PROBLEMS

○ More difficult ◐ Even more difficult ● Most difficult

1.1 Kirchhoff's Voltage and Current Laws

1.1 Use KVL in the circuit of Fig. 1.1 to find an expression for v_4 in terms of other voltages in the circuit.

1.2 Use KVL to express the voltage drop across resistor R_1 in the circuit of **Fig. P1.2** in terms of V_1 and v_2.

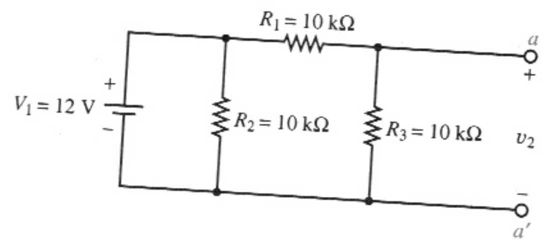

Fig. P1.2

1.3 Consider the circuit of **Fig. P1.3**. Write down a set of KVL and KCL equations and use them to find voltage v_3 across resistor R_3.

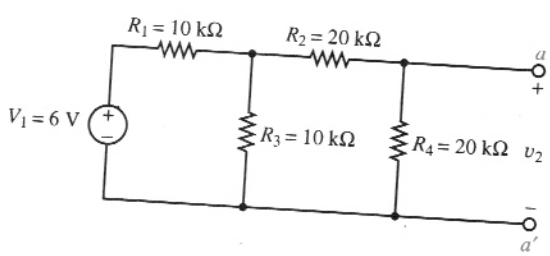

Fig. P1.3

1.4 In the circuit of **Fig. P1.3**, solve for the voltage drop across R_1 by writing down KVL for each loop in the circuit and KCL for each node.

1.5 Suppose that a load element is connected to terminals a–a' in the circuit of **Fig. P1.5**. Use KVL to write down an expression for the voltage V_A in terms of the current I_A flowing through R_A.

1.6 Write down KVL for the left-hand and right-hand loops in the circuit of **Fig. P1.34**.

1.7 Consider the circuit of **Fig. P1.65(a)**. Use KVL once for each loop in the circuit to find a value for v_{OUT}.

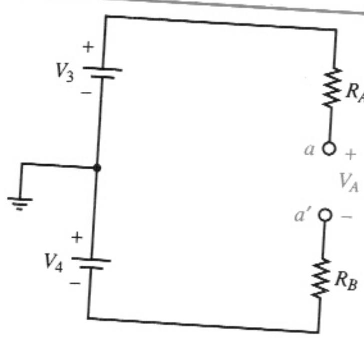

Fig. P1.5

1.8 ○ Consider the circuit of **Fig. P1.65(b)**. Use KVL and KCL to find an expression for the voltage across R_1. Note that the current flowing through R_2 will be equal solely to the current flowing through the dependent source.

1.9 ○ Consider the circuit of **Fig. P1.65(c)**. Use KVL and KCL to find an expression for the voltage across R_2. Note that the current flowing through R_2 will be equal solely to the current flowing through the dependent source.

1.10 Use KVL and KCL to find an expression for the voltage across resistor R_2 in the circuit of **Fig. P1.10**.

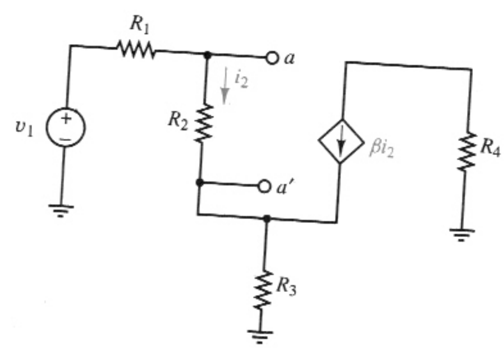

Fig. P1.10

1.2 Voltage Bus Notation

1.11 A circuit is powered by two voltage sources $V_A = 10\,\text{V}$ and $V_B = -10\,\text{V}$, as in Fig. 1.2(b). If 16 mA flows out of the positive terminal of the upper supply, and 11 mA flows out of the positive terminal of the lower supply, what is the net current (magnitude and direction) flowing into the ground node G between the two supplies? What is the total power dissipated in the circuit?

1.12 A circuit is powered by two voltage sources $V_1 = 12\,\text{V}$ and $V_2 = -12\,\text{V}$. The properties of the circuit are such that its output voltage relative to ground can approach to within 0.7 V of either supply bus. What are the most positive and most negative values possible for the output voltage? What is the total possible output voltage "swing"?

1.13 Consider the circuit of Fig. 1.2(b). Suppose that each of the various circuit elements are resistors of the following values: $R_1 = 8.6\,\text{k}\Omega$, $R_2 = 2.2\,\text{k}\Omega$, $R_3 = 12\,\text{k}\Omega$, $R_4 = 47\,\text{k}\Omega$.

