CHAPTER ONE
INTRODUCTION AND BASIC CONCEPTS

CHARGE AND CURRENT

1.1: How many electrons pass a given point in a conductor in 20 s if the conductor is carrying 10 A?

1.2: If 240 C pass through a wire in 12 s what is the current?

1.3: What current passes through a conductor if 3.2×10^{21} electrons flow through the conductor in 16 s?

1.4: If the current in a conductor varies in accordance with the relationship

$$i = 4t + 24(1 - e^{-4t})\,\text{A}$$

how much charge flows from time, $t = 0$ to time, $t = 5\,s$?

ENERGY, POWER, VOLTAGE, CURRENT AND CHARGE

1.5: How much work is done in moving 10 nC of charge a distance of 68 cm in the direction of a uniform electric field of having a field strength of $E = 80\,\text{kV/m}$?

1.6: A charge of 0.5 C is brought from infinity to a point. Assume that infinity is at 0 V and determine the voltage at the terminal point if 14.5 J is required to move the charge.

1.7: If the potential difference between two points is 125 V, how much work is required to move a 3.2 C charge?

1.8: How many coulombs can be moved from point-A to point-B if $\Delta V_{AB} = 440\,\text{V}$ and a maximum of 842 J can be expended?

1.9: If 1 horsepower (hp) is equal to 0.746 kW, how much energy does a 20 hp motor deliver in 20 min?

1.10: If a 150 W incandescent bulb operates at 120 V, how many coulombs and electrons flow through the bulb in 1 h?

1.11: If a light bulb takes 1.2 A at 120 V and operates for 8 h/day, what is the cost of its operation for 30 days if power costs \$0.21/kwh?

1.12: If 1 calorie (1 cal) is equal to 4.184 J and it takes 1000 cal to raise 1 kg of water 1°C. how much current is carried by a 120 V heater if it is used to heat 4.82 kg of water from 25°C to 45°C in 4 min?

1.13: The waveforms for the current through and the voltage across a certain resistor are as shown in Fig 1.1. Determine the energy dissipated.

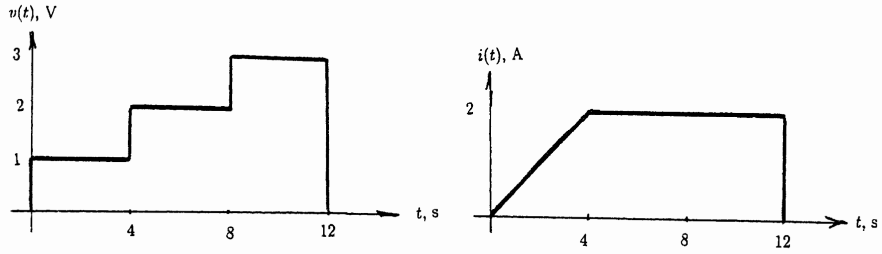


Figure 1.1.

1.14: The waveforms for the current through and the voltage across a certain resistor are as shown in Fig 1.2. Determine the energy dissipated.

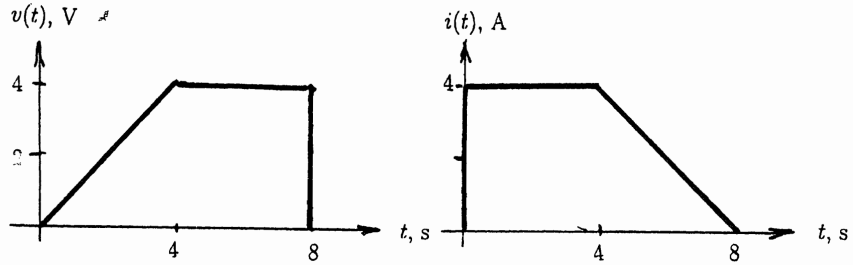


Figure 1.2.

RESISTANCE

1.15: A certain resistor dissipates heat at the rate of 8.12 kJ/min. If charge is passing through the resistor at the rate of 312.5 C/min, what is the potential difference across its terminals?

1.16: A copper transmission line consists of 24 strands of copper wire, each 1.62 mm in diameter. If the resistivity of copper is $1.72 \times 10^{-8}\,\Omega$-m. find the resistance of a 10 km length of wire.

1.17: What is the resistance between the circular faces of a right circular cylinder that is 1.8 m high and 1.88 cm in diameter if the cylinder is made from a material having a conductivity of $8 \times 10^{6}\,\mho$/m?

1.18: A sheet of foil that is 10.16 cm wide and 0.0108 cm thick must carry 4 amperes and is permitted to dissipate a maximum of 5.104 mW. If its conductivity is $5.805 \times 10^{7}\,\mho$/m, determine the maximum length of foil that can be used?

1.19: What is the length of a rectangular aluminum bus bar having dimensions 16 cm by 1.4 cm, a conductivity of $3.61 \times 10^{4}\,\mho$/m and a resistance of 1.527 Ω?

1.20: A metal wire having a resistance of 0.1567 Ω at a temperature of 20°C is to be used in an application where its resistance can lie between 0.1314 Ω and 0.1872 Ω. If its temperature coefficient of resistance is 0.00314 °C^{-1}, find the permitted temperature extremes?

1.21: Measurements taken on a conductor show a resistance of 8.24 Ω at 0°C and a resistance of 8.88 Ω at 20°C. Determine the temperature coefficient of resistance at 20°C.

1.22: A light bulb has a filament with a "cold" resistance of 25 Ω and a temperature coefficient of resistance of 0.0048°C^{-1}. If the bulb, while operating, draws 0.48 A at 120 V, determine the "hot" resistance of the bulb and the operating temperature of its filament.

1.23: An electric heater takes 1.8 kW at 120 V for 20 min to boil a quantity of water. Find the current through the heater and its resistance.

1.24: What is the resistance of the element in Problem 1.15?

APPLICATIONS OF OHM'S LAW

1.25: Two resistors are connected across the same voltage source. The length and diameter of resistor-1 are L_1 and d_1 respectively. Resistor-2 has a length of $0.40L_1$ and a diameter of $0.75d_1$. Determine the ratio of the currents and powers, I_1/I_2 and P_1/P_2.

1.26: If the same current flows through the two resistors of Problem 1.25, determine the ratios, V_1/V_2 and P_1/P_2?

1.27: A 0.5 Ω resistor is connected across a 6 V battery. Determine the current flowing through the resitor, the power absorbed by the resistor and the power delivered by the source.

1.28: What is the length of the resistor in Problem 1.27 if it is an aluminum wire with a diameter of 16 BWG (1.651 mm) and a resistivity of $2.72 \times 10^{-8}\,\Omega$-m?

1.29: An unspecified resistance, R, and a 12 Ω resitor are both connected across a 24 V source. The power dissipated by R is 12 W. Determine the value of R and the total power delivered by the source.

1.30: Three resistors having identical magnitudes are fed, in turn, by a 12 A current source. The power delivered by the current source is 1728 W. What is the magnitude of the resistances?

1.31: In a certain network containing four resistors, the resistors dissipate powers (with the subscript corresponding to the value of the resistor) of

$$P_{30} = 750\,\text{W}$$

$$P_3 = 1875\,\text{W}$$
$$P_4 = 1406.25\,\text{W}$$

and

$$P_{12} = 468.755\,\text{W}$$

Determine V_{30}, V_3, I_4 and I_{12}.

1.32: In a certain network containing four resistors, the resistors dissipate powers (with the subscript corresponding to the value of the resistor) of

$$P_5 = 45\,\text{W}$$
$$P_1 = 9\,\text{W}$$
$$P_3 = 12\,\text{W}$$

and

$$P_6 = 6\,\text{W}$$

Determine V_5, V_1, I_3 and I_6.

CONTROLLED SOURCES

1.33: In the circuit in Fig 1.3, if the resistor dissipates 2304 W, determine the value of β,

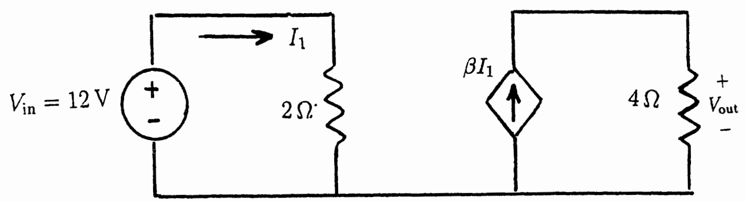


Figure 1.3.

1.34: In the circuit of Problem 1.33, determine the voltage gain, $|V_{\text{out}}/V_{\text{in}}|$ and the power gain, $|P_{\text{out}}/P_{\text{in}}|$

1.35: If $\mu = 10$ in Fig 1.4, determine the value of R_1 that is required to deliver a power of 25,600 W to the $16\,\Omega$ resistor.

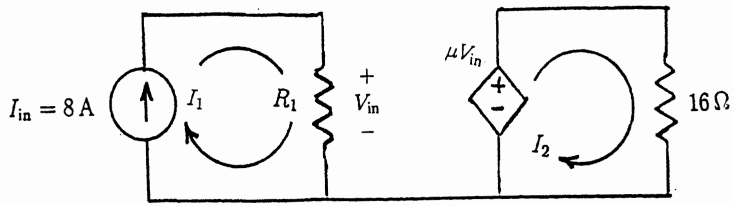


Figure 1.4.

1.36: Determine the current gain $|I_2/I_1|$ in the circuit of Problem 1.35.

1.37: In the circuit of Fig 1.5, $\beta = 8$ and $r_m = 8\,\Omega$. Determine the voltage gain, $|V_{\text{out}}/V_{\text{in}}|$ and the power gain, $|P_{\text{out}}/P_{\text{in}}|$.

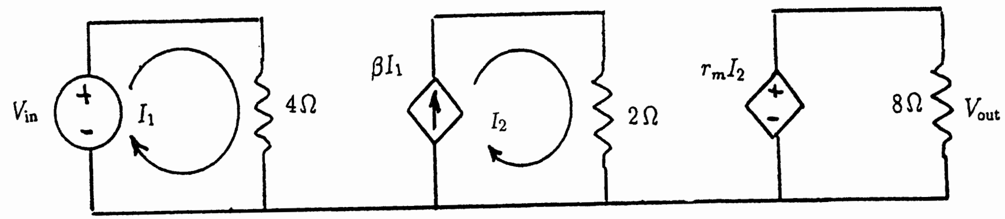


Figure 1.5.

1.38: In the circuit of Fig 1.6, $\mu = 8$ and $g_m = 0.5\,\mho$. Determine the current gain, $|I_3/I_{\text{in}}|$.

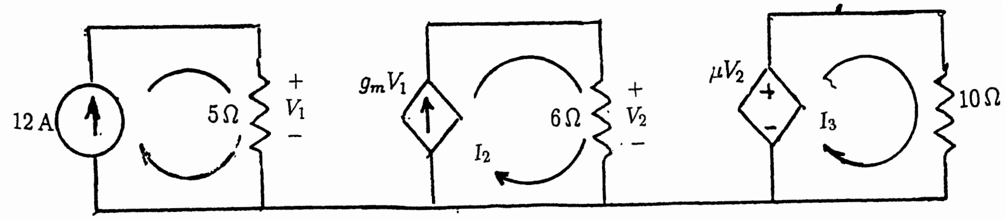


Figure 1.6.

CHAPTER TWO

KIRCHHOFF'S CURRENT AND VOLTAGE LAWS AND SERIES-PARALLEL RESISTIVE CIRCUITS

KCL PROBLEMS

2.1: Determine i_1, i_2 and i_3 in the network of Fig 2.1.

2.2: Determine i_1 through i_5 in the network of Fig 2.2.

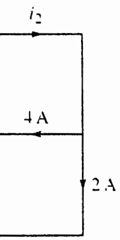


Figure 2.1

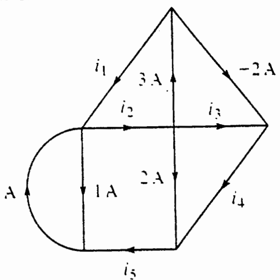


Figure 2.2

2.3: Determine i_1 through i_4 in the network of Fig 2.3.

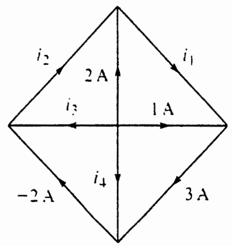


Figure 2.3

KVL PROBLEMS

2.4: Determine v_1 through v_5 in the network of Fig 2.4.

2.5: Determine v_1 through v_7 in the network of Fig 2.5.

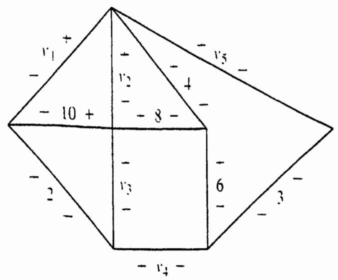


Figure 2.4

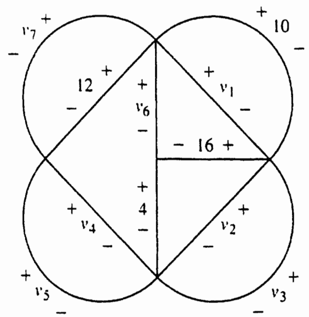


Figure 2.5

2.6: Determine v_1 through v_6 in the network of Fig 2.6.

