$ watts, find I_0.
Answer: $R_L = 3/2\ \Omega$
$I_0 = 18$ A

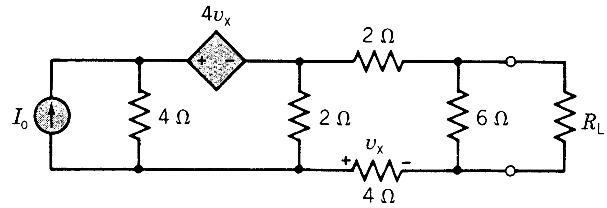

Figure P 5-29

***P 5-30** For the circuit of Figure P 5-30 (a) find the Thévenin equivalent of the network to the left of terminals a–b and (b) find the value of α such that maximum power is delivered to the circuit to the right of terminals a–b.
Answer: (a) $v_{oc} = 30$ V, $R_t = 6\ \Omega$, (b) $\alpha = 6$

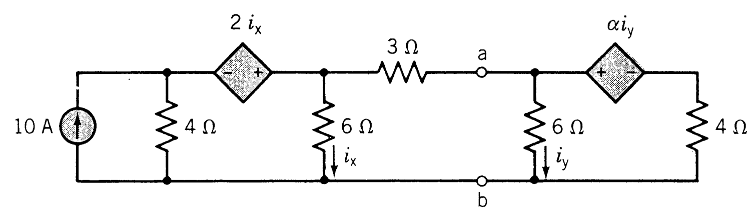

Figure P 5-30

P 5-31 For the circuit shown in Figure P 5-31, use superposition to find v in terms of the R's and source values.

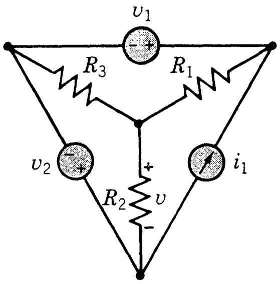

Figure P 5-31

P 5-32 Find the Thévenin equivalent of the circuit of Figure P 5-32 at terminals a–b.

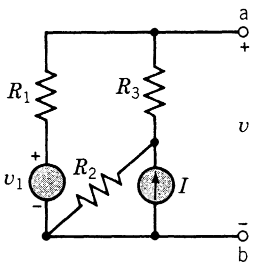

Figure P 5-32

P 5-33 Measurements made on terminals a–b of a linear circuit, Figure P 5-33*a*, that is known to be made up only of independent and dependent voltage sources and current sources and resistors yield the current–voltage characteristics shown in Figure P 5-33*b*. Find the Thévenin equivalent circuit.

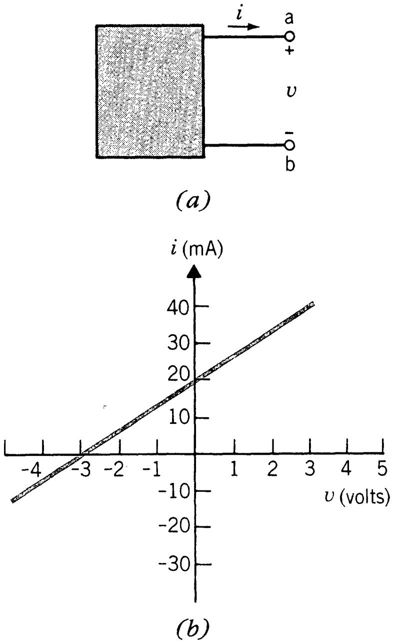

Figure P 5-33

P 5-34 Find the Thévenin equivalent for terminals a–b for the circuit of Figure P 5-34.

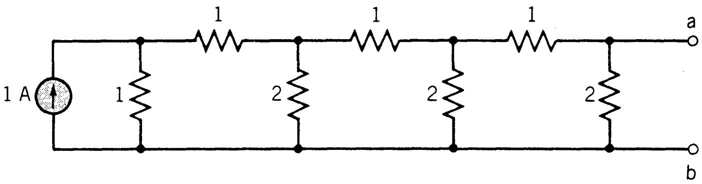

Figure P 5-34 All resistances are in ohms.

P 5-35 An engineer has an unknown circuit A, as shown in Figure P 5-35. She wishes to determine whether the network is linear and, if it is, to determine its Thévenin equivalent. The only equipment available to the engineer is a voltmeter (assumed ideal), a 10-kΩ and a 100-kΩ test resistors that can be placed across the terminals during a measurement. The following data were recorded:

Test Resistor	Meter Reading
Absent	1.5 volts
10 kΩ	0.25 volt
100 kΩ	1.0 volt

What should the engineer conclude about the network from these results? Support your conclusion with plots of the network's $v - i$ characteristics.

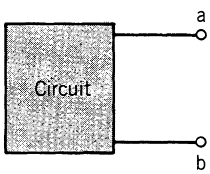

Figure P 5-35

P 5-36 Determine the Norton equivalent of the circuit shown in Figure P 5-36.

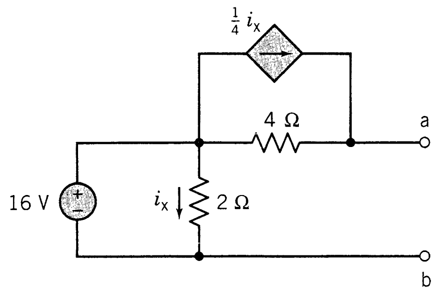

Figure P 5-36

P 5-37 Determine the Thévenin equivalent circuit for the circuit of Figure P 5-37 at the output terminals a–b.

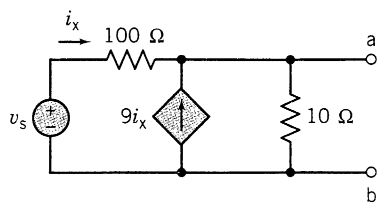

Figure P 5-37

P 5-38 Determine the Norton equivalent circuit for the circuit shown in Figure P 5-38.

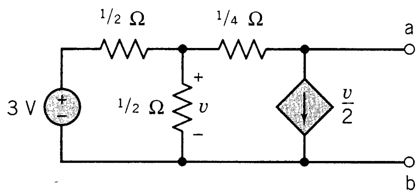

Figure P 5-38

P 5-39 Determine the voltage v using the principle of superposition for the circuit of Figure P 5-39.

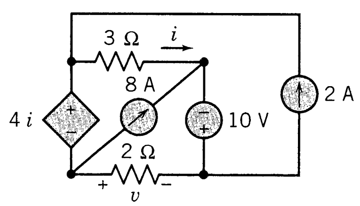

Figure P 5-39

P 5-40 Determine the Thévenin equivalent circuit for the circuit shown in Figure P 5-40.

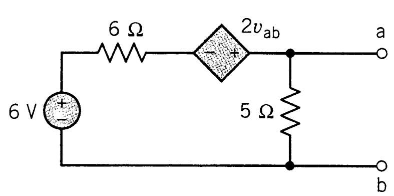

Figure P 5-40

P 5-41 Obtain the Thévenin equivalent for the circuit shown in Figure P5-41.

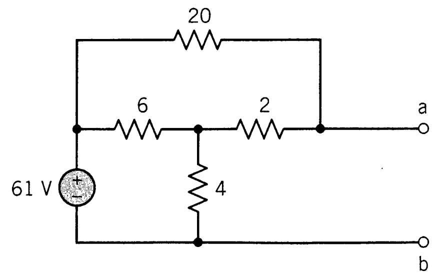

Figure P 5-41 All resistances in ohms.

P 5-42 Determine the current i of the circuit shown in Figure P 5-42.

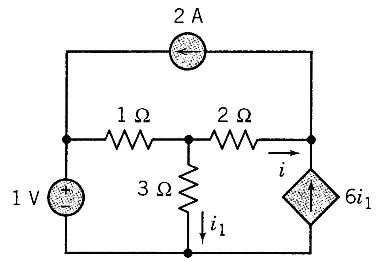

Figure P 5-42

P 5-43 Determine the Thévenin equivalent circuit for the circuit shown in Figure P 5-43.

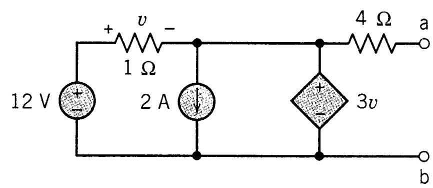

Figure P 5-43

P 5-44 Determine the Thévenin equivalent circuit at terminals a–b for the circuit shown in Figure P 5-44.