(a) Find the current flowing through each resistor in the circuit.

(b) Show that KCL is satisfied at node G for the current values found in part (a).

1.14 Consider the circuit of **Fig. P1.14** with $V_1 = 12\,\text{V}$, $V_2 = 5\,\text{V}$, and all resistors equal to $10\,\text{k}\Omega$.

(a) Find the open circuit voltage V_A measured between terminals a–a'.

(b) This circuit can be represented by the equivalent circuit of **Fig. P1.5**. Find appropriate numerical values for V_3, V_4, R_A, and R_B.

(c) What is the short-circuit current measured between terminals a–a' for each circuit?

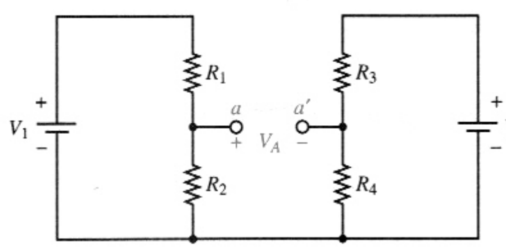

Fig. P1.14

1.15 A circuit powered from a 15-V voltage supply bus drives a load element at 10 V. The load element draws 10 mA of current. The entire circuit draws 18 mA from the supply.

(a) What is the power dissipated in the circuit exclusive of the load?

(b) What is the power dissipated in the load?

1.16 A particular circuit delivers 1 V to a 1-kΩ resistive load. The circuit is powered from ±15-V supply buses. With the load connected, the circuit draws 10 mA from each supply bus. With the load disconnected, the circuit draws 1 mA from each bus.

(a) Draw a diagram of the supply buses, circuit, load element, and current flow direction from each bus.

(b) Compute the power dissipated in the circuit (not including the power dissipated in the load) with the load connected.

(c) What is the power dissipated in the circuit with the load disconnected?

1.3 Definition of Voltage–Current Characteristic

1.17 On the same set of axes, plot the v–i characteristics for resistors of value 4.7 kΩ, 47 kΩ, and 470 kΩ.

1.18 A 27-kΩ resistor is connected in series with a 14-V voltage source. Plot the resulting v–i equation with voltage on the horizontal axis and current on the vertical axis. The arrow of the dc current source points toward the positive output terminal.

1.19 A 100-kΩ resistor is connected in parallel with a 1-mA dc current source. Plot the circuit's v–i equation with voltage on the horizontal axis and current on the vertical axis.

1.20 Consider the circuit of Fig. 1.4(a). Suppose that V_1 is set to the value $-10\,\text{V}$. Plot the resulting v–i equation with voltage on the horizontal axis and current on the vertical axis.

1.21 Show that the slope of the v–i equation of the circuit of Fig. 1.4(a) depends only on R_1, and not on V_1. Plot each of the v–i equations, with v_X on the horizontal axis and i_X on the vertical axis, for $-2\,\text{V} < V_1 < 2\,\text{V}$ in steps of 1 V.

1.22 (a) Under what conditions can the circuit of Fig. 1.4(a) have a *negative* value of v_X?

(b) Under what conditions can the circuit have a negative value of i_X?

(c) Under what conditions will the slope of the circuit's v–i equation become negative?

1.23 Suppose that the voltage source V_1 in Fig. 1.4(a) is replaced by a dc current source of value $I_1 = 5\,\text{mA}$ (arrow pointing up). Plot the v–i equation of the modified circuit.

1.24 A dc current source of value $I_1 = 15\,\text{mA}$ is connected in parallel with a resistor of value $R_1 = 2\,\text{k}\Omega$. Plot the resulting v–i equation of the circuit if the direction of current flow from the source points into the positive output terminal.

1.4 Superposition in Linear Circuits

1.25 A particular circuit can be described by Eq. (1.13) with coefficients $a = 0.5\,\text{V/mA}$ and $b = 1.2\,\text{V/mA}$. Show that the circuit obeys superposition for two sets of inputs given by ($i_1 = 1\,\text{mA}$; $i_2 = 2\,\text{mA}$) and ($i_1 = 3.3\,\text{mA}$; $i_2 = 4\,\text{mA}$).

1.26 ○ A particular linear circuit can be described by a matrix equation of the form

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

where a, b, c, and d are constants. Show that this circuit obeys superposition.

1.27 Consider the circuit of Fig. 1.5 with $v_1 = 15\,\text{V}$, $v_2 = -6\,\text{V}$, and $I_O = 10\,\text{mA}$. Use superposition to find the currents through R_1 and R_2.

1.28 Consider the circuit of Fig. 1.5 with $v_1 = -10\,\text{V}$, $v_2 = 3\,\text{V}$, and $I_O = -1.1\,\text{mA}$. Use superposition to find the currents through R_1 and R_2.