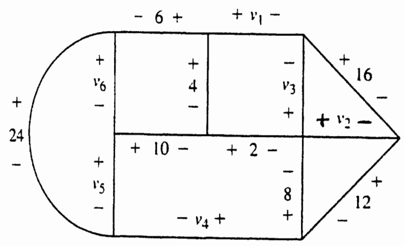


Figure 2.6

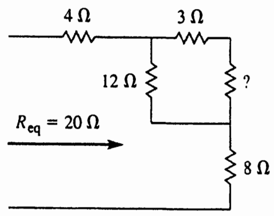
EQUIVALENT RESISTANCE PROBLEMS

2.7: Two resistors, R_1 and R_2 are connected in parallel. What is the value of the equivalent resistance if

(a) $R_1 = 20\,\Omega$ and $R_2 = 20\,\Omega$
(b) $R_1 = 20\,\Omega$ and $R_2 = 80\,\Omega$
(c) $R_1 = 20\,\Omega$ and $R_2 = \infty\,\Omega$
(d) $R_1 = 20\,\Omega$ and $R_2 = 0\,\Omega$
(e) $R_1 = 20\,\Omega$ and $R_2 = 50\,\Omega$

2.8: One of the resistances in the network shown in Fig 2.7 is blurred because of coffee spillage. If the equivalent resistance of the network is $R_{eq} = 20\,\Omega$, what is the value of the blurred resistor?

2.9: Determine the equivalent resistance looking into terminals *a*-*b* of the network shown in Fig 2.8.



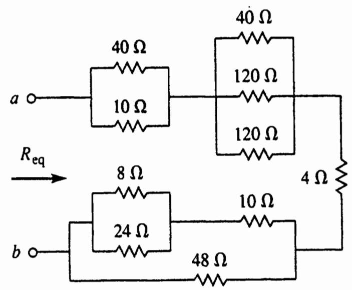


Figure 2.7

Figure 2.8

2.10: Determine the equivalent resistance looking into terminals *a*-*b* of the network shown in Fig 2.9.

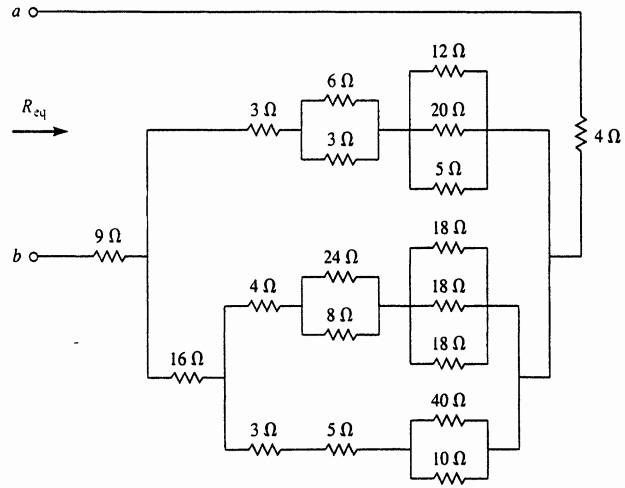


Figure 2.9

2.11: Determine the equivalent resistance looking into terminals *a*-*b* of the network shown in Fig 2.10.

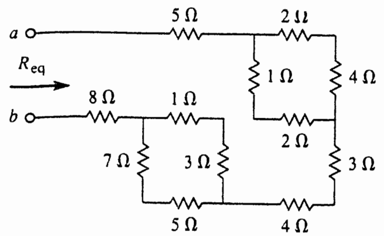


Figure 2.10

2.12: Find the equivalent resistance looking into terminals *a*-*b* in Fig 2.11.

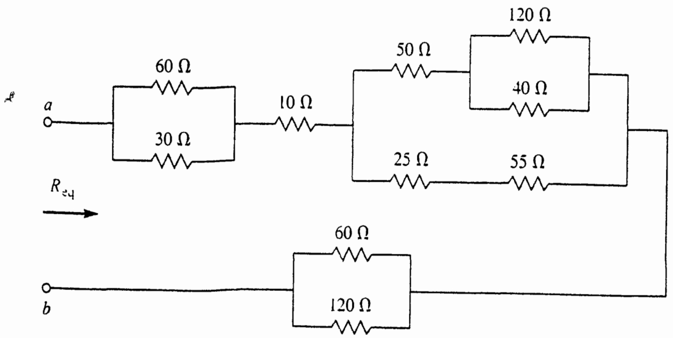


Figure 2.11

OHM'S LAW PROBLEMS

These problems include applications of KCL, KVL, current dividers and voltage dividers.

2.13: Two resistors of 4 Ω and 12 Ω are connected in series to a 24 V source. Determine (a) the current flow and (b) the voltage across each resistor.

2.14: Determine the power drawn by each resistor in Problem 2.13.

2.15: Use the voltage divider principle to determine the voltage across each resistor in the series connection of the 4 Ω and 12 Ω resistors of Problem 2.12

2.16: A 4 Ω resistor is connected in parallel to a 12 Ω resistor and the combination is connected to a 12 A source. Determine (a) the voltage across the combination and (b) the current through each resistor.

2.17: Determine the power drawn by each resistor in Problem 2.16.

2.18: Use the current divider principle to determine the current through each resistor in the parallel connection of the 4 Ω and 12 Ω resistors of Problem 2.16.

2.19: In the network of Fig 2.12, designate each resistor by its resistance value and find the current in all four of the resistors.

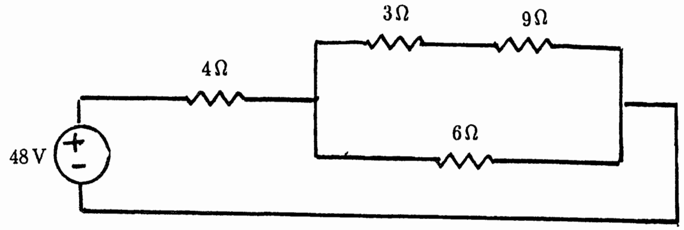


Figure 2.12

2.20: Determine the power dissipated by each resistor in the network of Problem 2.19.

2.21: In the series network shown in Fig 2.13, $R_{eq} = 10\,\Omega$, $V_2 = 24$ V and $P_3 = 16$ W. Determine the values of R_1, R_2 and R_3?

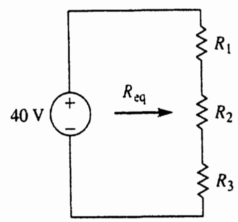


Figure 2.13

2.22: Figure 2.14 shows four resistors with subscripts corresponding to their resistance values. The right hand leg containing the 2 Ω and 4 Ω resistors is designated as R_s (*s* for series combination) and the current entering the parallel combination of the 3 Ω, 2 Ω and 4 Ω resistors is designated as I_p. If the current entering the network is $I = 6$ A, determine the current through and the voltage across each resistor.

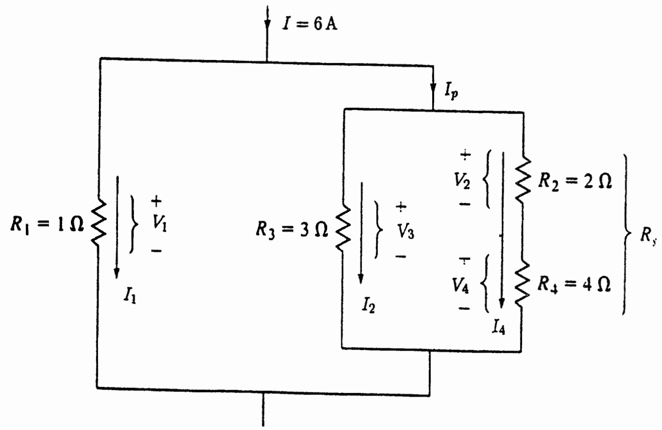


Figure 2.14

2.23: Find the current through and the voltage across each resistor in Fig 2.15.

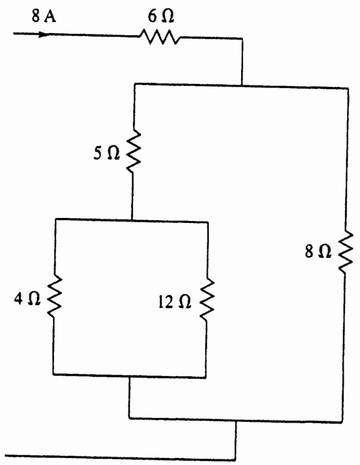


Figure 2.15

2.24: In the network of Fig 2.16, the resistance designators correspond to the resistance values. Determine the currents, I_1 and I_2 and the voltage across R_6 without using current and voltage division.

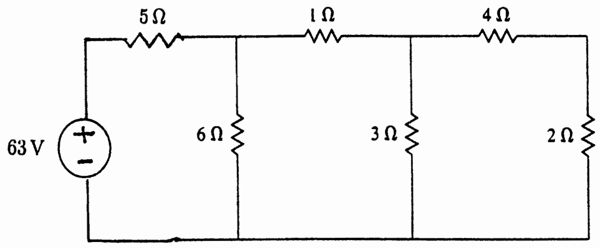


Figure 2.16

2.25: In the network of Problem 2.24, determine the currents, I_1 and I_2 and the voltage across R_6 by employing current and voltage division in place of KVL and KCL.

2.26: Find I_9, I_4 and V_7 in the network shown in Fig 2.17 without using voltage division.

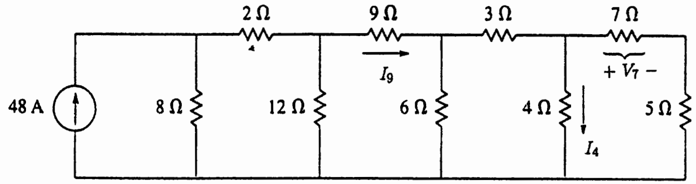


Figure 2.17

2.27: Find I_9, I_4 and V_7 in the network shown in Fig 2.17 without using current division.

2.28: Find I_3, I_4, V_{12} and V_{14} in the network shown in Fig 2.18.

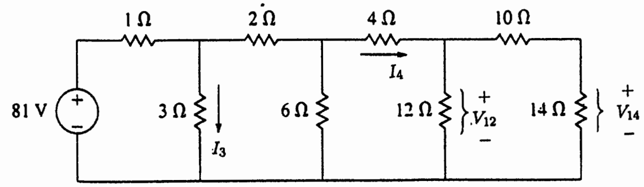


Figure 2.18

2.29: Find I_6, I_{10} and V_2 in the network shown in Fig 2.19.

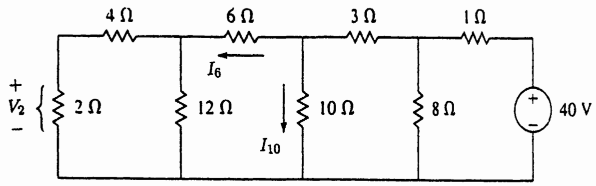


Figure 2.19

2.30: Find I_9, I_{40} and V_7 in the network shown in Fig 2.20.

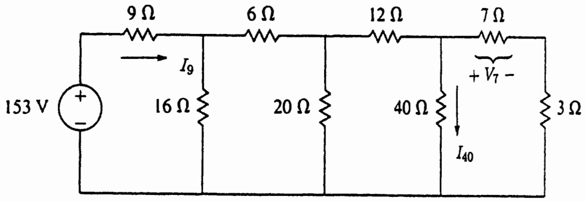


Figure 2.20

2.31: Find I_{13}, I_{14}, V_6 and V_7 in the network shown in Fig 2.21.

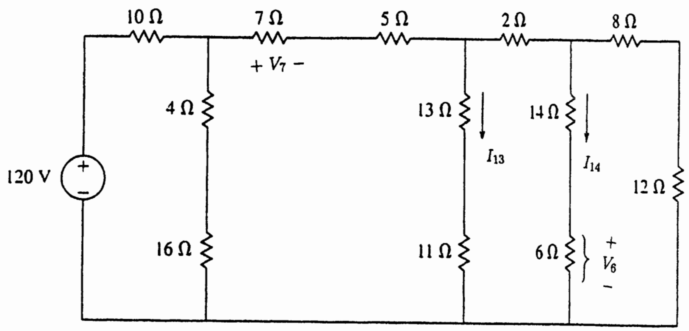


Figure 2.21

2.32: Find I_5, V_{20} and the power dissipated in the $24\,\Omega$ resistor in Fig 2.22.

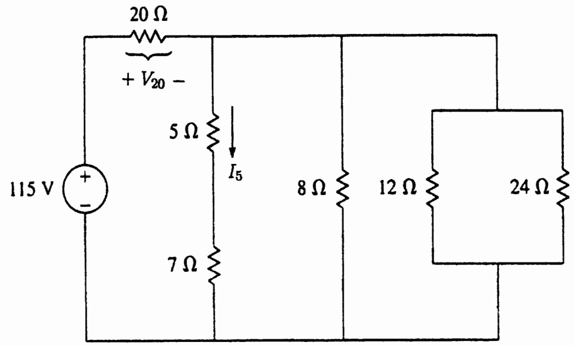


Figure 2.22

CHAPTER THREE

NODAL AND LOOP ANALYSES

SINGLE NODE PROBLEMS

3.1: Use nodal analysis to determine the voltage at point-1 (Node-1) in the network of Fig 3.1.

3.2: Use nodal analysis to determine the voltage at point-1 (Node-1) in the network of Fig 3.2.

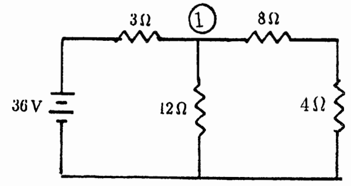


Figure 3.1

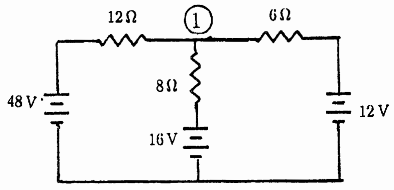


Figure 3.2

3.3: Use nodal analysis to determine the voltage at point-1 (Node-1) in the network of Fig 3.3.