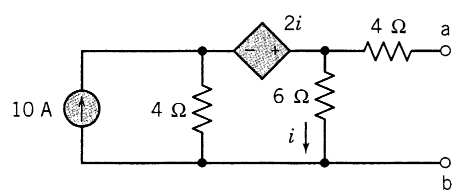

Figure P 5-44

ADVANCED PROBLEMS

AP 5-1 The model of a transistor amplifier is shown in Figure AP 5-1. Determine the output resistance at terminals a–b.

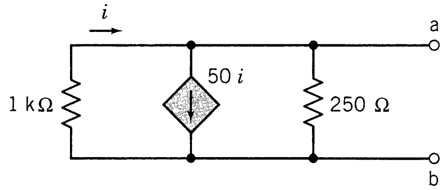

Figure AP 5-1 Model of transistor amplifier

AP 5-2 Determine the Thévenin equivalent circuit at terminals a–b of the circuit shown in Figure AP 5-2.

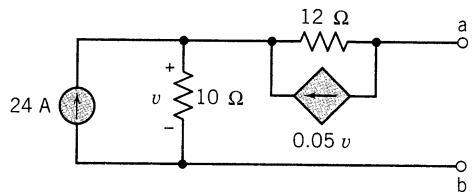

Figure AP 5-2

AP 5-3 Determine the current i_L through the load resistor R_L by first determining the Thévenin equivalent circuit to the left of terminals a–b in Figure AP 5-3 and then connecting $R_L = 2.2\ \Omega$.

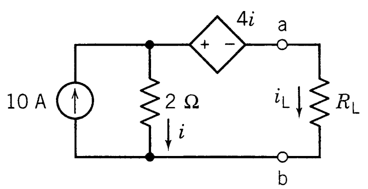

Figure AP 5-3

AP 5-4 Determine the maximum power that can be absorbed by a resistor, R, connected to terminals a–b of the circuit shown in Figure AP 5-4. Specify the value of R.

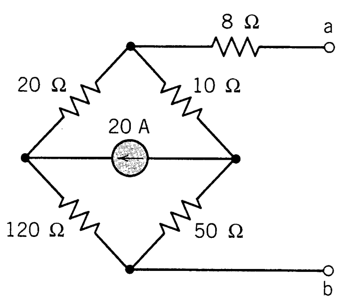

Figure AP 5-4 Bridge circuit.

AP 5-5 Determine v_x for the circuit shown in Figure AP 5-5.

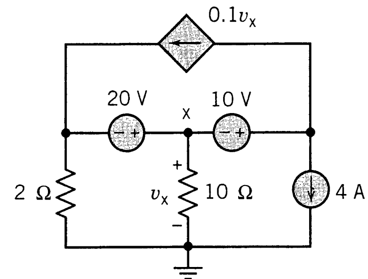

Figure AP 5-5

AP 5-6 Two black boxes are shown in Figure AP 5-6. Box A contains the Thévenin equivalent of some linear circuit, and box B contains the Norton equivalent of the same circuit. With access to just the outsides of the boxes and their terminals, how can you determine which is which, using only one shorting wire?

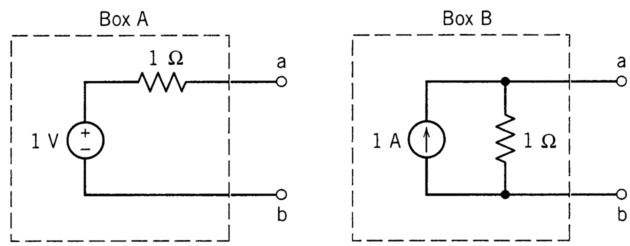

Figure AP 5-6 Black boxes problem

AP 5-7 A student uses a voltmeter with an internal resistance of 5 kΩ to investigate a network with a constant Thévenin voltage. With the voltmeter across the open-circuited network terminals, the meter reads 91.25 V. When the student places a 2-kΩ resistor in parallel with the meter, across the network terminals, the meter reads 37.5 V. What are the Thévenin voltage and resistance for the network?

AP 5-8 The "tunnel diode" is a high-impurity-density p-n junction device. It can exhibit a negative resistance characteristic for certain current areas. Figure AP 5-8 shows the i-v characteristic of a tunnel diode. In three ranges, it exhibits a linear i-v characteristic. Find the Thévenin equivalent circuit of the tunnel diode in these three areas.

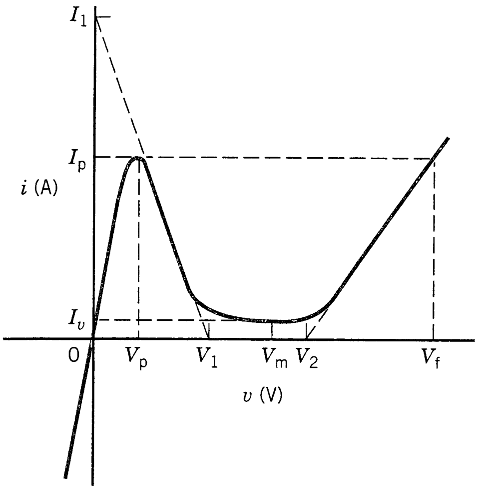

Figure AP 5-8 Tunnel diode characteristic

AP 5-9 Many communication circuits are designed to transfer maximum power to an electronic receiver as shown in Figure AP 5-9. Select R in order to maximize the power to the receiver.

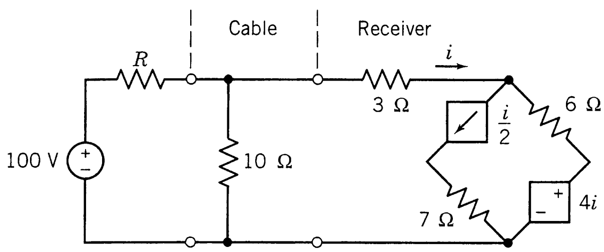

Figure AP 5-9 Communication circuit

AP 5-10 For the circuit of Figure AP 5-10, determine the resistance R so that the power to R is maximum. For that value of R, determine the power delivered to R.

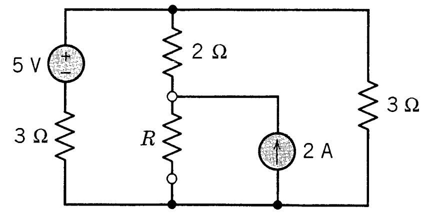

Figure AP 5-10

AP 5-11 The model of a bipolar junction transistor (BJT) amplifier is shown in Figure AP 5-11.

(a) Determine the gain ratio $v_o(t)/v_i(t)$.

(b) Calculate the required value of g in order to obtain a gain $v_o/v_i = -170$ when $R_L = 5$ kΩ, $R_1 = 100$ Ω, and $R_2 = 1$ kΩ.

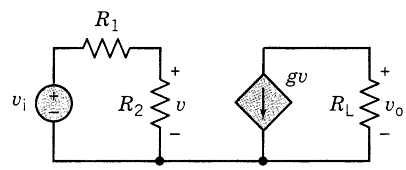

Figure AP 5-11 Model of bipolar junction transistor amplifier.

DESIGN PROBLEMS

DP 5-1 It is desired to deliver 150 W to the load resistor R_L of the circuit shown in Figure DP 5-1. Determine a suitable value for R_L.

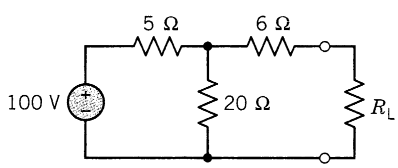

Figure DP 5-1

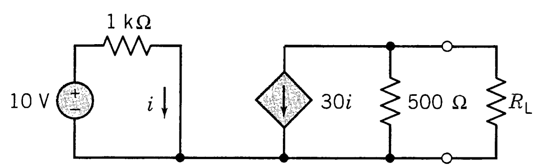

Figure DP 5-2

DP 5-2 It is desired to deliver maximum power to a load resistor R_L as shown in Figure DP 5-2. Determine the required R_L and find the power delivered to the load.

DP 5-3 The model of a transistor amplifier is shown in Figure DP 5-3. The output resistance at terminals a–b is desired to be 50 kΩ. Determine the required coefficient g when $d = 4 \times 10^{-4}$.