1.29 ○ Consider the circuit of Fig. 1.5 with $v_1 = 2\,\text{V}$, $v_2 = -1\,\text{V}$, and $I_O = 30\,\text{mA}$. Use superposition to find the current flow through the v_1 and v_2 sources.

1.30 Use superposition to find an expression for the voltage measured between terminals a–a' in the two-source circuit of **Fig. P1.30**.

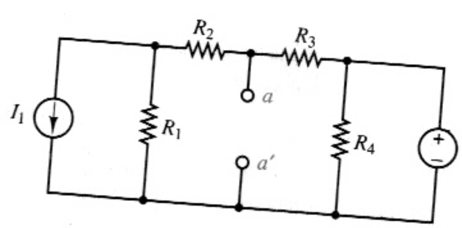

Fig. P1.30

1.31 Consider the two-source circuit of **Fig. P1.30**. If $V_1 = 10\,\text{V}$, $I_1 = -10\,\text{mA}$, and $R_1 = 1\,\text{k}\Omega$, choose values of R_2 through R_4 such that the voltage measured between terminals a–a' is zero.

1.32 The circuit of **Fig. P1.2** and the circuit of **Fig. P1.32** are connected together in parallel at terminals a–a'. Use superposition to find the voltage v_2.

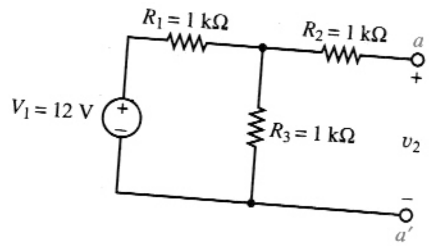

Fig. P1.32

1.33 ○ The circuit of **Fig. P1.3** and the circuit of **Fig. P1.33** are connected together in parallel at terminals a–a'. Use superposition to find voltage v_2. In this case, let V_1 be a 6-V rms, 60-Hz ac source.

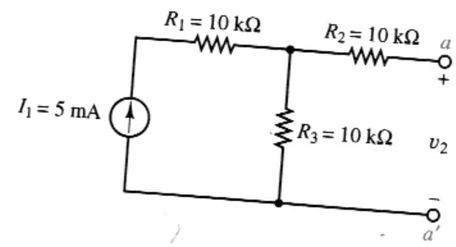

Fig. P1.33

1.34 Use superposition to find the Thévenin equivalent of the resistive circuit connected to the diode in **Fig. P1.34**. Note that the Thévenin equivalent found in this way can subsequently be used to determine the current i_D through the diode. However, superposition *cannot* be used to find i_D directly. Why?

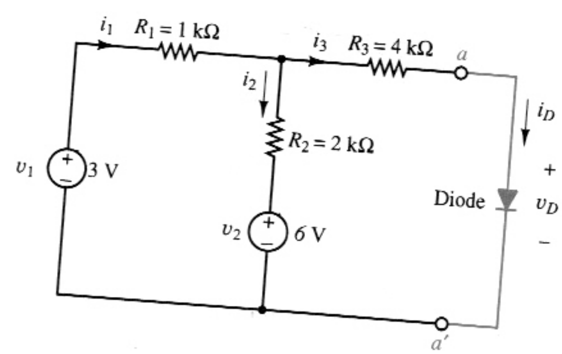

Fig. P1.34

1.35 A voltage source $V_1 = 10\,\text{V}$ is connected from the top terminal of the circuit of **Fig. P1.35** to ground. A second voltage source $V_2 = 5\,\text{V}$ is connected from the lower terminal of the circuit to ground. If $R_1 = 1.5\,\text{k}\Omega$, $R_2 = 1.8\,\text{k}\Omega$, $R_3 = 2.7\,\text{k}\Omega$, and $R_4 = 3.9\,\text{k}\Omega$, find the voltage measured from the junction of R_1 and R_2 to the junction of R_3 and R_4.

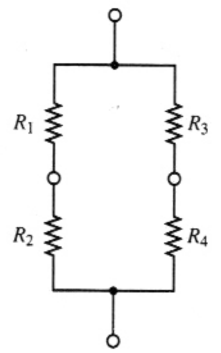

Fig. P1.35

1.36 A voltage source $V_1 = 11\,\text{V}$ is connected from the top terminal of the circuit of **Fig. P1.35** to ground. A *current* source $I_2 = 6\,\text{mA}$ is connected from the lower terminal of the circuit to ground (current flowing into ground from the circuit). If $R_1 = 10\,\text{k}\Omega$, $R_2 = 20\,\text{k}\Omega$, $R_3 = 33\,\text{k}\Omega$, and $R_4 = 56\,\text{k}\Omega$, find the voltage measured from the junction of R_1 and R_2 to the junction of R_3 and R_4.