3.4: Using nodal analysis, determine I_2 in the network of Fig 3.4.

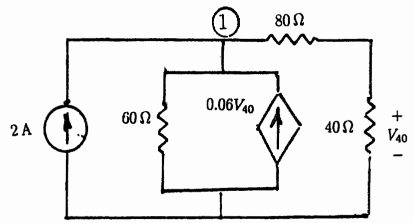


Figure 3.3

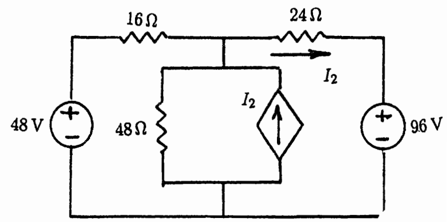


Figure 3.4

3.5: Use nodal analysis to determine the current flowing downward in the 8 Ω resistor in the network of Fig 3.5.

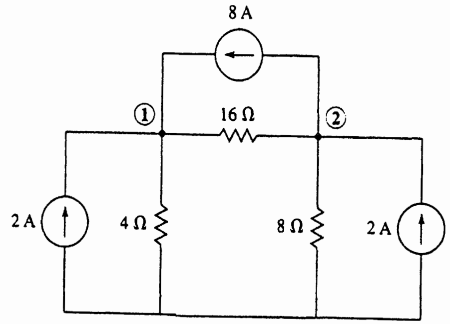


Figure 3.5

3.6: Determine the node voltages, V_1 and V_2, in the network shown in Fig 3.6.

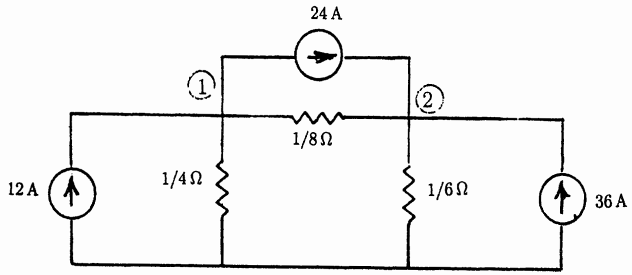


Figure 3.6

3.7: Use nodal analysis to determine the node voltages, V_1 and V_2 and then find the current through the 4 Ω resistor in the network of Fig 3.7.

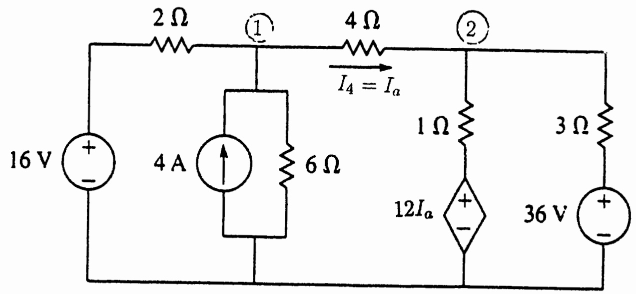


Figure 3.7

3.8: Write the node equations for the network shown in Fig 3.8 but do not attempt to solve them.

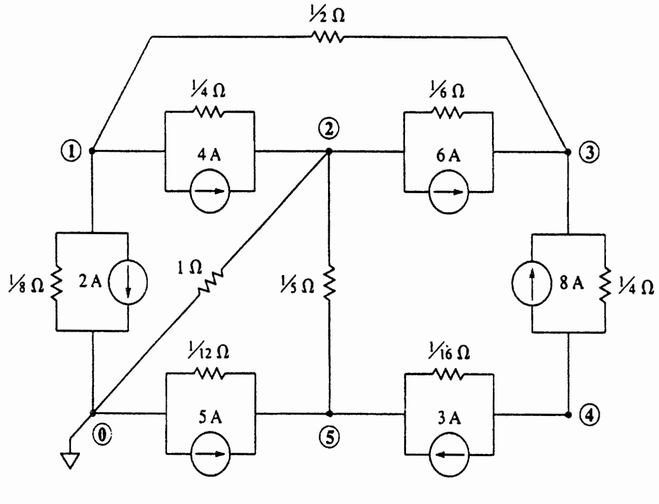


Figure 3.8

3.9: Determine the value of I_s that will produce a voltage of 36 V at node-2 in the network of Fig 3.9.

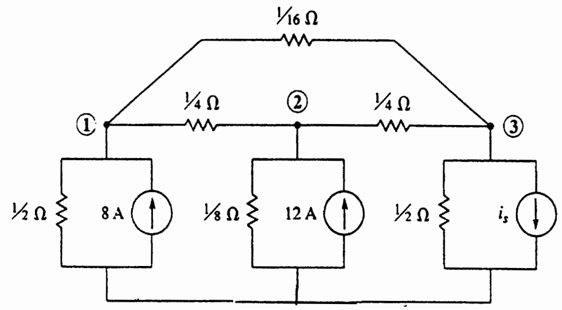


Figure 3.9

3.10: In the network of Fig 3.10, determine the current I_{40} using nodal analysis.

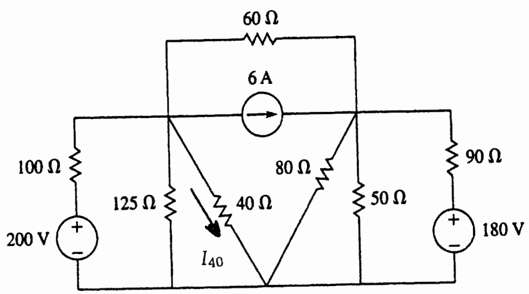


Figure 3.10

3.11: Determine the node voltages, V_1 and V_2 in the network shown in Fig 3.11.

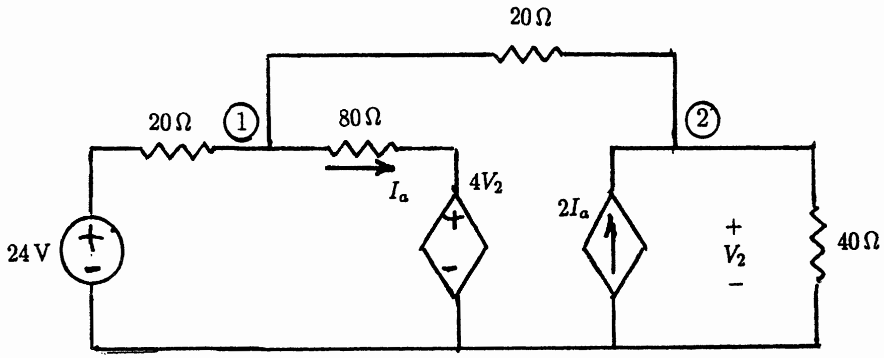


Figure 3.11

3.12: Use nodal analysis to determine the current in the $1/8\,\Omega$ resistor in the network of Fig 3.12.

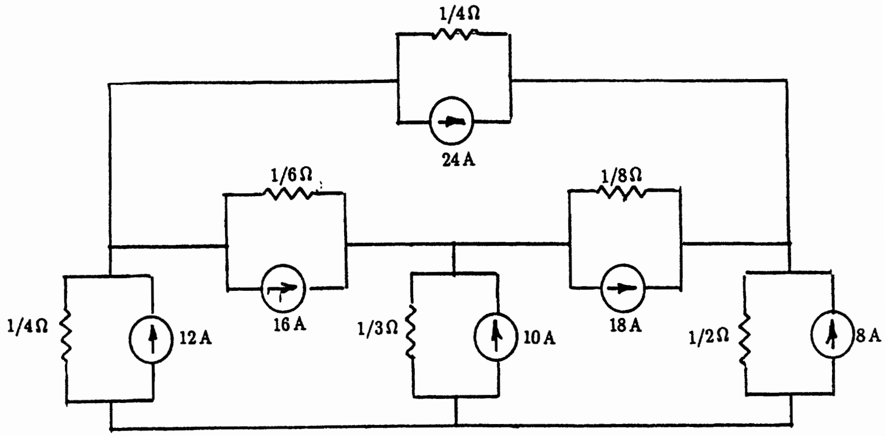


Figure 3.12

3.13: Determine the node voltages, V_1, V_2 and V_3 in the network of Fig 3.13.

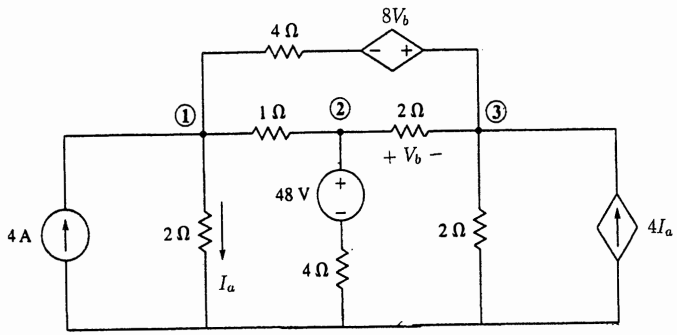


Figure 3.13

SUPERNODE PROBLEMS

3.14: Determine the node voltages, V_1, V_2 and V_3 in the network of Fig 3.14.

3.15: Determine the node voltages, V_1, V_2, V_3 and V_4 in the network of Fig 3.15.

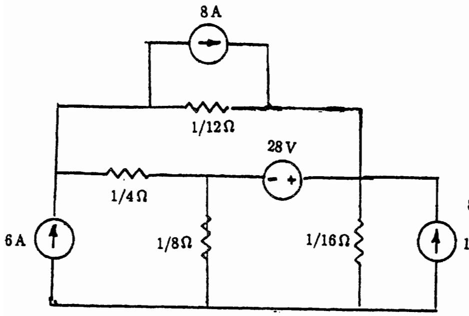


Figure 3.14

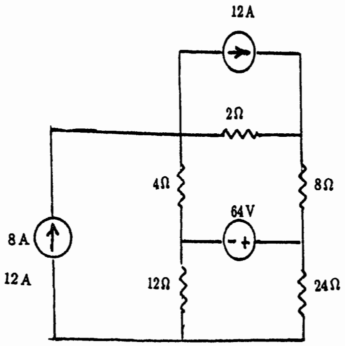


Figure 3.15

3.16: Determine the node voltages, V_1, V_2 and V_3 in the network of Fig 3.16.

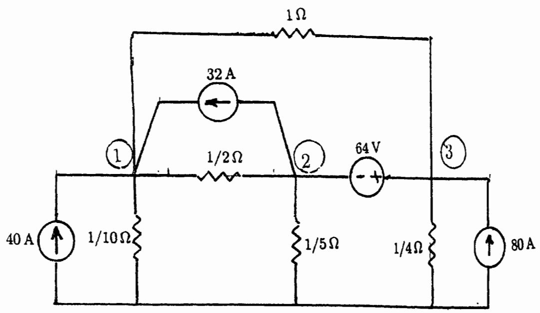


Figure 3.16

3.17: Determine the node voltages, V_1, V_2 and V_3 in the network of Fig 3.17.

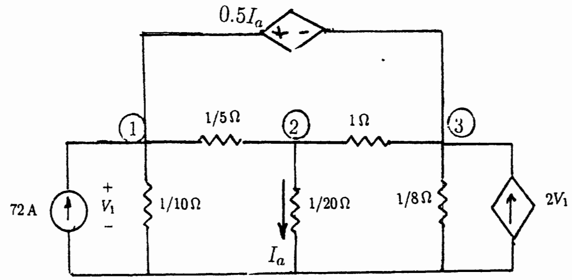


Figure 3.17

A LINK TO CHAPTER TWO

3.18: Figure 2.14 shows four resistors with subscripts corresponding to their resistance values. The right hand leg containing the 2 Ω and 4 Ω resistors is designated as R_s (s for series combination) and the current entering the parallel combination of the 3 Ω, 2 Ω and 4 Ω resistors is designated as I_p. If the current entering the network is $I = 6$ A, determine the current through and the voltage across each resistor (This is a repetition of Problem 2.22).

3.19: In the network of Fig 2.16, the resistance designators correspond to the resistance values. Use nodal analysis to determine the currents, I_1 and I_2 and the voltage across R_6 (This is a repetition of Problem 2.24).

3.20: Use nodal analysis to determine I_3, I_4, V_{12} and V_{14} in the network shown in Fig 2.18 (This is a repetition of Problem 2.28).

3.21: Use nodal analysis to determine I_5 and V_{20}. Then determine the power dissipated in the 24 Ω resistor in Fig 2.22 (This is a repetition of Problem 2.32).

SINGLE LOOP ANALYSIS

3.22: Determine the current, I, in the network shown in Fig 3.18.

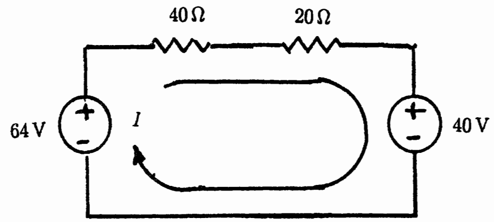


Figure 3.18

3.23: Determine the current, I, in the network shown in Fig 3.19.

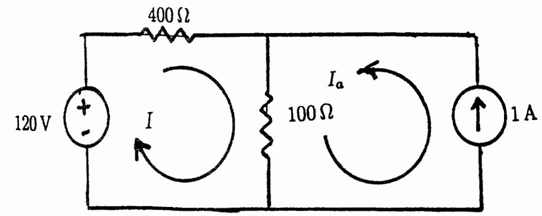


Figure 3.19

3.24: Determine the current, I, in the network shown in Fig 3.20.