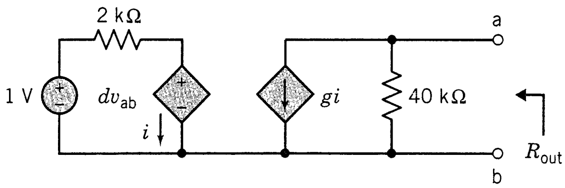

Figure DP 5-3 Transistor amplifier

DP 5-4 A transistor amplifier can be represented by the circuit shown in Figure DP 5-4 with $R_L = 30\ \Omega$. The input terminals are to be connected to a source. Determine the required constant, b, so that the input resistance is 2705 Ω.

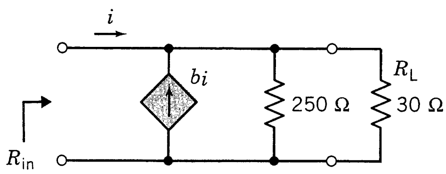

Figure DP 5-4 Transistor amplifier

DP 5-5 For the circuit shown in Figure DP 5-5, choose the constant d so that the Thévenin equivalent resistance is 64 Ω. Calculate the resulting v_t at terminals a–b.

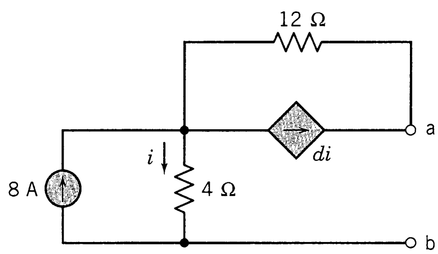

Figure DP 5-5

DP 5-6 Select v_s so that $v = 0$ in the circuit of Figure DP 5-6.

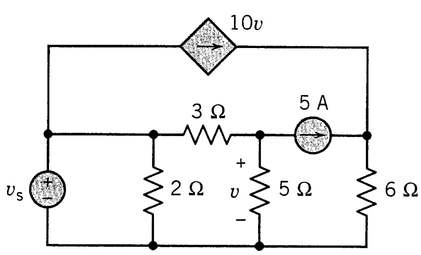

Figure DP 5-6

DP 5-7 A model of a transistor amplifier is shown in Figure DP 5-7. It is specified that the output resistance, R_{ab}, is greater than 60 Ω and less than 70 Ω. Select an appropriate value for the constant b. Determine the resulting magnitude of the output voltage v_{ab}.

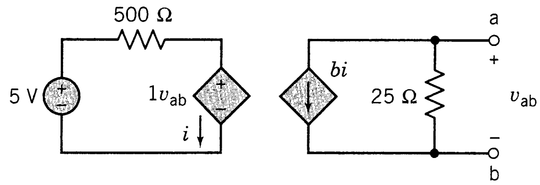

Figure DP 5-7 Transistor amplifier

DP 5-8 We wish to supply two TV sets from one antenna as shown in Figure DP 5-8*a*. The coaxial cables have a 300-Ω input resistance, and maximum power is to be delivered to each TV set. A coupler (splitter) circuit is proposed as shown in Figure DP 5-8*b*, where it is assumed that we can design an antenna with a Thévenin resistance equal to 300 Ω. Select the appropriate resistance R.

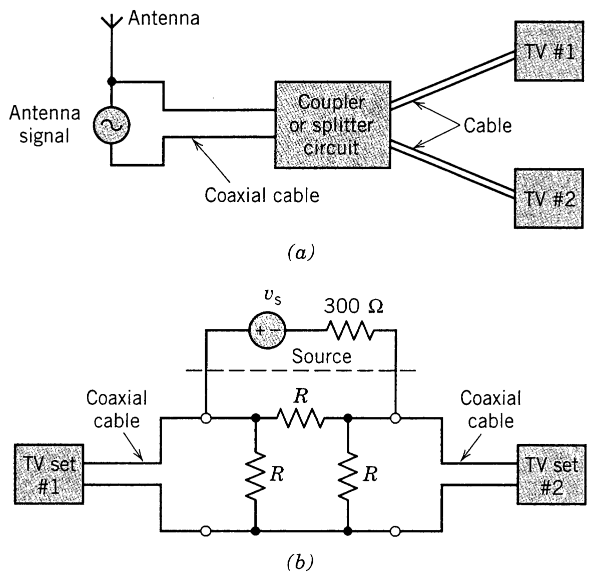

Figure DP 5-8 Two TV sets and a coupler circuit.

DP 5-9 There are many applications in dc, ac, and radio frequency (RF) circuits where power division is required. Consider the two-way resistive power divider circuit shown in Figure DP 5-9. If maximum power transfer to each TV set and equal power division

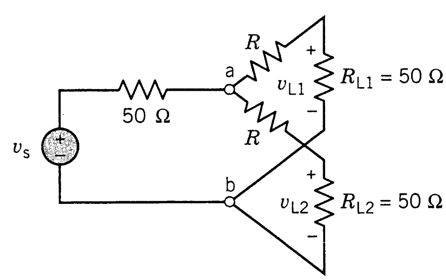

Figure DP 5-9 Power divider circuit.

are required at the interface a–b, what is the value of the resistor, R, that is necessary?

DP 5-10 If the resistive power divider of Design Problem 5-9 is changed to obtain an N-way power divider by adding additional series sections of R and a 50-ohm load resistor in shunt at a–b, derive an expression for the value of resistance, R, that is required as a function of N. Note that power is lost in the resistive divider circuits and that not all of the total power is delivered to the N loads.

DP 5-11 Design a four-way resistive power divider for the source and load resistances of Design Problems 5-9 and 5-10, and verify that the output powers are equal. Compute the relative voltage loss or attenuation by comparing the voltage across one of the loads to the input voltage (V_{load}/V_s).

PSPICE PROBLEMS

SP 5-1 Determine the current i for the circuit of Problem P 5-1 using PSpice.

SP 5-2 Determine the voltage v for the circuit shown in Figure P 5-39 using PSpice.

SP 5-3 Determine the voltage v for the circuit of Problem P 5-5 using PSpice.

SP 5-4 Use PSpice to aid in the determination of the Thévenin equivalent of the circuit of Problem P 5-30a.

SP 5-5 Obtain the Thévenin equivalent circuit for Problem P 5-41 using PSpice.

SP 5-6 Determine the output voltage v for the circuit shown in Figure SP 5-6.

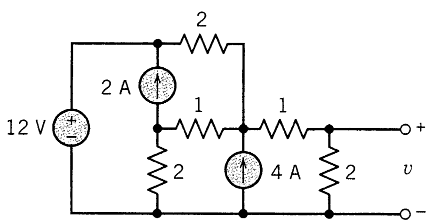

Figure SP 5-6

SP 5-7 Determine the current i for the circuit shown in Figure SP 5-7.

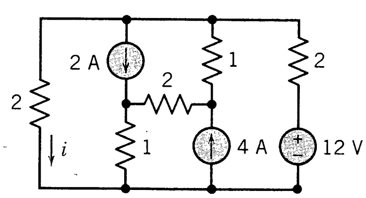

Figure SP 5-7

SP 5-8 Determine v for the circuit shown in Figure SP 5-8.

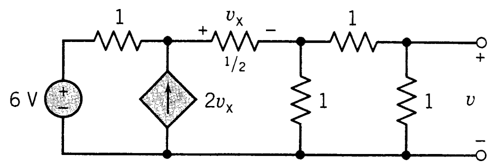

Figure SP 5-8

SP 5-9 Determine the current i of Problem P 5-42.

SP 5-10 Determine the Thévenin equivalent circuit for Problem P 5-45.

SP 5-11 A circuit with a constant voltage source and a variable current source is shown in Figure SP 5-11. Use PSpice to obtain a graphic plot of v_2 versus i_s when i_s is a constant I_o, which varies between 0 and 2 mA.

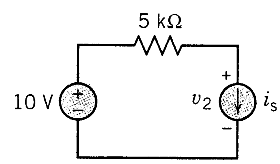

Figure SP 5-11

SP 5-12 A transistor amplifier circuit is shown in Figure SP 5-12. Use PSpice to calculate i.
Answer: $i = 9.52$ mA.