1.5 Resistive Circuits

1.37 Prove that a resistor is a linear circuit element by showing that it obeys the property of superposition. Test your proof by considering the case of a 10-kΩ resistor connected in series with two voltage sources $v_1 = 10\,\text{V}$ and $v_2 = 5\,\text{V}$.

1.38 Under what conditions will the v–i equation of i_X versus v_X for the circuit of Fig. 1.11 have a positive slope?

1.39 Consider the circuit of Fig. 1.11. What condition will yield the output $v_X = 0$? What is the value of i_1 when this condition occurs?

1.40 Plot the v–i equation of the circuit of Fig. 1.11 as seen at the v_X–i_X port if $\beta = 75$, $v_1 = 1\,\text{V}$, $v_2 = 3\,\text{V}$, $R_1 = 82\,\text{k}\Omega$, and $R_2 = 10\,\text{k}\Omega$.

1.41 Plot the v–i equation of the circuit of Fig. 1.11 as seen at the v_X–i_X port if $\beta = 250$, $v_1 = -4\,\text{V}$, $v_2 = 5\,\text{V}$, $R_1 = 1.2\,\text{k}\Omega$, and $R_2 = 2.2\,\text{k}\Omega$.

1.42 For the circuit of Fig. 1.11, how large must β be if the magnitude of v_X is to be larger than the quantity $|v_2 - v_1|$? A circuit that meets this condition is said to *amplify* the difference signal between the two inputs. If $|v_X|$ is smaller than $|v_2 - v_1|$, the circuit is said to *attenuate* the difference signal.

1.43 For the circuit of Fig. 1.11, plot the open-circuit voltage value of v_X as v_1 changes over the range $0 < v_1 < 5\,\text{V}$ in steps of 1 V. Voltage v_2 should remain constant at the indicated value. This plot is called the circuit's v_1–v_X *transfer characteristic*. Evaluate graphically the slope of the transfer characteristic and compare with the derivative $\partial v_X/\partial v_1$ of Eq. (1.38).

1.44 Suppose that the βi_1 dependent source in Fig. 1.11 is replaced by a current-dependent *voltage* source of value ri_1. Find the resulting open-circuit value of v_X.

1.45 Show that each of the circuits of **Fig. P1.45** is resistive.

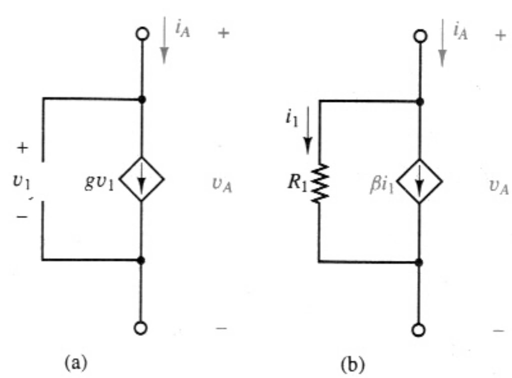

Fig. P1.45

1.46 ○ Consider the circuit of **Fig. P1.46** in which a voltage-dependent voltage source of value av_A is connected in series with a resistor R_1. Show that the relationship between v_A and i_A is linear, indicating the combination to be a resistive circuit.

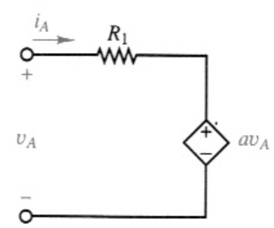

Fig. P1.46

1.47 ○ The circuit of **Fig. P1.47** contains a voltage-dependent voltage source and a current-dependent current source. Show that the relationship between v_A and i_A is linear, indicating the entire combination to behave as a resistive circuit.

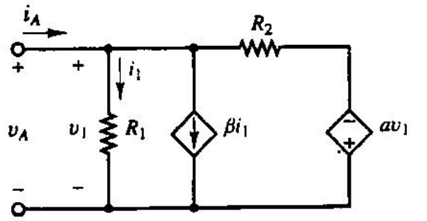

Fig. P1.47

1.6 Thévenin Equivalent Circuits

1.48 Equation (1.47) describes the voltage-current equation of the resistive portion of the circuit of Fig. 1.17 and also of the Thévenin equivalent circuit of Fig. 1.18. The equation is written in terms of a function $v_X = f(i_X)$. Express this same equation as a function $i_X = g(v_X)$.

1.49 Find v_{Th} and R_{Th} for the resistive portion of the circuit in Fig. 1.17 if $V_1 = 8\,V$, $R_1 = 15\,k\Omega$, and $R_2 = 22\,k\Omega$.

1.50 Find the Thévenin equivalent for the two resistive circuits in Fig. 1.20 if $V_{CC} = 2\,V$, $V_{EE} = -5\,V$, $R_A = 120\,k\Omega$, $R_B = 180\,k\Omega$, $R_C = 9.1\,k\Omega$, and $R_L = 22\,k\Omega$. What is the maximum current available from each resistive circuit?