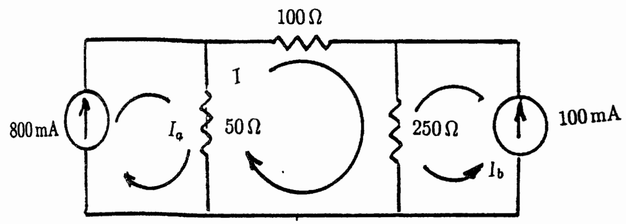


Figure 3.20

3.25: Determine the current, I, and the equivalent resistance seen by the 102 V source in Fig 3.21.

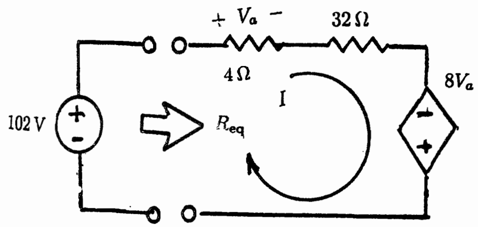


Figure 3.21

3.26: Use loop analysis to determine the current flowing in the 8 Ω resistor in Fig 3.5 (This is a repeat of Problem 3.5).

3.27: Determine the current, I, in the network shown in Fig 3.22.

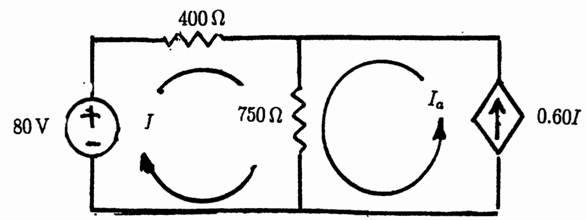


Figure 3.22

MULTIPLE LOOP ANALYSIS

3.28: Use loop analysis to determine the current flowing in the 4 Ω resistor in Fig 3.7 (This is a repeat of Problem 3.7).

3.29: Write the mesh equations for the network shown in Fig 3.23 but do not attempt to solve them.

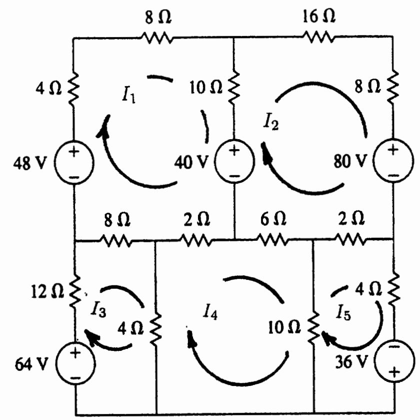


Figure 3.23

3.30: Determine the value of V_s that will produce a current of $I_2 = 1.532\,\text{A}$ in the network of Fig 3.24.

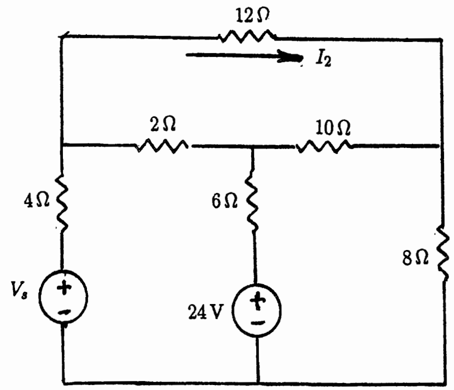


Figure 3.24

3.31: Use mesh analysis to determine the current flowing through the 16 Ω resistor and the voltage across the 8 Ω resistor in the network of Fig 3.25.

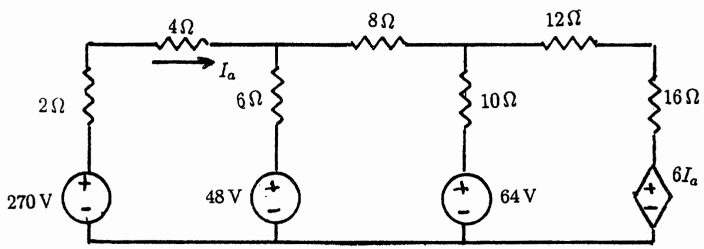


Figure 3.25

3.32: Use mesh analysis to find the current through the 6 Ω and 4 Ω resistors, the voltage drop across the 12 Ω resistor and the power dissipated by the 24 Ω resistor in Fig 3.26.

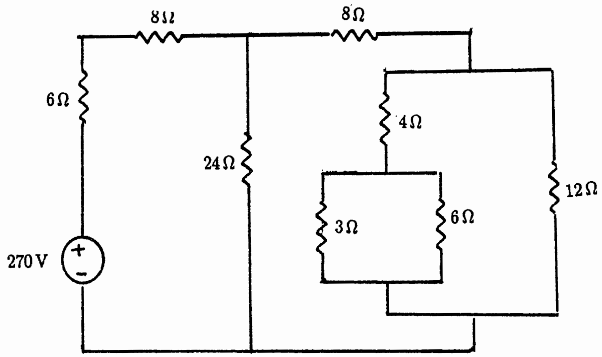


Figure 3.26

3.33: Use mesh analysis to find the current through, the voltage across and the power dissipated by the 6 Ω resistor in Fig 3.27.

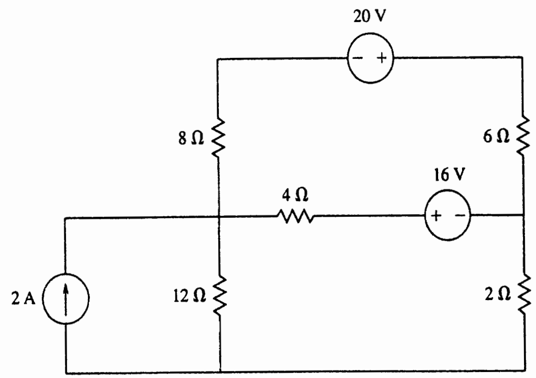


Figure 3.27

3.34: Use mesh analysis to find the power delivered by the 24 V source in Fig 3.28.

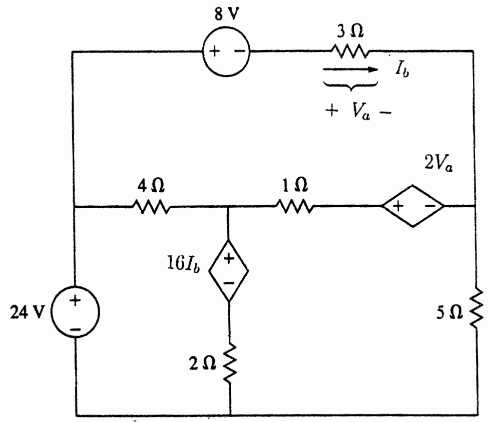


Figure 3.28

3.35: Problem 2.22 described a problem in which the network contained four resistors driven by a current of 6 A. The problem is repeated here with excitation by a current source of 6 A as shown in Fig 3.29. Use mesh analysis to determine the currents through and the voltage across each resistor. (This is a repeat of Problem 2.22 and Problem 3.18).

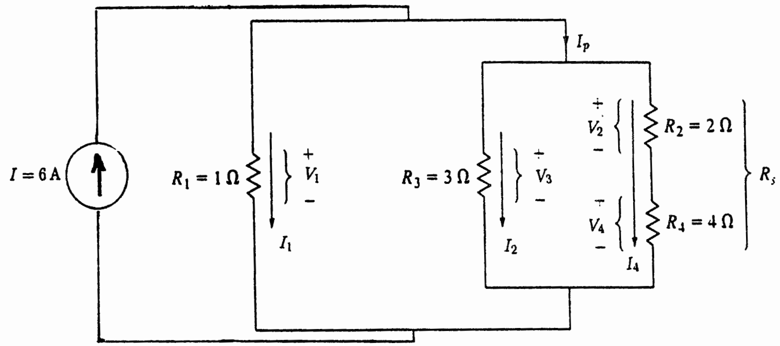


Figure 3.29

3.36: Use mesh analysis to determine the currents, I_1 and I_2 and the voltage across R_6 in the network of Fig 2.16 (This is a repeat of Problems 2.24 and 3.19).

3.37: Use mesh analysis to find I_3, I_4, V_{12} and V_{14} in the network shown in Fig 2.18 (This is a repeat of Problems 2.28 and 3.20).

3.38: Use mesh analysis to determine I_5, V_{20} and the power dissipated in the 24 Ω resistor in Fig 2.22 (This is a repeat of Problems 2.32 and 3.21).

CHAPTER FOUR
THE OPERATIONAL AMPLIFIER

ANALYSIS USING THE IDEAL OP-AMP MODEL

4.1: Determine the voltage gain and the input resistance for each of the ideal operational amplifier circuits of Fig 4.1.

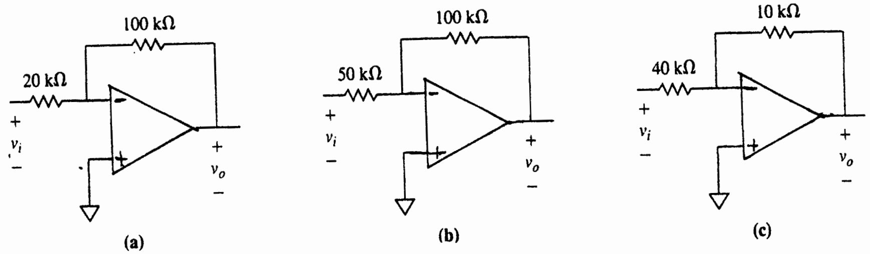


Figure 4.1

4.2: Determine the voltage gain and the input resistance for each of the ideal operational amplifier circuits of Fig 4.2.

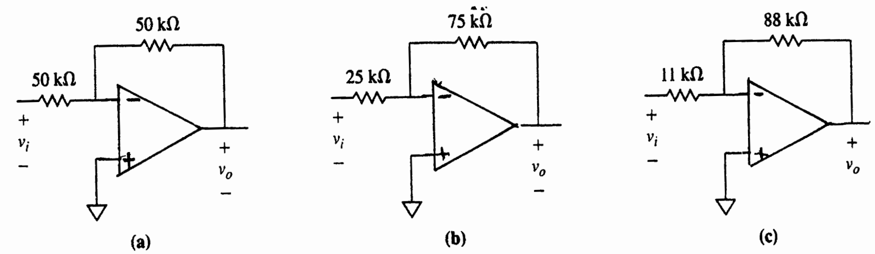


Figure 4.2

4.3: Determine the voltage gain of the ideal operational amplifier circuit of Fig 4.3.

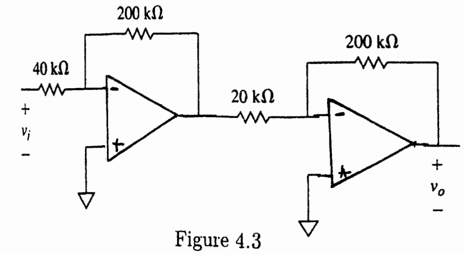


Figure 4.3

4.4: Determine the ratio, v_o/v_i, in the ideal operational amplifier circuit of Fig 4.4.

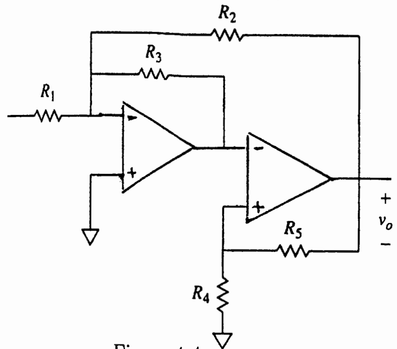


Figure 4.4

4.5: For the ideal operational amplifier shown in Fig 4.5, determine the gain $G = v_o/v_i$, for the conditions of (a) $R_1 = 100\,\text{k}\Omega$ and $R_f = 900\,\text{k}\Omega$, (b) $R_1 = 50\,\text{k}\Omega$ and $R_f = 750\,\text{k}\Omega$ and (c) $R_1 = 100\,\text{k}\Omega$ and $R_f = 1.1\,\text{M}\Omega$.

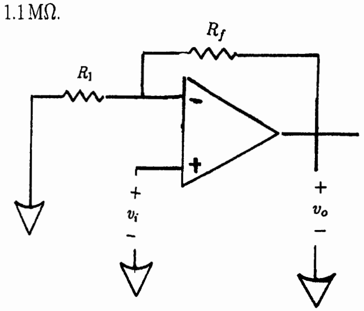


Figure 4.5

4.6: For the ideal operational amplifier arrangement shown in Fig 4.6, determine the output voltage, v_o if the input voltage, v_i, is equal to 1.20 V.

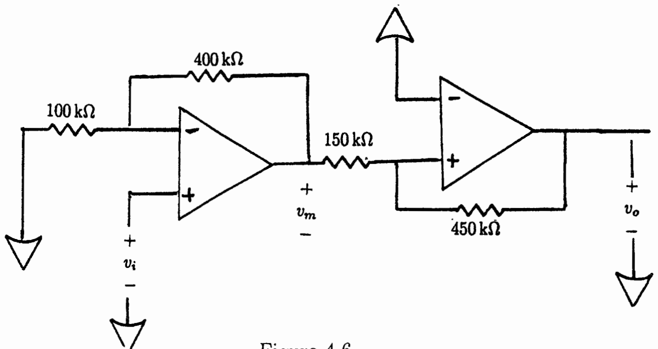


Figure 4.6

4.7: Figure 4.7 shows an ideal operational amplifier connected as a *differential amplifier*. Both the inverting and non-inverting terminals are used. Determine an expression for the output voltage, v_o, as a function of v_{i1} and v_{i2} $[v_o = f(v_{i1}, v_{12})]$. Then determine $v_o = v_o = f(v_{i1}, v_{12})$ if $R_1 = R_2$.