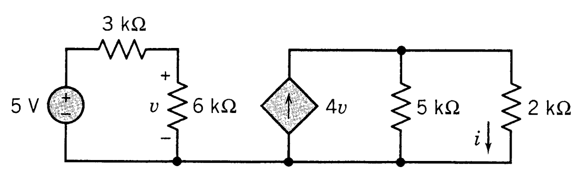

Figure SP 5-12 Transistor amplifier circuit

Operational Amplifier Amplifier with a high gain designed to be used with other circuit elements to perform a specified signal processing operation (often called an op amp).

Power Gain Ratio of the power delivered to a load with an amplifier, P_a, to the power delivered when the source is directly connected to the load, P_d.

Semiconductor Electronic conductor with resistivity in the range between metals and insulators.

Slew Rate (SR) Maximum rate at which the output of an operational amplifier can change when an input signal saturates the amplifier. It is normally expressed in V/μs.

Transistor Active semiconductor device with three or more terminals.

Vacuum Tube Electron tube evacuated so that its electrical characteristics are unaffected by the presence of residual gas or vapor.

Virtual Ground Terminal in a circuit that appears to the observer to be essentially (virtually) connected to ground.

Voltage Follower Amplifier with a voltage gain of one so that the output voltage follows the input voltage.

REFERENCES Chapter 6

Graeme, Jerald, "Feedback Linearizes Current Source," *Electronic Design,* January 23, 1992, pp. 69–70.

Svoboda, James A., "Using Spreadsheets in Introductory Electrical Engineering Courses," *IEEE Transactions on Education,* Nov. 1992, pp. 16–21.

PROBLEMS

P 6-1 A voltage-subtracting circuit is shown in Figure P 6-1. (a) Show that v_o can be expressed as

$$v_o = \frac{1 + R_2/R_1}{1 + R_3/R_4} v_2 - \frac{R_2}{R_1} v_1$$

(b) Design a circuit with an output $v_o = 4v_2 - 11v_1$.

Answer: $R_1 = 10$ kΩ (one solution)
$R_2 = 110$ kΩ
$R_3 = 20$ kΩ
$R_4 = 10$ kΩ

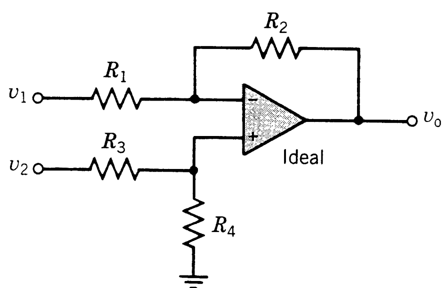

Figure P 6-1 A voltage subtracting circuit.

***P 6-2** Design an operational amplifier circuit with output $v_o = 6v_1 + 2v_2$, where v_1 and v_2 are input voltages. Assume $A \geq 10^6$.

P 6-3 If $R_1 = 4.8$ kΩ and $R_2 = R_4 = 30$ kΩ, find v_o/v_s for the circuit shown in Figure P 6-3 when $R_3 = 1$ kΩ.

Answer: $v_o/v_s = -200$

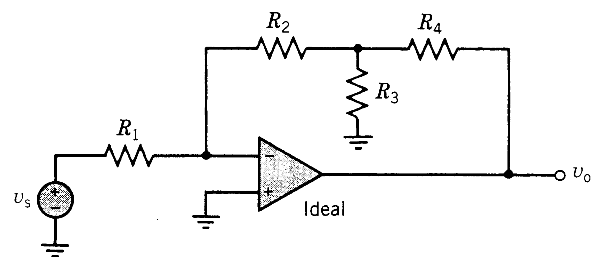

Figure P 6-3

* Note: An asterisk denotes a challenging problem.

P 6-4 For the circuit shown in Figure P 6-4, show that the magnitude of the load current i_L is 100 times the source current for any load that satisfies $R_L \ll R_2$. Use the ideal model of the operational amplifier and let $R_1 = 100$ kΩ and $R_2 = 1$ kΩ. Assume $A = 10^6$.

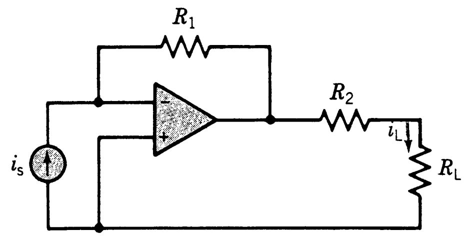

Figure P 6-4 A current multiplier circuit.

P 6-5 For the circuit shown in Figure P 6-5, find v_L if $R_L = 12$ kΩ. Assume an ideal operational amplifier with $A = \infty$.

Answer: $v_L = 1$ V

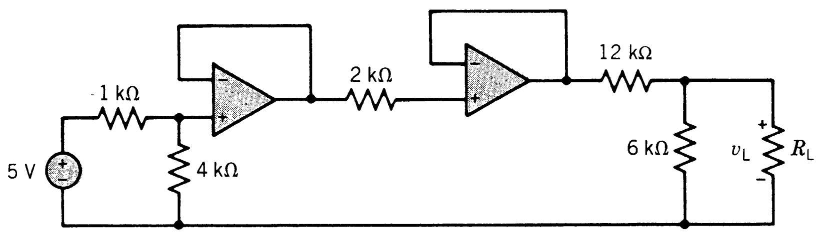

Figure P 6-5

P 6-6 Determine the gain ratio v_2/v_1 for the circuit shown in Figure P 6-6. Assume an ideal op amp.

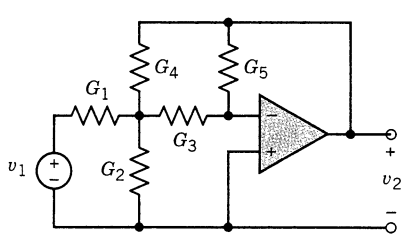

Figure P 6-6

P 6-7 Find v_o for the circuit shown in Figure P 6-7. Assume an ideal operational amplifier with $A = \infty$.

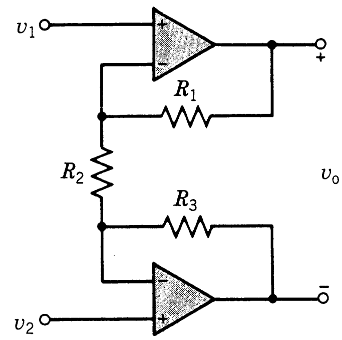

Figure P 6-7

P 6-8 For the circuit shown in Figure P 6-8, calculate the voltage v_o and the current i_o. Assume an ideal op amp.

Answer: $v_o = 12$ V, $i_o = 5.6$ mA

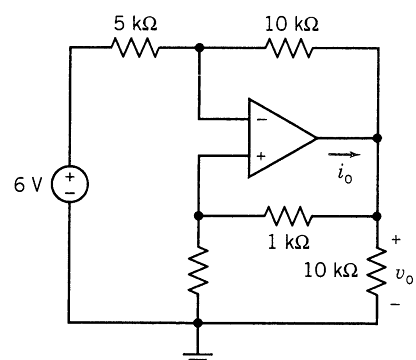

Figure P 6-8

P 6-9 The circuit shown in Figure P 6-9 is an example of a simple strain gauge. The resistor R changes its value by ΔR when it is twisted or bent. Derive a relation for the voltage gain v_o/v_s and show that it is proportional to the fractional change in R, namely $\Delta R/R_o$. Assume $A > 10^6$.

Answer: $v_o = -v_s \dfrac{R_o}{R_o + R_1} \dfrac{\Delta R}{R_o}$

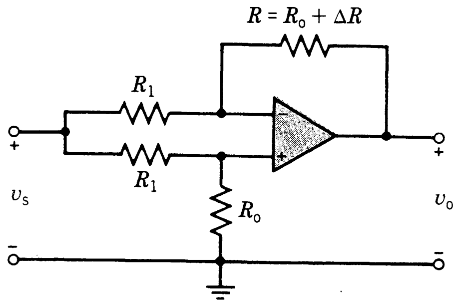

Figure P 6-9 A strain gauge circuit.

P 6-10 For the op-amp circuit shown in Figure P6-10, find and list all the possible voltage gains that can be achieved by connecting the resistor terminals to either the input or the output voltage terminals. Assume an ideal op amp.