1.51 Find the Thévenin equivalent of the circuit shown in **Fig. P1.2**. What is the role of resistor R_2?

1.52 Find the Thévenin equivalent of the circuit of **Fig. P1.14** as seen at the v_A terminals if $V_1 = 15\,V$, $V_2 = 20\,V$, $R_1 = 10\,k\Omega$, $R_2 = 12\,k\Omega$, $R_3 = 9.1\,k\Omega$, and $R_4 = 8.2\,k\Omega$.

1.53 Consider the circuit of **Fig. P1.5**. Determine the conditions under which the Thévenin equivalent seen at the v_A terminals will have a Thévenin voltage of zero. What will be R_{Th} under these conditions?

1.54 Find the Thévenin equivalent of the circuit of **Fig. P1.30** as seen at terminals a–a'.

1.55 Find the Thévenin equivalent of the circuit of **Fig. P1.33**. Note that a current is set to zero by making it an open circuit.

1.56 A 1-kΩ load resistor is connected across terminals a–a' in the circuit of **Fig. P1.3**. Find the resulting voltage v_2 by first finding the Thévenin equivalent of everything connected to the load resistor.

1.57 A 500-Ω load resistor is connected across terminals a–a' in the circuit of **Fig. P1.32**. Find the resulting voltage v_2 by first finding the Thévenin equivalent of everything connected to the load resistor.

1.58 Consider the resistive circuit of **Fig. P1.32**. Find the Thévenin equivalent at terminals a–a' if the V_1 source shown is replaced by a 60-Hz, 5-V rms ac voltage source.

1.59 Consider the resistive circuit of **Fig. P1.33**. Find the Thévenin equivalent if the I_1 source shown is replaced by a 100-Hz, 1.2-mA rms ac current source in parallel with a 1-mA dc current source.

1.60 ○ Measurements with a high input-resistance voltmeter are made at the port of a circuit that contains only resistors and dc sources. When a 2-kΩ resistor is connected across the terminals of the port, the port voltage is 12 V. If the load resistor is reduced to 1 kΩ, the port voltage drops to 10 V.

(a) Find the Thévenin equivalent of the circuit as observed at the measured port.

(b) How large must the input resistance of the meter be if your answer to part (a) is to be valid to better than 1%?

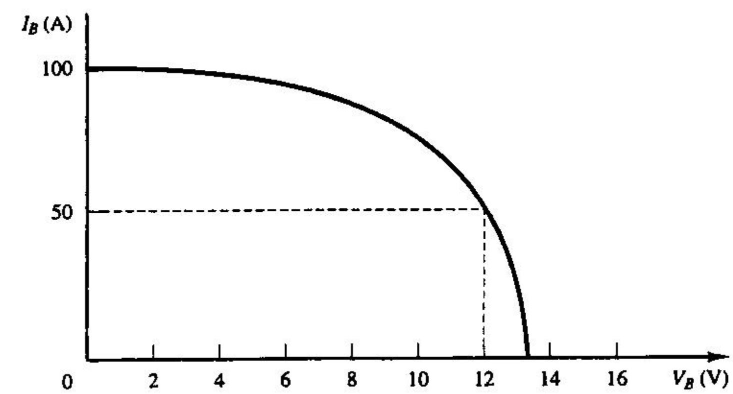

Figure P1.61

1.61 A 12-V storage battery has the measured voltage–current curve shown in **Fig. P1.61**. For small currents and for large currents, the battery can be modeled by Thévenin equivalent circuits. Find appropriate values for V_{Th} and R_{Th} in each regime.

1.62 Find the Thévenin equivalent of the circuit of **Fig. P1.62** as seen from the v_2 terminals if $V_O = 20\,\text{V}$, $R_1 = R_3 = 20\,\Omega$, and $R_2 = 100\,\Omega$.

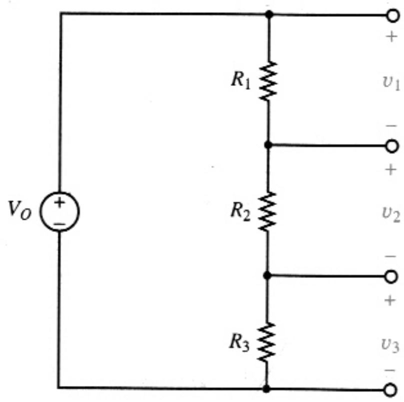

Fig. P1.62

1.63 The circuit of **Fig. P1.63** contains an unknown (and presumably nonlinear) element.

(a) Find the Thévenin equivalent of everything connected to the unknown element if $V_1 = 10\,\text{V}$ relative to ground.

(b) Write down an equation that relates i_X to v_X as determined by the resistive portion of the circuit.