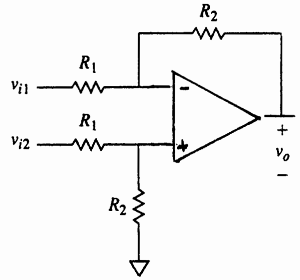


Figure 4.7

4.8: Figure 4.8 shows an ideal operational amplifier that can be used as a strain gage which is based on the fact that the the value resistance, ΔR, will change slightly when the resistor is bent or twisted. Determine the value of ΔR as a function of the input voltage, v_i, and the two resistances, R_a and R_b.

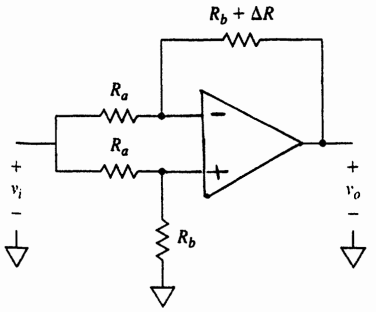


Figure 4.8

4.9: Figure 4.9 shows how an ideal operational amplifier can be put together by using resistors that have relatively small resistance values. If $R_1 = 2000\,\text{Om}$, determine the value of a single feedback resistor to produce a gain of -1200 and then, with $R_1 = 2000\,\Omega$ and $R_b = 50\,\Omega$, determine the value of R_a to provide a gain of -1200.

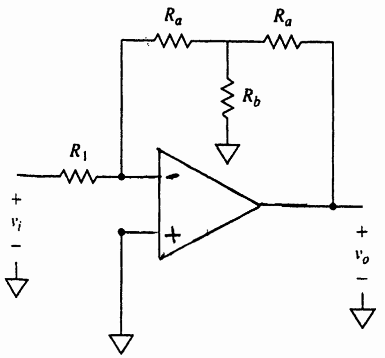


Figure 4.9

4.10: Figure 4.10 illustrates the use of an ideal operational amplifier as a *negative impedance converter*. Determine the input resistance.

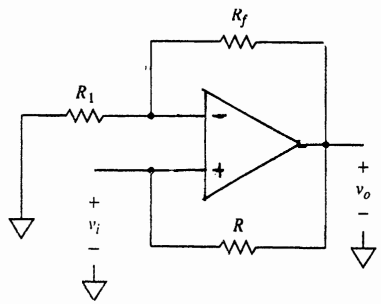


Figure 4.10

4.11: An ideal operational amplifier in the inverting configuraton is to have a gain of -125 and an input resistance as high as possible. If no resistance in the op-amp circuit is to have a value higher that $5\,\text{M}\Omega$, how is this design achieved by using just two resistors.

4.12: In the cascade of ideal operational amplifiers shown in Fig 4.11, if $v_i = 2\,\text{V}$ and $v_o = 30\,\text{V}$, determine the value of R.

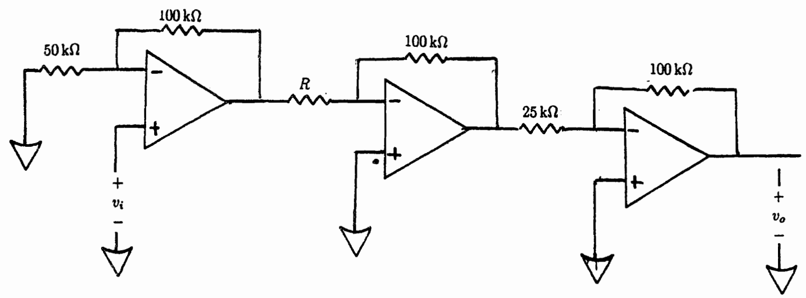


Figure 4.11

GENERAL SUMMING AMPLIFIER PROBLEMS (THE IDEAL OP-AMP MODEL)

4.13: Determine v_o in the ideal operational amplifier circuit shown in Fig 4.12.

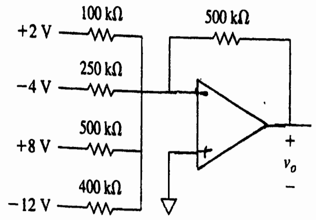


Figure 4.12

4.14: In the ideal operational amplifier circuit shown in Fig 4.13, determine the value of v_3 to make $v_o = 18.5\,\text{V}$.

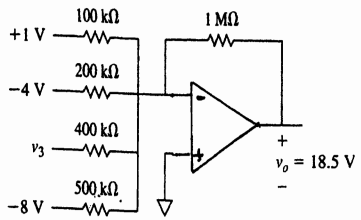


Figure 4.13

4.15: Determine v_o in the ideal operational amplifier circuit of Fig 4.14.

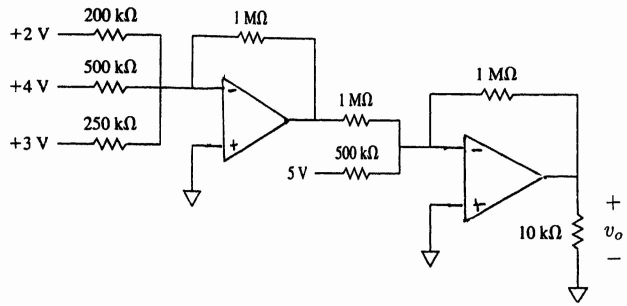


Figure 4.14

4.16: In the summing operational amplifier in Fig 4.15, $R_{1,1} = 5\,\text{k}\Omega$. Determine the values of $R_f, R_{1,2}$ and $R_{1,3}$ that will yield an output voltage of $v_o = -(4v_{i1} + 8v_{i2} + 10v_{i3})$.

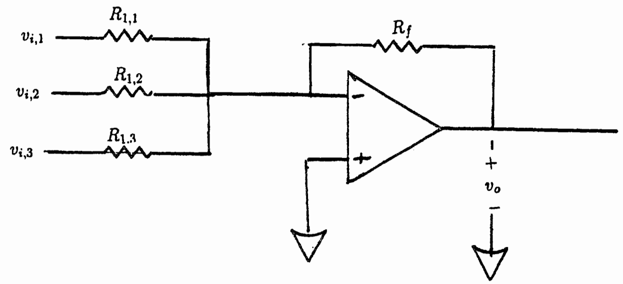


Figure 4.15

4.17: Determine the current, i_o, and the power drawn by R_o in the ideal operational amplifier circuit of Fig 4.16.

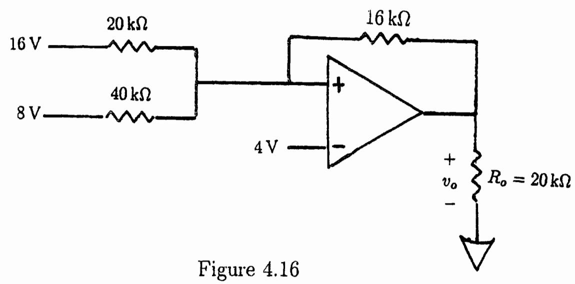


Figure 4.16

4.18: Determine the output voltage, v_o, in the ideal operational amplifier circuit shown in Fig 4.17.

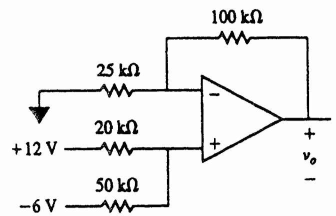


Figure 4.17

NON IDEAL OP-AMPS: FINITE OPEN LOOP GAIN

4.19: If the operational amplifier in Fig 4.18 has a finite gain of $A = 500$, determine the output voltage, v_o, if $v_i = 4\,\text{V}$.

4.20: In problem 4.19, to determine the value of the gain, A to make $v_o = -18.5\,\text{V}$.

4.21: Determine the value of R_f required in Fig 4.19 to make the outout voltage, $v_o = 16\,\text{V}$ when $R_1 = 50\,\text{k}\Omega, V_i = -4\,\text{V}$ and the amplifier has an actual gain of $A = 400$.

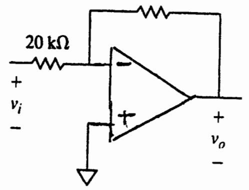


Figure 4.18

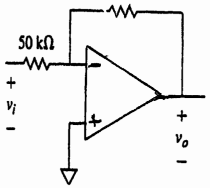


Figure 4.19

4.22: If the operational amplifier in Fig 4.20 has an actual gain of $A = 200$, determine the value of R_1 required to make $v_o = 18\,\text{V}$ with $v_i = -2\,\text{V}$.

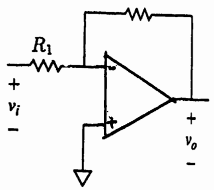


Figure 4.20

SATURATION EFFECTS

4.23: The input to an ideal operational amplifier in the inverting configuration is shown in Fig 4.21, If $R_f = 200\,\text{k}\Omega, R_1 = 50\,\text{k}\Omega$ and $V_{sat} = 12\,\text{V}$, determine and plot the output characteristic.

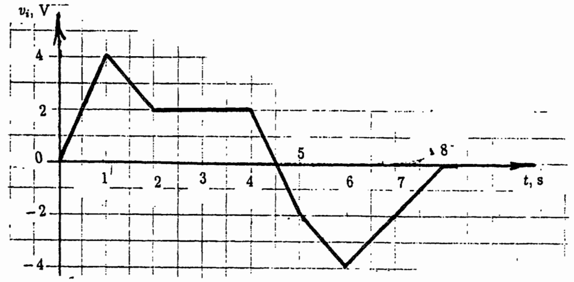


Figure 4.21

4.24: The operational amplifier of Problem 4.23 is subjected to a sinusoidal input of

$$v_i(t) = 3\sqrt{2}\sin 100t\ \text{V}$$

Determine the time intervals for operation in both the positive and negative saturation regions.

4.25: Determine the extremes of operation of an operational amplifier with a saturation voltage of 8 V and a gain of 400. Then determine the output voltage when $v_d = v_+ - v_- = -6\,\text{mV}$.

4.26: An ideal operational amplifier has a saturation voltage of $V_{sat} = 8\,\text{V}$ and operates in the inverting configuration with feedback and input resistances of $R_f = 100\,\text{k}\Omega$ and $R_1 = 25\,\text{k}\Omega$, Determine v_o and $v_d = v_+ - v_-$ if (a) $v_i = 0.625\,\text{V}$, (b) $v_i = -3\,\text{V}$ and (c) $v_i = +4\,\text{V}$

SELECTION OF OPERATIONAL AMPLIFIER COMPONENTS

4.27: Design an ideal operational amplifier circuit to have the general input-output relationship

$$v_o = -(8v_{a1} + 4v_{a2} + 2v_{a3}) + (3v_{b1} + 6v_{b2} + 9v_{a3})$$

4.28: Use the ideal operational amplifier circuit developed in Problem 4.27 to determine the output voltage if all input voltages are taken at a nominal 1 V.

4.29: Design an ideal operational amplifier circuit to have the general input-output relationship

$$v_o = -(4v_{a1} + 2v_{a2} + v_{a3} + 8v_{a4}) + (5v_{b1} + 2v_{b2})$$

4.30: Use the ideal operational amplifier circuit developed in Problem 4.27 to determine the output voltage if all input voltages are taken at a nominal 1 V.

CHAPTER FIVE
SUPERPOSITION AND SOURCE TRANSFORMATIONS

LINEARITY

5.1: Suppose that a system has its output, r (r for response), related to its input, e (e for excitation) by

$$r = \frac{a}{a+b}e$$

Determine if the system is linear if (a) $a = b$ and (b) $b = ae$.

5.2: A system has its output, r (r for response), related to its input, e (e for excitation) by

$$r = ae$$

Determine if the system is linear.

5.3: Consider the voltage-current relationship for a particular circuit component

$$v = L\frac{di}{dt}$$

Is this component a linear component?

5.4: Consider a device whose voltage-current relationship is given by

$$i = av + bv^2$$

Is the device linear?

5.5: Consider a diode whose voltage-current relationship is given by

$$i = I(e^{24v} - 2)$$

Is the diode linear?

PROPORTIONALITY

5.6: In the network of Fig 5.1, the resistance designators correspond to the resistance values. By assuming that $I_4 = 1$ A, determine I_3, I_4, V_{12} and V_{14}. (This is a repeat of Problem 2.28).

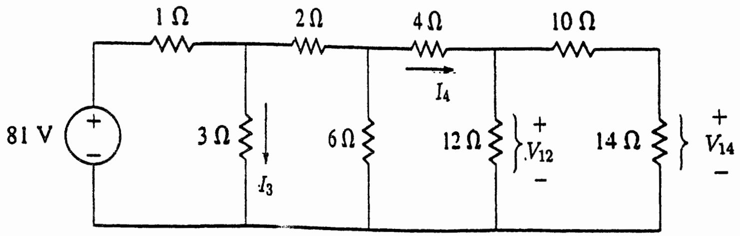


Figure 5.1

5.7: In the network of Fig 5.2, the resistance designators correspond to the resistance values. By assuming that $I_2 = 1$ A, determine I_6 and V_3. (This is a repeat of Problem 2.24).

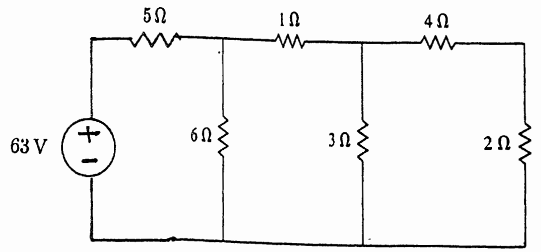


Figure 5.2

5.8: In the network of Fig 5.3, the resistance designators correspond to the resistance values. By assuming that $V_1 = 1$ V, determine I_4, I_6 and V_2.