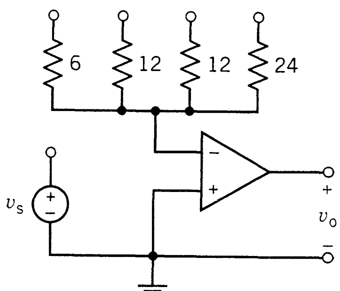

Figure P 6-10 All resistances in kΩ.

P 6-11 The circuit in Figure P 6-11 is called a direct coupled differential amplifier and is used for instrumentation circuits. The output of a measuring element is represented by the common mode signal v_{cm} and the differential signal $(v_n - v_p)$. Using the ideal model of the operational amplifier, show that

$$v_o = -\frac{R_4}{R_1}(v_n - v_p)$$

when

$$\frac{R_4}{R_1} = \frac{R_3}{R_2}$$

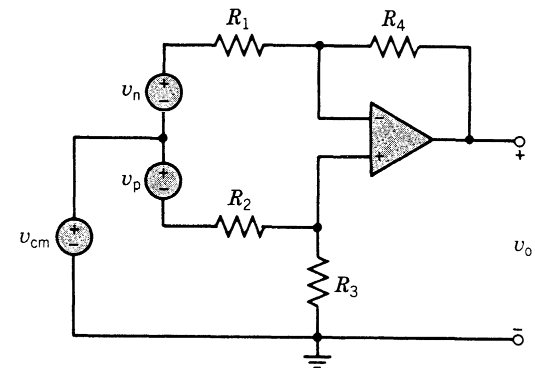

Figure P 6-11 A direct coupled differential amplifier.

P 6-12 A source voltage delivers a voltage of 1 cos ωt V and a maximum current of 10 mA. Design an amplifier circuit that will develop an output voltage of -10 cos ωt V when driven by the source.

P 6-13 One common application uses an operational amplifier to drive a low-resistance load, R_L, with a voltage source with a high resistance R_s as shown in Figure P 6-13. This circuit is called a voltage-to-current converter. Assume an ideal model and find i_L/v_s.
Answer: $i_L/v_s = 1/R$

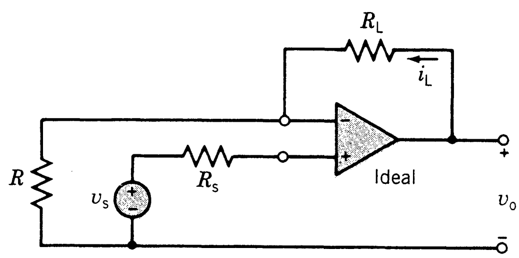

Figure P 6-13 A voltage-to-current converter.

P 6-14 Design an inverting amplifier with a gain of -100 and an input resistance seen by the voltage source of 1kΩ. Use a 741 op amp for the circuit.

P 6-15 An operational amplifier has a very high input resistance, and therefore an operational amplifier circuit is a good choice for building a voltmeter as shown in Figure P 6-15. The voltage to be measured is

v_s. The voltmeter is represented by resistance R_m. If the meter requires a current of 0.1 mA for full-scale deflection, find the appropriate resistor R for the meter to record in the range 0 to 1 V when $R_m = 10$ kΩ. Assume an ideal model for the operational amplifier.
Answer: $R = 10$ kΩ.

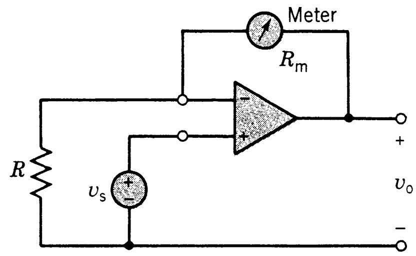

Figure P 6-15 A voltmeter circuit.

P 6-16 (a) Determine an expression for v_o in terms of v_a, v_b, and the resistors in Figure P 6-16. (b) What function does this circuit perform? (c) Design an equivalent circuit that requires only two operational amplifiers and few resistors. The voltages shown are referenced to ground. Assume an ideal operational amplifier with $A = \infty$.

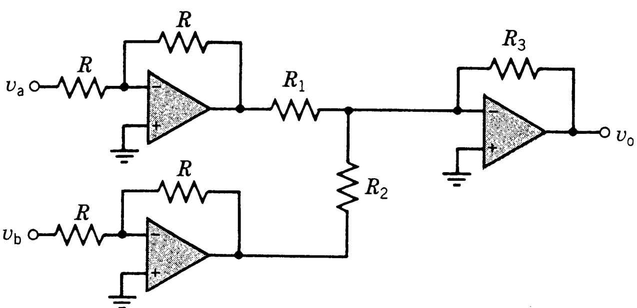

Figure P 6-16

P 6-17 Show that the circuit shown in Figure P 6-17 behaves as a current amplifier with a gain of

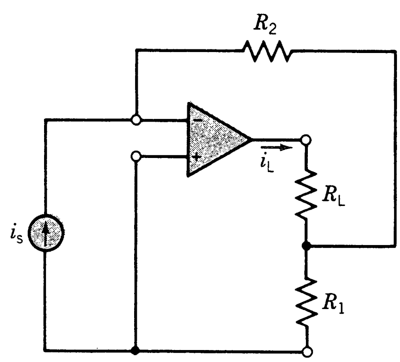

Figure P 6-17 A current amplifier circuit.

$$\frac{i_L}{i_s} = -\frac{R_1 + R_2}{R_1}$$

Assume an ideal model.

P 6-18 An operational amplifier can be used to convert a current source to a voltage, v_o, as shown in Figure P 6-18. Find the ratio v_o/i_s, using an ideal model of the operational amplifier.

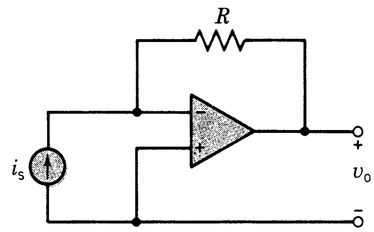

Figure P 6-18 A current-to-voltage converter.

P 6-19 A noninverting amplifier circuit is shown in Figure P 6-19. Using the nonideal model of the operational amplifier when $A > 10^5$, prove that the input resistance seen by the source voltage is

$$R_{in} \cong \left(\frac{AR_1}{R_1 + R_2 + R_o}\right) R_i$$

and the output resistance at terminals a–b is

$$R_{out} \cong \left(\frac{R_1 + R_2}{AR_1}\right) R_o$$

Hint: Assume that $R_i \gg R_2$ and use the model of Figure 6-21.

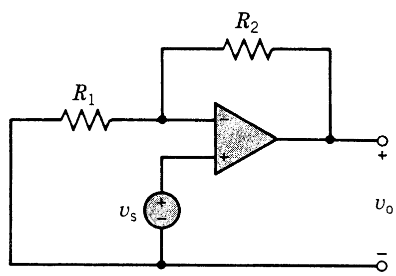

Figure P 6-19

P 6-20 A laboratory spectrophotometer uses a light source and prism to generate a wavelength of light and project it through a liquid sample, as shown in Figure P 6-20. The spectrophotometer uses light absorption to determine the chemical makeup of a sample. The photocell generates a voltage v_s, which is then amplified. Assume the photocell is represented by a voltage v_s in series with a negligible resistance. The gain of the operational amplifier is A. Find the ratio v_o/v_s.

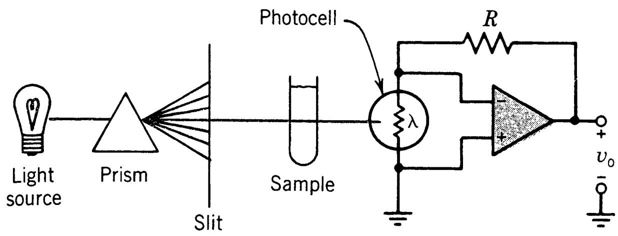

Figure P 6-20 A laboratory spectrophotometer circuit.