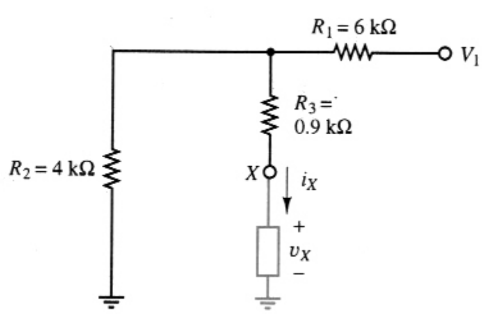

Fig. P1.63

1.64 The circuit of **Fig. P1.64** contains a nonlinear element.

(a) Find the Thévenin equivalent of everything connected to the nonlinear element.

(b) Write down an equation that relates i_X to v_X as determined by the resistive portion of the circuit.

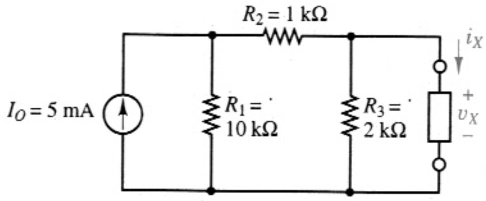

Fig. P1.64

1.65 ◐ Each of the circuits in **Fig. P1.65** contains a dependent source. Find the Thévenin equivalent of each circuit as seen from terminals a–a'. Use the test-source method to find R_{Th}. These circuits all represent the signal behavior of transistor amplifiers and will be examined in more detail in later chapters.

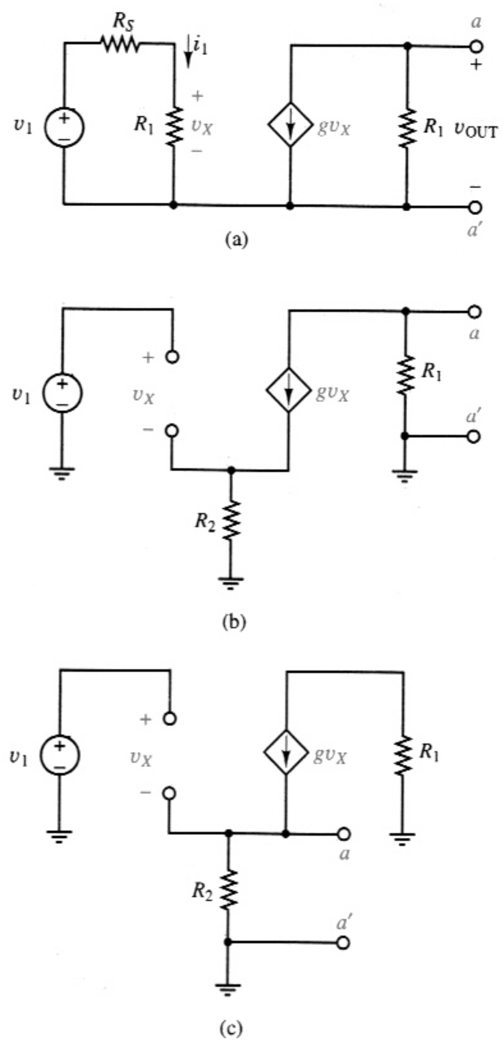

Fig. P1.65

1.66 Replace the voltage-dependent current source gv_X in **Fig. P1.65(a)** by an appropriate current-dependent current source such that the new circuit has the same Thévenin equivalent as the original.

1.67 Consider the amplifier circuit of **Fig. P1.65(b)**. Replace the voltage-dependent current source gv_X and parallel resistor R_1 by a voltage-dependent voltage source of value μv_1 and series resistor R_S. The new circuit should have the same Thévenin equivalent as the original. Express μ and R_S in terms of g and R_1.

1.7 Norton Equivalent Circuits

1.68 Prove that the series resistor in the Thévenin equivalent of a given circuit and the parallel resistor in the Norton equivalent of the same circuit have the same value.

1.69 Find the Norton equivalent of the circuit of **Fig. P1.2**. What effect does resistor R_2 have?

1.70 Two 500-Ω load resistors are connected in parallel across terminals a–a' in the circuit of **Fig. P1.3**. Find the resulting voltage v_2 by first finding the Norton equivalent of everything connected to the parallel combination of load resistors.

1.71 A 1-kΩ load resistor is connected across terminals a–a' in the circuit of **Fig. P1.32**. Find the resulting voltage v_2 by first finding the Norton equivalent of everything connected to the 1-kΩ load resistor.

1.72 Find the Norton equivalent of the circuit shown in **Fig. P1.33**.

1.73 Consider the resistive circuit of **Fig. P1.32**. Find the Norton equivalent if the V_1 source shown is replaced by a 150-Hz, 12-mA rms ac current source.