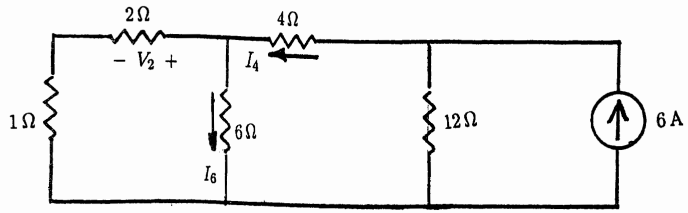


Figure 5.3

5.9: In the network of Fig 5.4, the resistance designators correspond to the resistance values. By assuming that $I_{10} = 1$ A, determine I_2, I_4 and V_8.

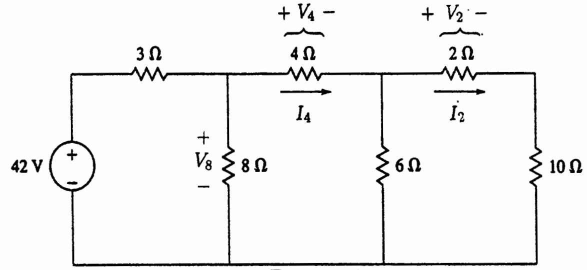


Figure 5.4

5.10: In the network of Fig 5.5, the resistance designators correspond to the resistance values. By assuming that $I_3 = 1$ A, determine I_9, I_{40} and V_7. (This is a repeat of Problem 2.30).

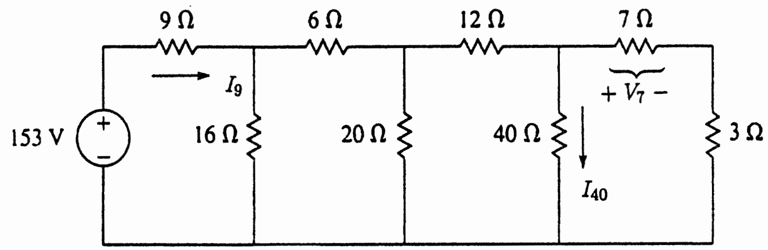


Figure 5.5

SOURCE TRANSFORMATION PROBLEMS

5.11: Transform the ideal voltage sources shown in Fig 5.6 to ideal current sources.

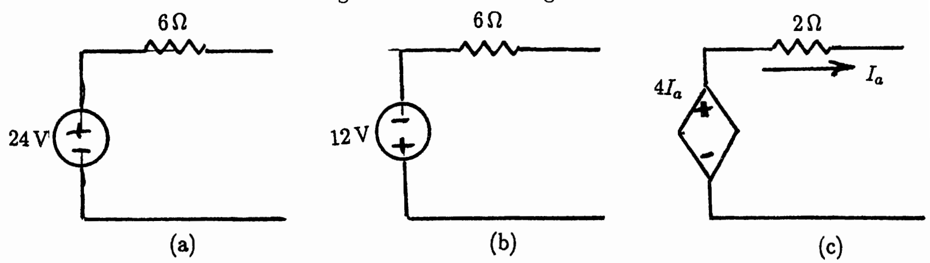


Figure 5.6

5.12: Transform the ideal current sources shown in Fig 5.7 to ideal voltage sources.

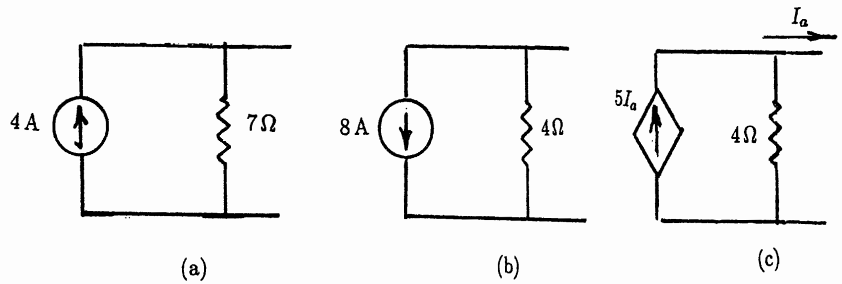


Figure 5.7

5.13: Transform the network of ideal voltage and current sources in Fig 5.8 to a single ideal voltage source.

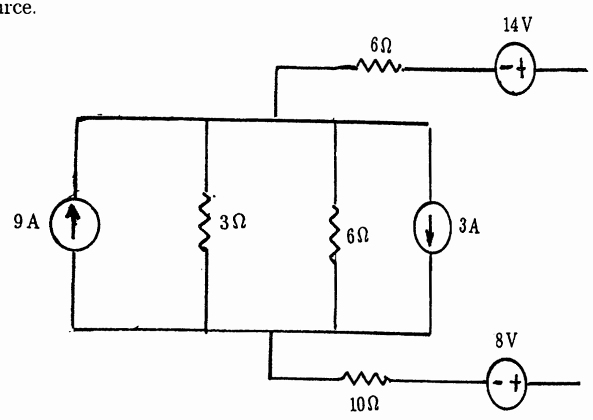


Figure 5.8

5.14: Transform the network of ideal voltage sources, ideal current sources and resistors in Fig 5.9 to a single ideal voltage source.

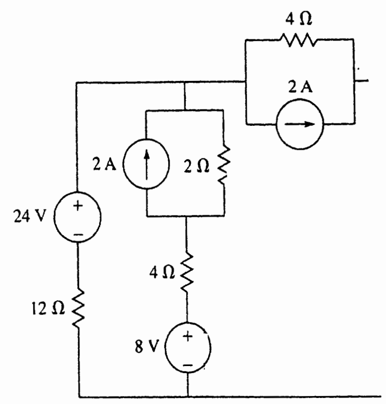


Figure 5.9

5.15: Transform the network of ideal voltage sources, ideal current sources and resistors in Fig 5.10 to a single ideal voltage source.

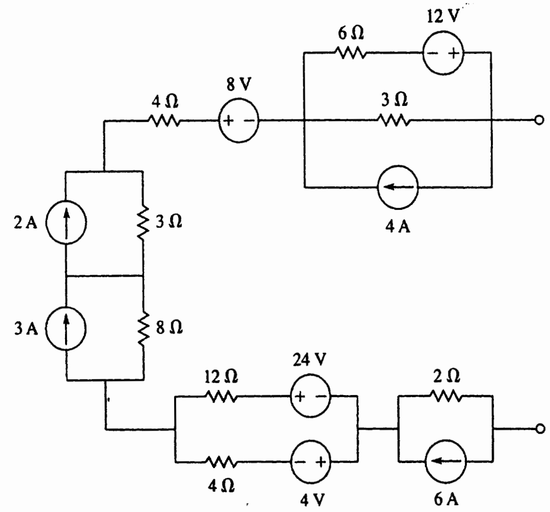


Figure 5.10

SUPERPOSITION PROBLEMS

5.16: Use superposition to determine the value of the current, I, in the network of Fig 5.11.

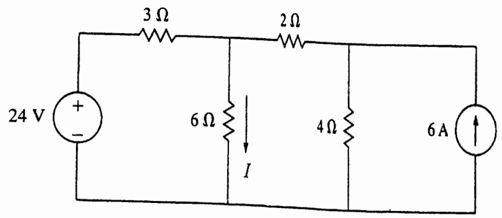


Figure 5.11

5.17: Use superposition to determine the value of the current, I, in the network of Fig 5.12.

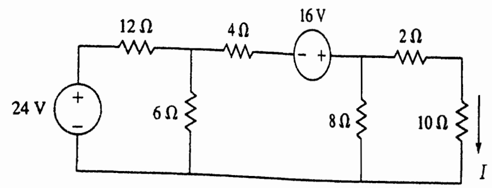


Figure 5.12

5.18: Use superposition to determine the value of the current, I, in the network of Fig 5.13.

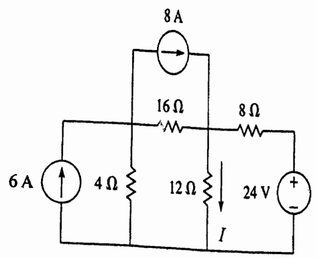


Figure 5.13

5.19: Use superposition to determine the value of the current, I, in the network of Fig 5.14.

5.20: Use superposition to determine the value of the voltage, V, in the network of Fig 5.15.

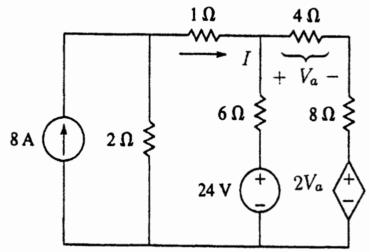


Figure 5.14

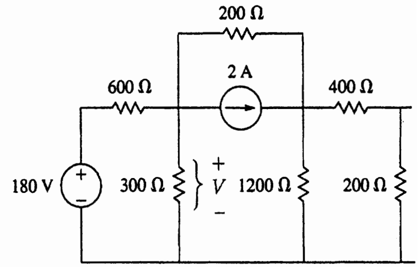


Figure 5.15

5.21: Use superposition to determine the value of the current, I, in the network of Fig 5.16.

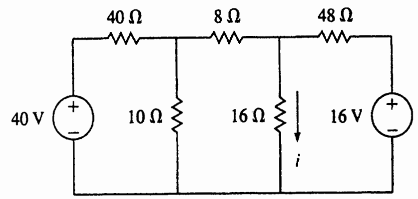


Figure 5.16

5.22: Use superposition to determine the value of the voltage, V, in the network of Fig 5.17.

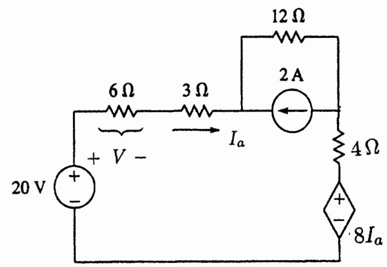


Figure 5.17

5.23: Use superposition to determine the value of the current, I, in the network of Fig 5.18.

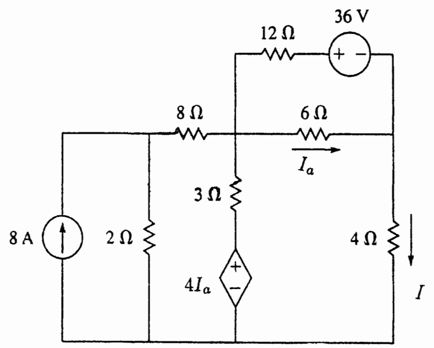


Figure 5.18

5.24: Use superposition to determine the value of source voltage, V_s to make the current, I_a = 3 A in the network of Fig 5.19.

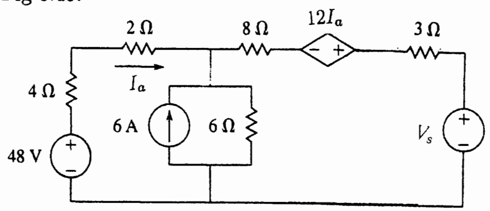


Figure 5.19

5.25: Use superposition to determine the power dissipated in the 8 Ω resistor in the network of Fig 5.20.

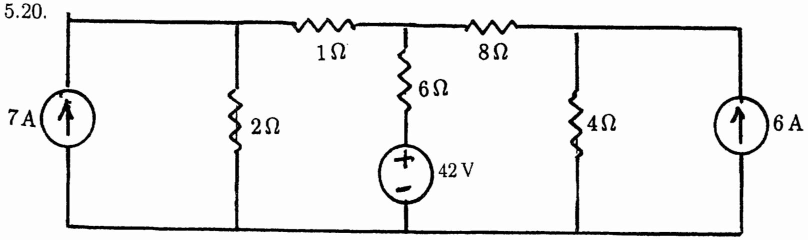


Figure 5.20

SUPERPOSITION AND OPERATIONAL AMPLIFIERS

5.26: Figure 5.21 shows an operational amplifier circuit with the op-amp connected as a differential amplifier. Use superposition to evaluate v_+ and v_- in terms of v_{i1} and v_{i2} and find an expression for $v_o = f(v_{i1}, v_{i2})$.

5.27: For the operational amplifier arrangement shown in Fig 5.22, if $v_{i2} = 6$ V, select the value of R to make $v_o = 24$ V.

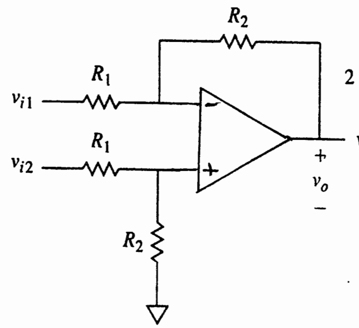


Figure 5.21

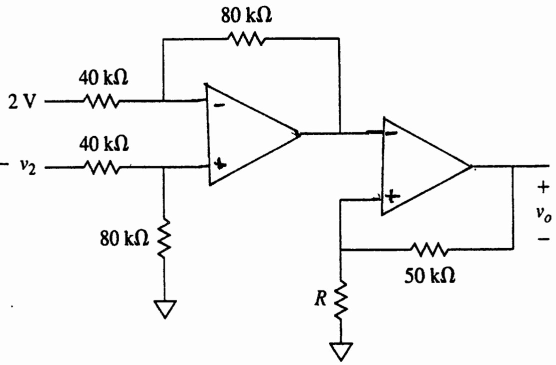


Figure 5.22

5.28: For the operational amplifier arrangement shown in Fig 5.22, if $R = 40\,\text{k}\Omega$, determine the value of v_2 required to make $v_o = 11.25$ V.