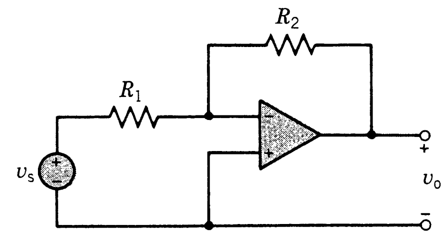

Figure P 6-23

P 6-21 Consider the inverting amplifier circuit shown in Figure P 6-21. Determine the input resistance seen by the source, v_s, using the nonideal model. Assume that $A \geq 10^5$ and R_o is negligible.
Answer: $R_{in} \cong R_1$

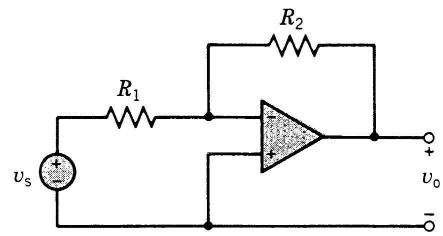

Figure P 6-21

P 6-22 For the circuit of Figure P 6-22, find the ratio v_o/v_s as a function of the four resistor values R_1, R_2, R_3, and R_4. Use an ideal model.

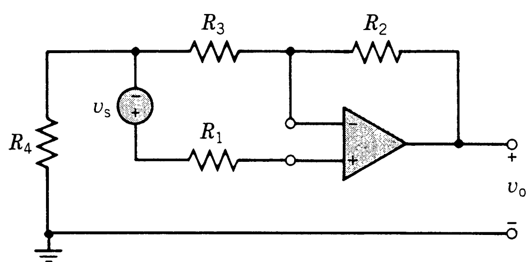

Figure P 6-22

P 6-23 An inverting operational amplifier is shown in Figure P 6-23. (a) Using the nonideal model of Figure 6-21, show that the output resistance seen at the output terminal is

$$R_{out} \cong \frac{R_o}{Ak}$$

where

$$k = \frac{R_1}{R_1 + R_2}$$

Assume that R_i is much greater than R_1 and R_2. (b) If $R_o = 1000\ \Omega$, $A = 10^5$, and $k = 0.1$, find R_{out}.
Answer: (b) $R_{out} = 0.1\ \Omega$

P 6-24 For the circuit of Figure P 6-24, find the value of R such that $v_o = -100v_s$ when $R_1 = 10\ \text{k}\Omega$. Assume an ideal model.

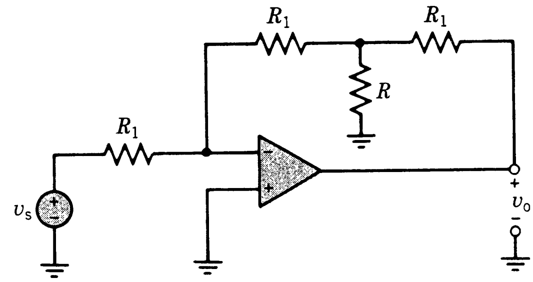

Figure P 6-24

***P 6-25** An operational amplifier circuit which appears to the load as a current source so that $i_L \cong v_s/R_s$ is shown in Figure P 6-25. (a) Using a nonideal model, show that the output resistance seen at the terminals of R_L is $R_{out} \cong AR_s + R_o \approx AR_s$. (b) Find R_{out} when $A = 10^5$, $R_s = 10\ \text{k}\Omega$, and $R_o = 1\ \text{k}\Omega$.
Answer: (b) $R_{out} = 10^9\ \Omega$

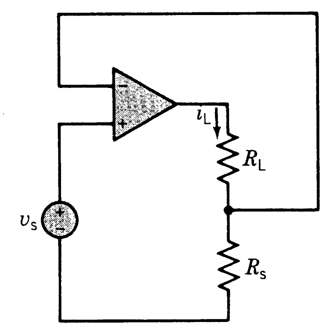

Figure P 6-25

P 6-26 A sensor is normally connected to a meter with a resistance equal to 500 Ω. The sensor is represented by a voltage source in series with R_s, a 500-Ω resistance. An engineer designs a circuit with a buffer amplifier with an input resistance of 1 MΩ and the gain A of the operational amplifier is 10^5. Find (a) the ratio v_o/v_s with and without the amplifier and (b) the power gain using the buffer amplifier. (c) A power gain of 16 is desired. Determine the value of the meter resistance that will be required if the sensor resistance remains unchanged.

*P 6-27 Find $v_o(t)/v_s(t)$ for the circuit of Figure P 6-27. Assume that the operational amplifiers are ideal. Assume an ideal operational amplifier with $A = \infty$.

Answer: $v_o/v_s = 22$

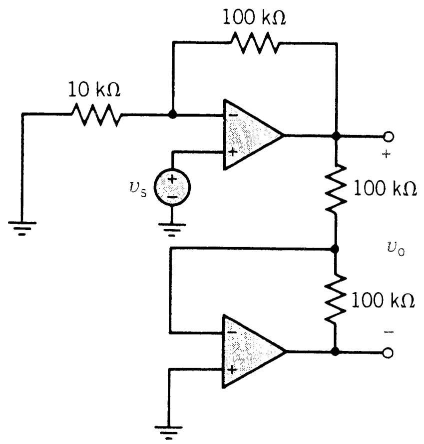

Figure P 6-27

P 6-28 A circuit with two sources is shown in Figure P 6-28. Find v_o when the operational amplifier is assumed to be ideal.

Answer: $v_o = -2$ V

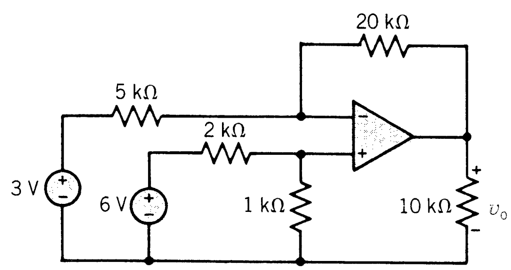

Figure P 6-28

P 6-29 An op amp circuit is shown in Figure P 6-29 with a load resistor. It is desired to determine the output voltage for (a) an ideal op amp and (b) an op amp with $A = 10^4$, $R_i = 200$ kΩ, and $R_o = 5$ kΩ. Compare the results.

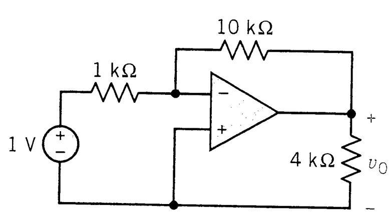

Figure P 6-29

P 6-30 Determine the permissible range of R for the circuit shown in Figure P 6-30 when the circuit saturates at $V_o = \pm 14$ V. Assume an ideal op amp.

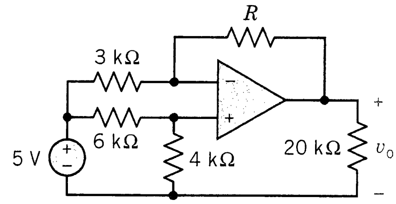

Figure P 6-30

P 6-31 Determine v_o and i_o for the op amp circuit shown in Figure P 6-31. Assume an ideal op amp.

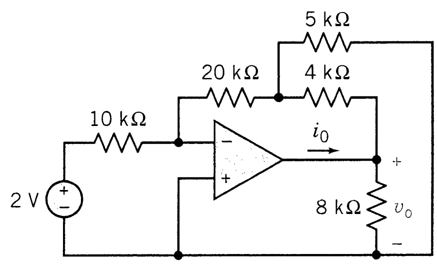

Figure P 6-31

P 6-32 Determine the required value of R so that $v_o = -1.95$ for the circuit of Figure P 6-32. Assume an ideal op amp.

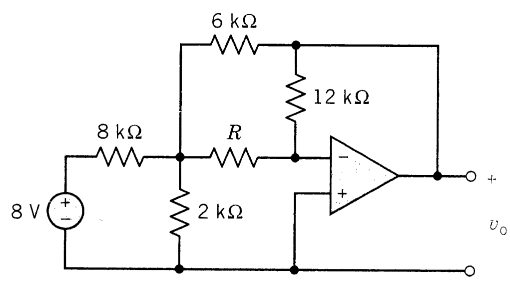

Figure P 6-32

P 6-33 Assuming that all the op amps are ideal, determine v_o in terms of v_1 and v_2 for the circuit shown in Figure P 6-33.