1.74 Consider the resistive circuit of **Fig. P1.33**. Find the Norton equivalent if the I_1 source shown is replaced by a 100-Hz, 5-V rms ac voltage source.

1.75 Find the Norton equivalent of everything connected to the nonlinear diode in the circuit of **Fig. P1.34**. For a specific diode, $i_D = 1.7\,\text{mA}$. What is the value of the diode voltage v_D?

1.8 Voltage and Current Division

1.76 Consider the circuit of **Fig. P1.62** with $V_O = 10\,\text{V}$, $R_1 = 1.2\,\text{k}\Omega$, $R_2 = 2.7\,\text{k}\Omega$, and $R_3 = 5.6\,\text{k}\Omega$. Use voltage division to find the voltages v_1, v_2, and v_3.

1.77 Consider the circuit of **Fig. P1.5** with the a and a' terminals connected together. Suppose that $V_3 = 10\,\text{V}$, $V_4 = -5\,\text{V}$, $R_A = 10\,\text{k}\Omega$, and $R_B = 12\,\text{k}\Omega$. Use voltage division to find the voltage between the joined a–a' terminal and ground.

1.78 Consider the circuit of **Fig. P1.14** with $V_1 = 10\,\text{V}$, $V_2 = 20\,\text{V}$, $R_1 = 10\,\text{k}\Omega$, $R_2 = 20\,\text{k}\Omega$, $R_3 = 200\,\text{k}\Omega$, and $R_4 = 100\,\text{k}\Omega$. Use voltage division to find voltage V_A.

1.79 ○ In the circuit of **Fig. P1.63**, the unknown load element has an operating point $v_X = 1.2\,\text{V}$; $i_X = 1\,\text{mA}$. Show that an attempt to use "inverse" voltage division to find V_1 leads to an erroneous result.

1.80 In the circuit of **Fig. P1.3**, the current through R_1 has a root-mean-square (rms) magnitude of 0.33 mA. Use current division to find the rms magnitude of the current through R_4.

1.81 Consider the circuit of **Fig. P1.30** with $V_1 = 0$ (V_1 set to a short circuit). Use current division to find the current through R_1.

1.82 The V_1 source in **Fig. P1.30** is replaced by an open circuit. Use current division to find the currents through R_1 and R_4.

1.9 Single-Time-Constant Resistor–Capacitor Circuits

1.9.1 *RC* Circuit Transient Response

1.83 Determine the response of the circuit of **Fig. P1.83** to an input step of value $v_{IN} = 5\,\text{V}$ if $R_1 = 5.6\,\text{k}\Omega$ and $C_1 = 22\,\mu\text{F}$.

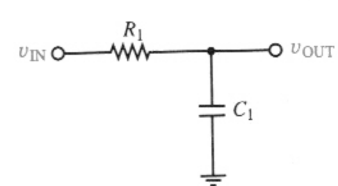

Fig. P1.83

1.84 The v_{OUT} terminal of the circuit of **Fig. P1.83** drives a load resistor $R_2 = 10\,\text{k}\Omega$ to ground. If v_{IN} is a 1-V step function, $R_1 = 47\,\text{k}\Omega$, and $C_1 = 0.33\,\mu\text{F}$, plot v_{OUT} versus time. Also plot the current i_1 through R_1 as a function of time.

1.85 ○ Determine the response of the circuit of **Fig. P1.83** to a 1-V *impulse* function if $R_1 = 10\,\text{k}\Omega$ and $C_1 = 10\,\mu\text{F}$. The impulse response can be found by applying an appropriate step input and taking the derivative of the resulting output.

1.86 Consider the circuit of **Fig. P1.83** with $R_1 = 22\,\text{k}\Omega$ and $C_1 = 0.22\,\mu\text{F}$. If v_{IN} is a 10-V step function, find an expression for the voltage across R_1 as a function of time.

1.87 Consider the circuit of **Fig. P1.83** with $R_1 = 180\,\mathrm{k\Omega}$ and $C_1 = 0.001\,\mu\mathrm{F}$. A second resistor $R_2 = 100\,\mathrm{k\Omega}$ is connected in parallel with C_1. Plot the voltage across R_1 as a function of time if v_{IN} is a 5-V step function.

1.88 Consider the circuit of **Fig. P1.88** with $R_1 = 2\,\mathrm{k\Omega}$, $R_2 = 5\,\mathrm{k\Omega}$, and $C_1 = 0.1\,\mu\mathrm{F}$. Plot v_{OUT} and i_2 as functions of time if v_{IN} is a 12-V step function.