5.29: For the operational amplifier arrangement shown in Fig 5.23, use superposition to find $v_o = f(v_{i1}, v_{i2})$.

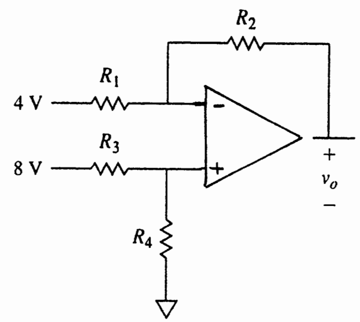


Figure 5.23

5.30: In the arrangement of Fig 5.23, $v_{i1} = 4\,\text{V}, v_{i2} = 8\,\text{V}, R_2 = 80\,\text{k}\Omega$ and $R_4 = 40\,\text{k}\Omega$. Find the values of R_1 and R_3 needed to make $v_o = 4\,\text{V}$ suject to the constraint that $R_1 = 1.25R_3$.

CHAPTER SIX

THEVENIN, NORTON AND MAXIMUM POWER TRANSFER THEOREMS

THEVENIN AND NORTON THEOREMS FOR NETWORKS WITHOUT CONTROLLED SOURCES

6.1: Use Thevenin's theorem to find the resistance that must be connected across terminals *a-b* in Fig 6.1 in order for the resistor current to be 3 A.

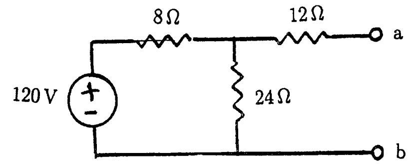


Figure 6.1

6.2: Determine the Thevenin equivalent network between terminals *a-b* in Fig 6.2.

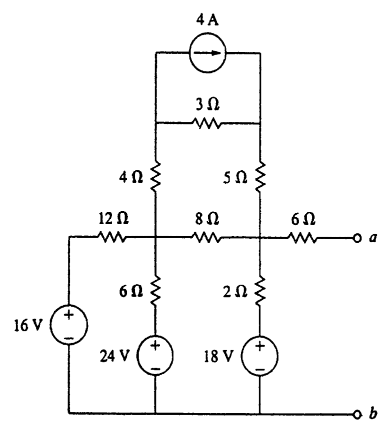


Figure 6.2

6.3: Use Thevenin's theorem to find the current, I, in the network of Fig 6.3.

6.4: Use Thevenin's theorem to find the current, I, flowing through the 600 Ω resistor in the network of Fig 6.4.

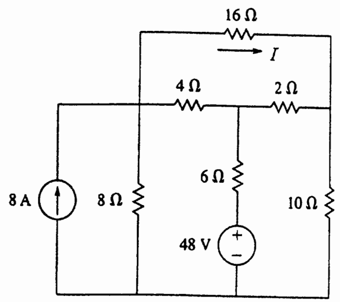


Figure 6.3

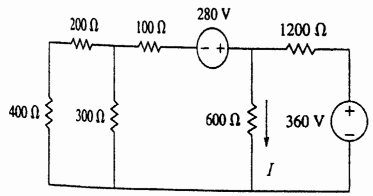


Figure 6.4

6.5: Determine the Norton equivalent circuit for terminals a-b in the network of Fig 6.5.

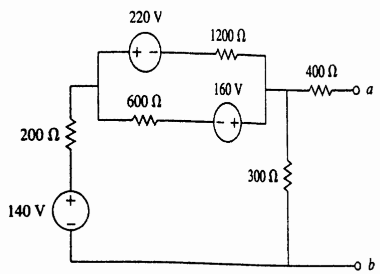


Figure 6.5

6.6: Use Thevenin's theorem to find the voltage across the 320 Ω resistor in the network of Fig 6.6.

6.7: Use the Thevenin's theorem or the Norton's theorem to determine the value of R that will allow a current of 1 A to flow through the 2 Ω resistor in Fig 6.7.

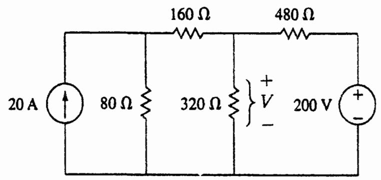


Figure 6.6

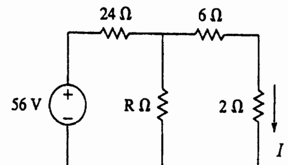


Figure 6.7

6.8: Use Norton's theorem to determine the current through the 10 Ω resistor in the network of Fig 6.8.

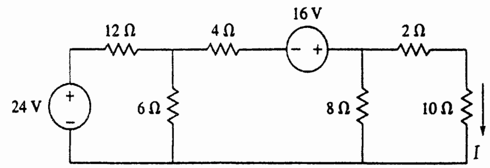


Figure 6.8

THEVENIN AND NORTON THEOREMS FOR NETWORKS WITH CONTROLLED SOURCES

6.9: Use Thevenin's theorem to determine the power dissipated by the 12 Ω resistor in Fig 6.9.

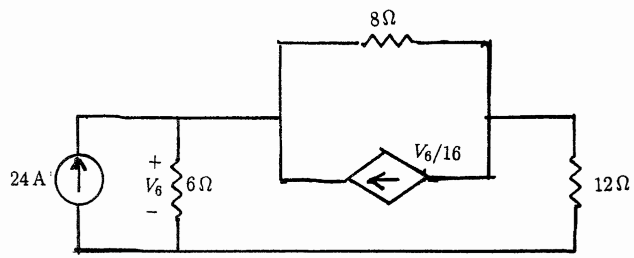


Figure 6.9

6.10: Determine the Norton equivalent for terminals a-b in the network of Fig 6.10.

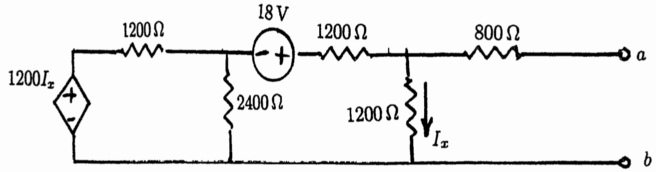


Figure 6.10

6.11: Use Thevenin's theorem to determine the current flowing through the 1.6 Ω resistor in Fig 6.11.

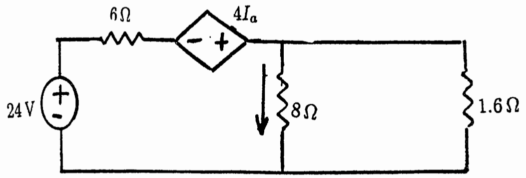


Figure 6.11

6.12: Use Norton's theorem to determine the current flowing through the right-hand 4 Ω resistor in Fig 6.12.

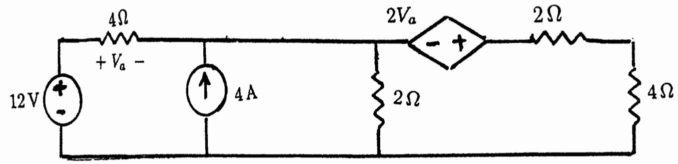


Figure 6.12

6.13: Use Thevenin's theorem to determine the current flowing through the 16 Ω resistor in Fig 6.13.

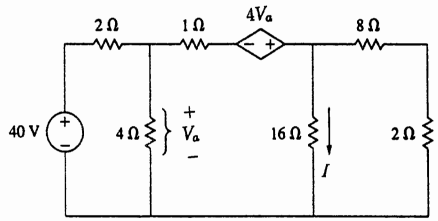


Figure 6.13

6.14: Use Thevenin's theorem to determine the power dissipated by a 300 Ω resistor connected across terminals a-b in Fig 6.14.

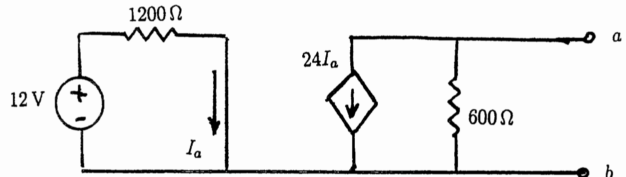


Figure 6.14

6.15: Use Thevenin's theorem to determine the current through the 6 Ω resistor in the network of Fig 6.15.

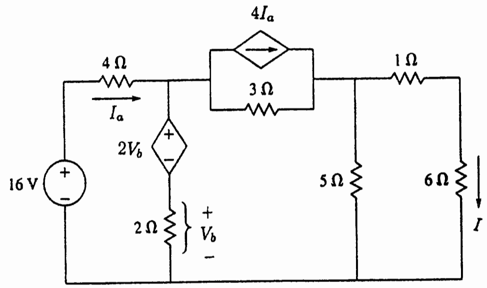


Figure 6.15

6.16: Determine the current through the 3 Ω resistor in Fig 6.16 by using superposition to find the Thevenin equivalent circuit.

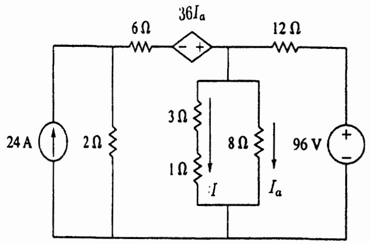


Figure 6.16

MAXIMUM POWER TRANSFER

6.17: In the network of Fig 6.17, determine the value of the load to be placed across terminals *a*-*b* in order for the load to draw maximum power. Then, determine the value of this power.

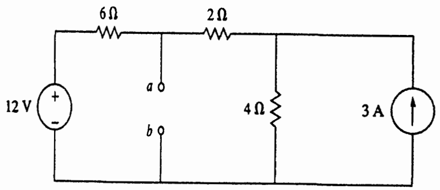


Figure 6.17

6.18: In the network of Fig 6.18, determine the value of the load to be placed across terminals *a*-*b* in order for the load to draw maximum power. Then, determine the value of this power.

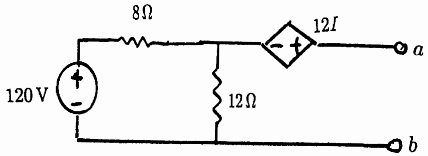


Figure 6.18

6.19: In the network of Fig 6.19, determine the value of the load to be placed across terminals *a*-*b* in order for the load to draw maximum power. Then, determine the value of this power.

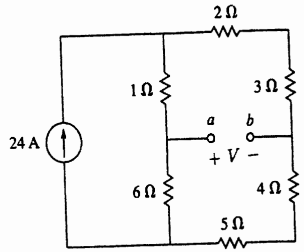


Figure 6.19

6.20: In the network of Fig 6.20, determine the value of the load to be placed across terminals *a*-*b* in order for the load to draw maximum power. Then, determine the value of this power.

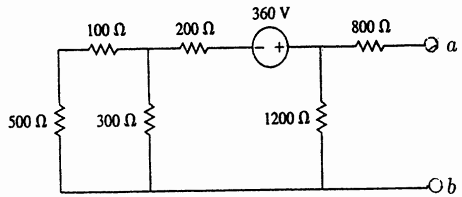


Figure 6.20

6.21: In the network of Fig 6.21, determine the value of the load to be placed across terminals *a*-*b* in order for the load to draw maximum power. Then, determine the value of this power.

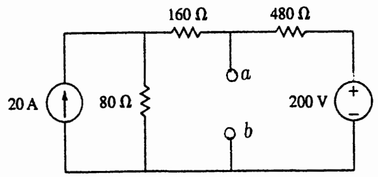


Figure 6.21

6.22: In the network of Fig 6.22, determine the value of the load to be placed across terminals a-b in order for the load to draw maximum power. Then, determine the value of this power.

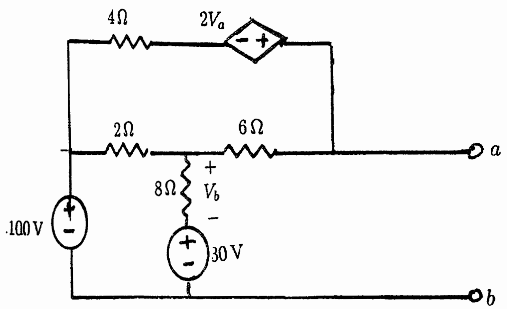


Figure 6.22

CHAPTER SEVEN

INDUCTORS, CAPACITORS AND DUALITY

INDUCTORS

7.1: Determine the voltage induced in a 250 mH inductor when the current changes at the rate of 50A/s.

7.2: Two inductors of 300 mH and 600 mH are connected in parallel. Determine the equivalent inductance.

7.3: If the current through an 80 mH inductor is

$$i = 20\sqrt{2}\sin 400t \text{ A}$$

determine the power drawn by the inductor.

7.4: The current through a 400 mH inductor is given by

$$i = 4e^{-t} - 4e^{-2t} \text{ A}$$

Determine
(a) the energy stored in the inductor at $t = 0\,s$,
(b) the energy stored in the inductor between $t = 0$ s and $t = 0.5$ s,
(c) the voltage at $t = 0.5$ s and
(d) the instantaneous power at $t = 0.5$ s

7.5: A parallel combination of two inductors ($L_1 = 1.2$ H and $L_2 = 0.60$ H) is placed in series with two more inductors ($L_3 = 1.0$ H and $L_2 = 0.80$ H). Determine the equivalent inductance.

7.6: The simple network shown in Fig 7.1 is connected to a current source at $t = 0$. The current provided by the source is $i = 4t$ A.

At $t = 5$ s, find
(a) the instantaneous power drawn by the resistor,
(b) the instantaneous power drawn by the inductor,
(c) the instantaneous power delivered by the source,

and between $0 \leq t \leq 4$ s,

(d) the energy dissipated by the resistor
(e) the energy stored by the inductor
(f) the energy delivered by the current source.