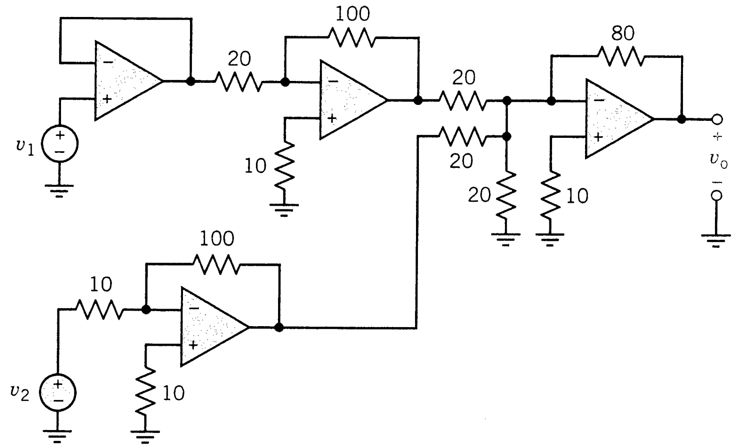

Figure P 6-33 All resistances in kΩ.

P 6-34 Determine v_o for the circuit of Figure P 6-34 when all the op amps are ideal.

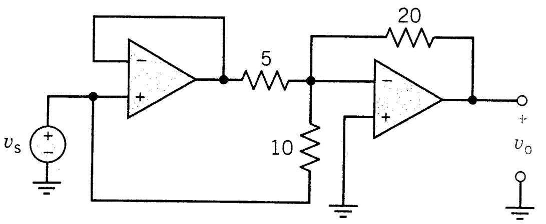

Figure P 6-34 All resistances in kΩ.

P 6-35 Assuming an ideal op amp, find the output voltage v_o in terms of the two input voltages v_1 and v_2 of the circuit of Figure P 6-35.

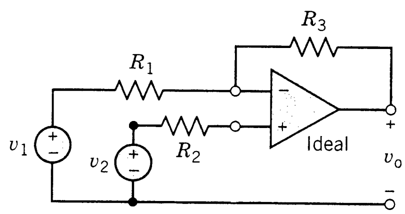

Figure P 6-35

P 6-36 The two-op amp circuit shown in Figure P 6-36 is used to obtain an output voltage in terms of two input voltages. Obtain an expression for v_o. Select R_1, R_2, and R_G so that v_o is 10 times $(v_1 - v_2)$.

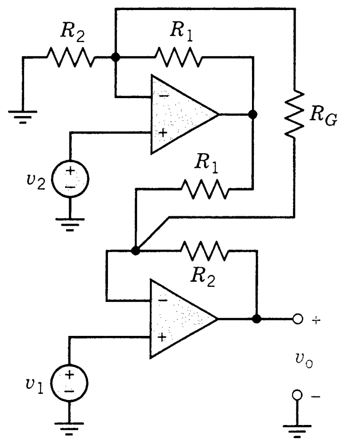

Figure P 6-36 Difference amplifier.

P 6-37 (a) Determine the voltage ratio v_o/v_1 and the input resistance for the circuit shown in Figure P 6-37. Use the model of Figure 6-21.

(b) Evaluate the voltage ratio and the input resistance when $R_1 = R_2 = 10$ kΩ and the op amp has $A = 10^4$ and $R_i =$ 100 kΩ. Assume R_o is negligible.

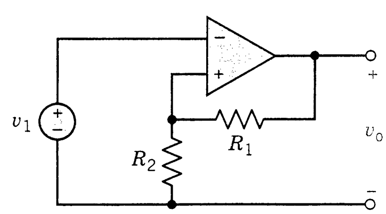

Figure P 6-37

P 6-38 Determine the input resistance seen by the source voltage at terminals a–b for the circuit shown in Figure P 6-38. Assume that $A \geq 10^4$ and $R_i \geq R_1$.

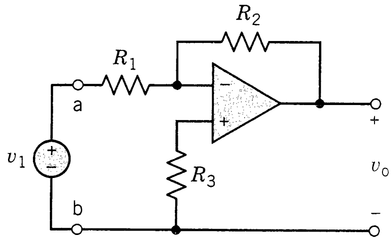

Figure P 6-38

P 6-39 Find v_o and i_o for the circuit of Figure P 6-39 when $R_1 = 7$ kΩ, $R_2 = 98$ kΩ, $R_3 = 10$ kΩ, $R_4 = 20$ kΩ, $R_L = 2$ kΩ, and $v_s = 0.1$ V.

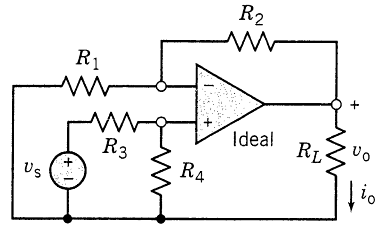

Figure P 6-39

ADVANCED PROBLEMS

AP 6-1 Determine v_o for the circuit shown in Figure AP 6-1. Assume ideal op amps.

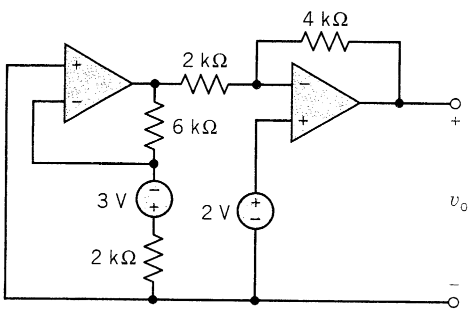

Figure AP 6-1

AP 6-2 Show that the load current i_L in Figure AP 6-2 is independent of R_L, thus providing a constant current source. Assume an ideal op amp. Find an expression for i_L when $v_1 = V_o$, a constant voltage.

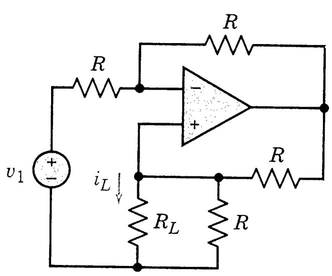

Figure AP 6-2 Constant current source circuit.

AP 6-3 A circuit used to measure temperature is shown in Figure AP 6-3. The temperature sensor has a resistance R_T that varies with temperature according to $R_T = 1000e^{-T/25°C}$ Ω where T = temperature in °C. The output voltage, v_o, is 0 V at −55°C.

(a) Determine R_x required.
(b) A full-scale deflection of the meter is desired at 125°C and is achieved when the meter current is 1 mA. Determine the required R_y.

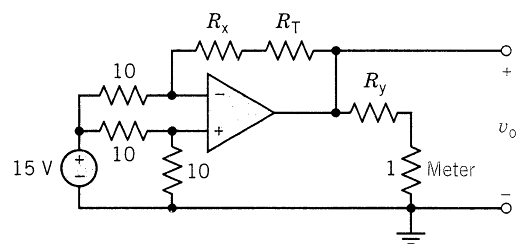

Figure AP 6-3 Temperature measurement circuit. All resistances in kΩ.

AP 6-4 A linear current source circuit provides a load current $i(t)$ as shown in Figure AP 6-4. A voltage reference V_R appears across a potentiometer R and then $v = xV_R$ (Graeme, 1992). The resistance xR adjusts the op amp circuit gain. Show that the current is $i = xV_R/R_s$. Determine the range of current that can be achieved.

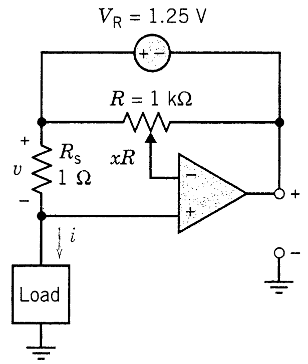

Figure AP 6-4

AP 6-5 An op-amp circuit is shown in Figure AP 6-5. Assume ideal op amps and find v_x so that $v_1 - v_2 = 13$ V.

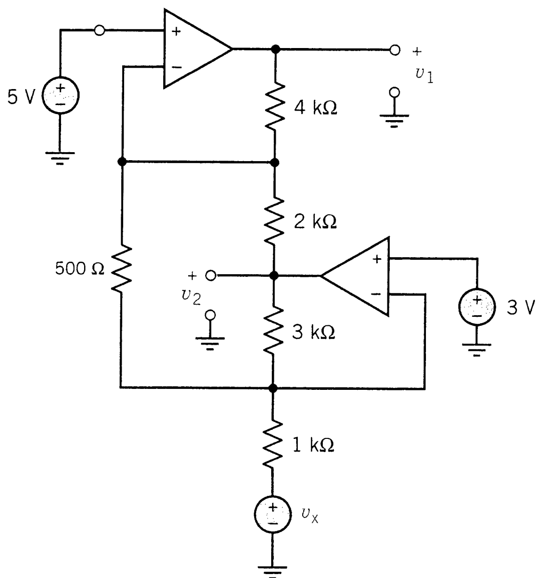

Figure AP 6-5

AP 6-6 The circuit shown in Figure AP 6-6 is called the inverted R-2R ladder digital-to-analog converter (DAC). The input to this circuit is a binary code represented by $b_1\ b_2\ \ldots\ b_n$, where b_i is either 1 or 0. Each switch shown in the figure is controlled by only one of the digits of the binary code. If $b_i = 1$, the switch will be at the left position, whereas if $b_i = 0$, the switch will be at the right position. Depending on the position of the switch, each current I_i is diverted either to true ground bus (adding to I^+) or the virtual ground bus (adding to I^-).