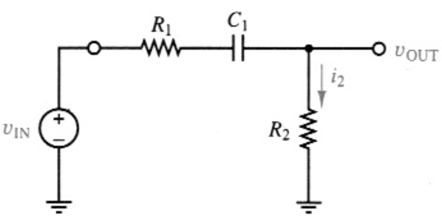

Fig. P1.88

1.89 ○ Consider the circuit of **Fig. P1.88** with $R_1 = 200\,\Omega$, $R_2 = 5\,\mathrm{k\Omega}$, and $C_1 = 0.5\,\mu\mathrm{F}$. A second capacitor $C_2 = 200\,\mathrm{pF}$ is connected in parallel with R_2. If v_{IN} is a 5-V step function, plot v_{OUT} as a function of time over the range $0 < t < 100\,\mathrm{ns}$ and over the range $0 < t < 10\,\mathrm{ms}$. Use engineering approximations where appropriate.

1.90 ○ For the circuit of **Fig. P1.90**, derive an expression for v_{OUT} as a function of time if the input is a step function of value V_O.

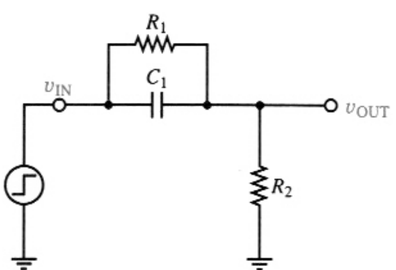

Fig. P1.90

1.91 ○ For the circuit of **Fig. P1.90**, plot the current i_{C1} flowing through C_1 as a function of time if $R_1 = 10\,\mathrm{k\Omega}$, $R_2 = 22\,\mathrm{k\Omega}$, $C_1 = 0.01\,\mu\mathrm{F}$, and the input is a step function of value $V_O = 5\,\mathrm{V}$.

1.9.2 *RC* Circuit Response in the Sinusoidal Steady State

1.92 Find expressions for v_{OUT} and the voltage across R_1 in the circuit of **Fig. P1.83** if v_{IN} is driven by a sinusoidal input voltage of frequency ω.

1.93 The circuit of **Fig. P1.83** is fed by a sinusoidal voltage source. Plot the magnitude of v_{OUT} versus frequency ω for the case $R_1 = 100\,\mathrm{k\Omega}$ and $C_1 = 0.0033\,\mu\mathrm{F}$.

1.94 Find an expression for v_{OUT} in the circuit of **Fig. P1.88** if v_{IN} is driven by a sinusoidal input voltage of frequency $f = \omega/2\pi$. Evaluate your expression at $f = 1\,\mathrm{kHz}$ if $R_1 = 1\,\mathrm{k\Omega}$, $R_2 = 10\,\mathrm{k\Omega}$, and $C_1 = 0.01\,\mu\mathrm{F}$.

1.95 The circuit of **Fig. P1.88** is fed by a sinusoidal voltage source. Plot the magnitude of v_{OUT} versus frequency ω for the case $R_1 = R_2 = 10\,\mathrm{k\Omega}$, and $C_1 = 0.22\,\mu\mathrm{F}$.

1.96 Find an expression for v_{OUT} in the circuit of **Fig. P1.90** if v_{IN} is driven by a sinusoidal input voltage of frequency $f = \omega/2\pi$. Evaluate your expression at $f = 100\,\mathrm{kHz}$ if $R_1 = 10\,\mathrm{k\Omega}$, $R_2 = 100\,\mathrm{k\Omega}$, and $C_1 = 0.005\,\mu\mathrm{F}$.

1.97 ○ The circuit of **Fig. P1.83** with $R_1 = 10\,\mathrm{k\Omega}$ and $C_1 = 0.033\,\mu\mathrm{F}$ drives a second similar circuit having component values $R_1 = 1\,\mathrm{M\Omega}$ and $C_1 = 0.0033\,\mu\mathrm{F}$. Find an approximate value for the overall v_{OUT} if $f = \omega/2\pi = 10\,\mathrm{kHz}$.

1.98 The circuit of **Fig. P1.90** feeds the circuit of **Fig. 1.83**. Find an expression for the overall output voltage $\mathbf{V}_{out}$ in terms of the input $\mathbf{V}_{in}$, where $\mathbf{V}_{out}$ and $\mathbf{V}_{in}$ are phasors.

1.99 ○ The circuit of **Fig. P1.99** is found inside many oscilloscope probes. It is designed to attenuate the incoming input signal while increasing the scope's input impedance. Find the condition for which the ratio v_{OUT}/v_{IN} will be independent of frequency. What will be the ratio v_{OUT}/v_{IN} under these conditions? What will be the value of $\mathbf{Z}_{in}$ measured between the v_{IN} terminal and ground?

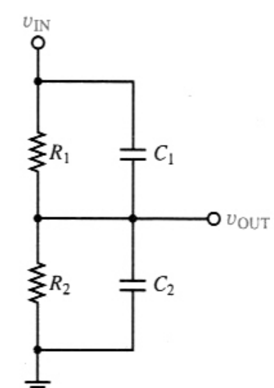

Fig. P1.99