(a) Show that $I = V_R/R$ regardless of the digital input code.

(b) Show that the output voltage can be expressed as

$$V_o = -\frac{R_f}{R} V_R\,(b_1 2^{-1} + b_2 2^{-2} + \ldots + b_{n-1} 2^{-n+1} + b_n 2^{-n})$$

(c) Show that $I^+ + I^- = (1 - 2^{-n})\ V_R/R$ regardless of the binary code.

(d) Given $R_f = R = 10\text{k}\Omega$, $V_R = -16$ V and assuming a four digit binary input code, find the output voltage V_o for each combination of the input code, ranging from 0000 to 1111. Explain the relationship between the output and the input code.

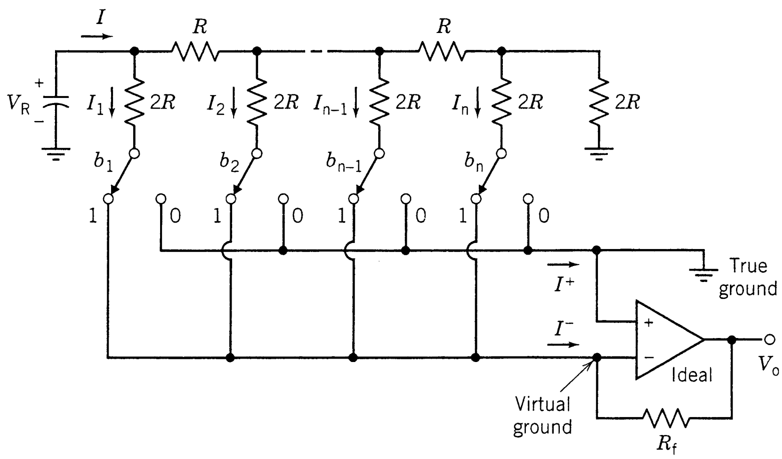

Figure AP 6-6

DESIGN PROBLEMS

DP 6-1 An op amp circuit is shown in Figure DP 6-1. Determine the maximum value of V_1 to retain linear operation when the output voltage saturates at $v_o = \pm 12$ V. Assume an ideal op amp in the linear region.

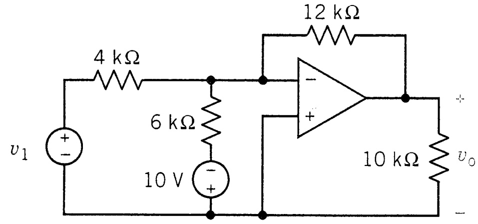

Figure DP 6-1

DP 6-2 An amplifier circuit is shown in Figure DP 6-2. Assume an ideal op amp and determine the required resistance R so that the magnitude of the input resistance is 1 MΩ. Discuss the sign of the input resistance. Note carefully the positive and negative terminals of the op amp.

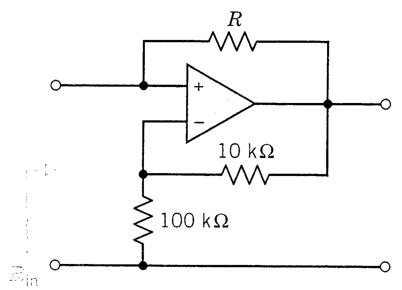

Figure DP 6-2

DP 6-3 Determine the resistance R in Figure DP 6-3 so that the output resistance is 570 Ω. Assume an ideal op amp. Note the positive and negative terminals of the op amp.

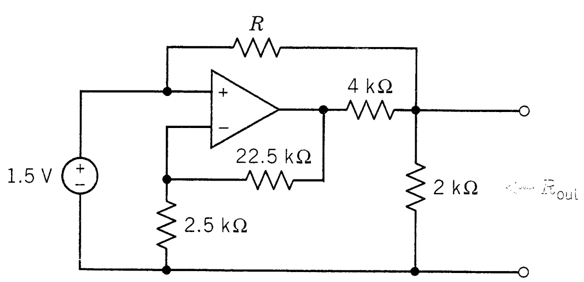

Figure DP 6-3

DP 6-4 An inverting amplifier is shown in Figure DP 6-4. Determine the value of R required so that $v_o/v_s = -1000$.

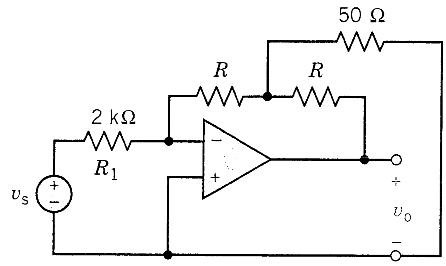

Figure DP 6-4

DP 6-5 A microphone has an unloaded voltage $v_s = 20$ mV rms, as shown in Figure DP 6-5*a*. An op amp is available as shown in Figure DP 6-5*b*. It is desired to provide an output voltage of 4 V rms. Design an inverting circuit and a noninverting circuit and contrast the input resistance at terminals x–y seen by the microphone. Which configuration would you recommend in order to achieve good performance in spite of changes in the microphone resistance R_s?

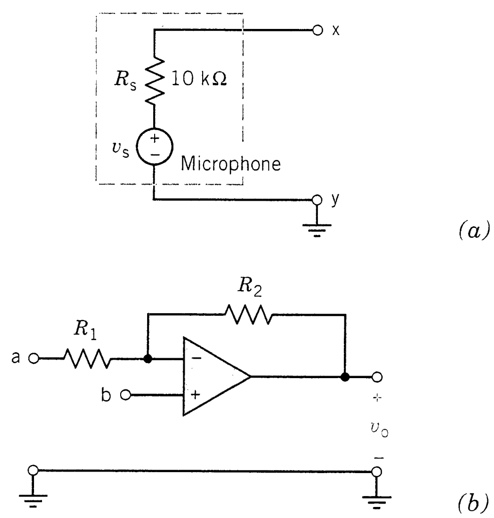

Figure DP 6-5 Microphone and op amp circuit.

PSpice PROBLEMS

SP 6-1 Consider the op amp circuit of Figure 6-22.

(a) Determine v_o/v_s for an ideal op amp.
(b) Determine R_{in} and v_o/v_s when $R_i = 80$ kΩ, $R_o = 100$ Ω, $A = 10^4$, $R_1 = 1$ kΩ, and $R_L = 5$ kΩ.

SP 6-2 Determine the output voltage for Problem 6-29 using PSpice for both the ideal and the nonideal case.

SP 6-3 Determine the voltage ratio v_o/v_s and the input resistance R_{in} for Exercise 6-6.

SP 6-4 Determine the output resistance R_{out} for the op amp circuit of P 6-25.

SP 6-5 Determine v_o/v_s and R_{in} for the noninverting circuit of Figure 6-22 when the op amp has $R_i = 100$ kΩ, $R_o = 100$ Ω, and $A = 10^4$. The circuit resistors are $R_1 = 10$ kΩ and $R_L = 10$ kΩ.

SP 6-6 Determine the voltage ratio v_o/v_s, R_{in}, and R_{out} of the circuit of Exercise 6-8 for the practical values given. Compare the results with those of an ideal op amp.

SP 6-7 Use PSpice to obtain the input resistance, output resistance, and voltage ratio for the op amp circuit of Figure SP 6-7. Assume an ideal op amp.

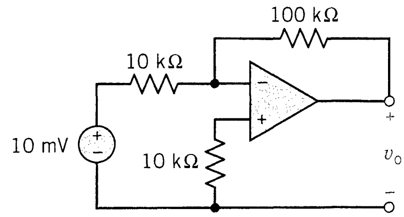

Figure SP 6-7