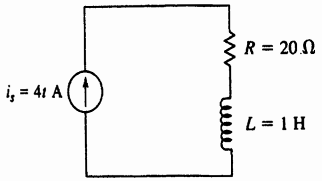


Figure 7.1

7.7: The current through a 240 mH inductor is given by $i = 4\sin 400t$ A. Determine

(a) the instantaneous power at $t = \pi/200$ s and

(b) the energy stored during the period $0 \le t \le \pi/200$ s.

7.8: If the current through a 135 mH inductor is given by $i = 8t^2 + 4t + 2$ A, how much energy is stored or removed in the inductor during the period, $0 \le t \le 1.2$ s?

7.9: In Fig 7.2, the current source is supplying 288 W at $t = 2$ s. Determine the value of R

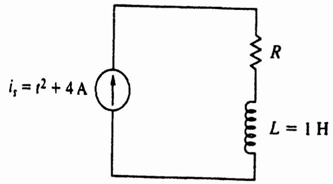


Figure 7.2

7.10: Two inductors of 0.080 H and 0.120 H are connected in parallel. If the current at a particular instant of time is 12.5 A, determine the currents in each inductor.

7.11: A pair of inductors, L_1 and L_2, are connected in parallel and the parallel combination is connected to an inductor with $L = 0.80$ H. Determine the value of L_1 and L_2 if the equivalent inductance for the combination is $L_{eq} = 1.60$ H and $L_1 = 4L_2$.

7.12: The current through a 400 mH inductor, over a period of 8 s, is described by the waveform

$$i = \begin{cases} 2t^2\text{ A}; & 0 < t < 2\text{ s} \\ 8\text{ A}; & 2\text{ s} < t < 4\text{ s} \\ 40 - 8t\text{ A}; & 4\text{ s} < t < 8\text{ s} \end{cases}$$

Determine the voltage across the inductor and sketch the waveform.

CAPACITORS

7.13: Determine the current through and the charge on a 50 μF capacitor subjected to a voltage of

$$v = 120\sin 250t \text{ V}$$

7.14: An 80 μF capacitor is charged so that it stores 0.40 J. If an uncharged 120 μF capacitor is hooked up across the terminals of the 80 μF capacitor, determine the final energy in the system.

7.15: If an 80 μF capacitor is charged to 600 μC and then connected across the terminals of an uncharged 160 μF capacitor, determine the charge transferred from the 80 μF capacitor to the 160 μF capacitor.

7.16: Two capacitors of 100 μF and 400 μF are connected in series. Determine the equivalent capacitance.

7.17: If the voltage across a 200 μF capacitor is

$$v = 120\sin 400t \text{ V}$$

determine the power provided to the capacitor.

7.18: A parallel combination of two capacitors ($C_1 = 80\,\mu$F and $C_2 = 120\,\mu$F) is placed in parallel with a series combination of two more capacitors ($C_3 = 40\,\mu$F and $C_4 = 160\,\mu$F). Determine the equivalent capacitance.

7.19: The simple network shown in Fig 7.3 is connected to a voltage source at $t = 0$. The voltage provided by the source is $v = 2t + 8$ V. At $t = 4$ s, find

(a) the instantaneous power drawn by the resistor,

(b) the instantaneous power drawn by the capacitor,

(c) the instantaneous power delivered by the source,

and between $0 \le t \le 4$ s,

(d) the energy dissipated by the resistor

(e) the energy stored by the capacitor

(f) the energy delivered by the current source.

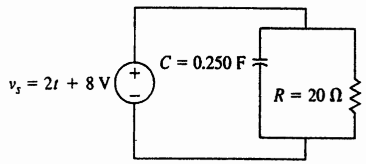


Figure 7.3

7.20: The voltage across a $40\,\mu$F capacitor is given by $v = 4e^{-t} - 2^{-2t}$ V. Determine how much energy will be stored or removed during the period $0 \le t \le 2$ s.

7.21: How much energy is stored in an initially uncharged $125\,\mu$F capacitor between 0 and 8 s when a voltage of $18e^{-t/10}$ V is placed across its terminals.

7.22: Each pair of two pairs of capacitors are connected in parallel. The first pair has $C_1 = 60\,\mu$F and $C_2 = 30\,\mu$F and the second pair has $C_3 = 120\,\mu$F with C_4 unknown. The two pairs of capacitors are connected in series and if the equivalent capacitance of the entire arrangement is $C_{eq} = 60\,\mu$F, determine the value of the unknown capacitor, C.

7.23: A $100\,\mu$F capacitor is connected in series to a $300\,\mu$F capacitor. At a certain instant of time, the total voltage across the two capacitors is 20 V. Determine the voltage distribution across the two capacitors.

7.24: The voltage across a 1 F capacitor during a period of 10 s is described by the waveform

$$v = \begin{cases} t\,\text{V}; & 0 < t < 2\,\text{s} \\ 3 - 0.5t\ \text{V}; & 2\,\text{s} < t < 4\,\text{s} \\ 1.5t - 5\,\text{V}; & 4\,\text{s} < t < 6\,\text{s} \\ 22 - 3t\,\text{V}; & 6\,\text{s} < t < 7\,\text{s} \\ 0.5t - 2.5\,\text{V}; & 7\,\text{s} < t < 9\,\text{s} \\ t - 7\,\text{V}; & 9\,\text{s} < t < 10\,\text{s} \end{cases}$$

Determine the current through the capacitor and sketch the waveform.

DUAL NETWORKS

7.25: Construct the dual network for the network in Fig 7.4 and then verify that the node equations for the dual network are in the same form as the mesh equations for the network in Fig 7.4.

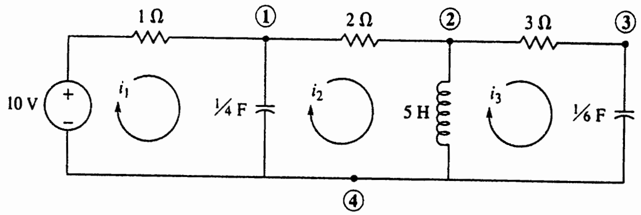


Figure 7.4

7.26: Construct the dual network for the network in Fig 7.5 and then verify that the node equations for the dual network are in the same form as the mesh equations for the network in Fig 7.5

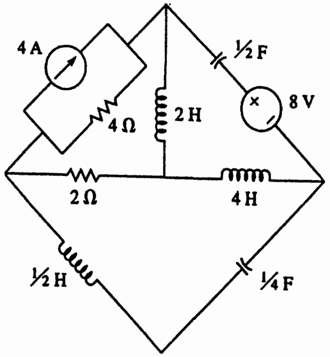


Figure 7.5

7.27: Construct the dual network for the network in Fig 7.6 and then verify that the node equations for the dual network are in the same form as the mesh equations for the network in Fig 7.6.

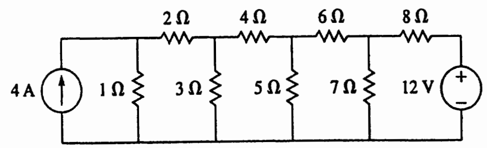


Figure 7.6

7.28: Construct the dual network for the network in Fig 7.7 and then verify that the node equations for the dual network are in the same form as the mesh equations for the network in Fig 7.7.

7.28: Construct the dual network for the network in Fig 7.7 and then verify that the node equations for the dual network are in the same form as the mesh equations for the network in Fig 7.7.

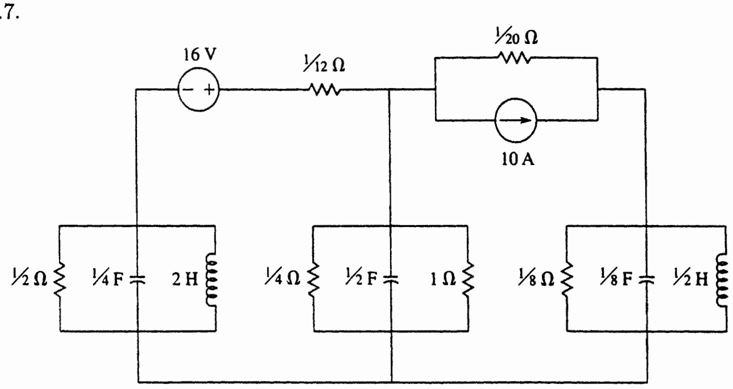


Figure 7.7

CHAPTER EIGHT

FIRST ORDER *RL* AND *RC* CIRCUITS

THE EXPONENTIAL FUNCTION

8.1: Measurements of the exponentially decaying charge on a sphere provide the following data:

Time, ms	Charge, μC
0.40	170.429
0.425	168.733

Determine the initial value of the charge, the time constant and the charge at $t = 0.625$ ms.

8.2 Measurements of an exponentially decaying voltage provide the following data:

Time, s	Voltage, V
0.12	658.574
0.15	566.840

Determine the initial value of the voltage, the time constant and the voltage at $t = 32.5$ ms.

8.3: If an exponentially decaying current has a time constant of 100 ms and if the current has a value of 12.42 A at $t = 165$ ms, determine the value of the current at $t = 0$ and the time at which the current has a value of 4.571 A.

8.4: An exponentially decaying voltage has a time constant of 400 ms and an initial value of 1.2 kV. What is the value of the voltage at $t = 125$ ms and what is the value of the voltage five time constants later.

8.5 Measurements of an exponentially decaying current yield the following data:

Time, s	Current, A
0.250	294.30
0.275	266.30

Determine the initial value of the current and the time constant.

8.6 Measurements of an exponentially decaying voltage yield the following data:

Time, ms	Voltage, A
10	53.375
25	25.214

Determine the initial value of the voltage and the time constant.

EVALUATION OF INITIAL CONDITIONS

8.7: In Fig 8.1 the switch has been in position-a for a long period of time. At $t = 0,^+$ it moves instantaneously to position-b. Determine

$i_R(0^-)$	$i_L(0^-)$	$i_C(0^-)$	$v_C(0^-)$
$v_L(0^-)$	$i_R(0^+)$	$i_L(0^+)$	$i_C(0^+)$
$v_C(0^+)$	$v_L(0^+)$	$i'_L(0^+)$	

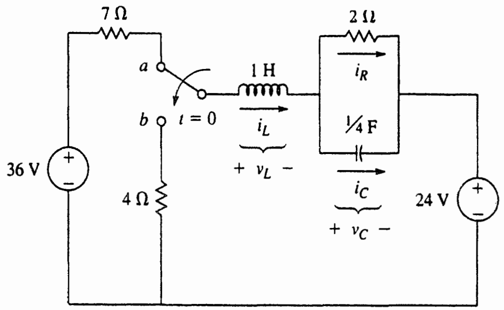


Figure 8.1

8.8: In Fig 8.2, the switch has been closed for a long period of time. At $t = 0,^+$ it opens instantaneously. Consider $t = 0^-$ and $t = 0^+$ as the instants just before and just after the switch opens and determine:

$i_{R1}(0^-)$	$i_L(0^-)$	$i_C(0^-)$	$i_{R2}(0^-)$
$v_L(0^-)$	$v_{R1}(0^-)$	$v_C(0^-)$	$v_{R2}(0^-)$
$i_{R1}(0^+)$	$i_L(0^+)$	$i_C(0^+)$	$i_{R2}(0^+)$
$v_L(0^+)$	$v_{R1}(0^+)$	$v_C(0^+)$	$v'_C(0^+)$

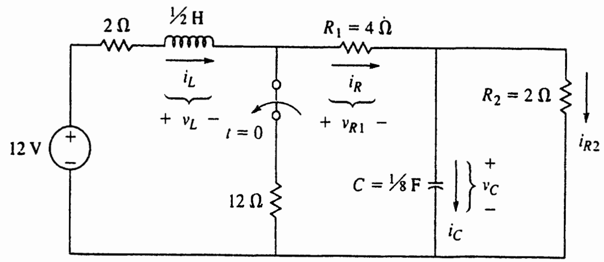


Figure 8.2

8.9: In Fig 8.3, the switch has been open for a long period of time and the voltage across the capacitor is 40 V. At $t = 0,^+$, the switch closes instantaneously. Consider $t = 0^-$ and $t = 0^+$ as the instants just before and just after the switch opens and determine:

$i_{R1}(0^+)$	$i_L(0^+)$	$i_C(0^+)$	$i_{R2}(0^+)$
$v_L(0^+)$	$v_{R1}(0^+)$	$v_C(0^+)$	$i'_L(0^+)$

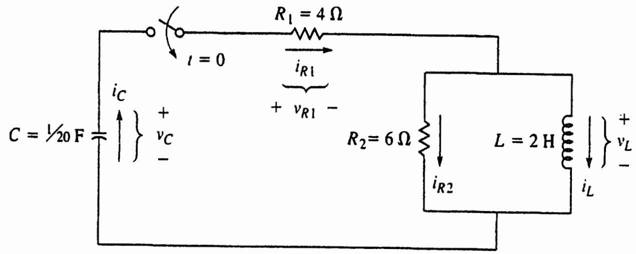


Figure 8.3

8.10: In Fig 8.4, the switch has been open for a long period of time and the voltage across the 1/100 F capacitor is 80 V. At $t = 0,^+$, the switch closes instantaneously. Consider $t = 0^-$ and $t = 0^+$ as the instants just before and just after the switch closes and determine:

$i_{R1}(0^+)$	$v_{R1}(0^+)$	$v'_C(0^+)$
$i_{R3}(0^+)$	$i_{R2}(0^+)$	$i_C(0^+)$
$v_{R3}(0^+)$	$v_{R2}(0^+)$	$v_C(0^+)$

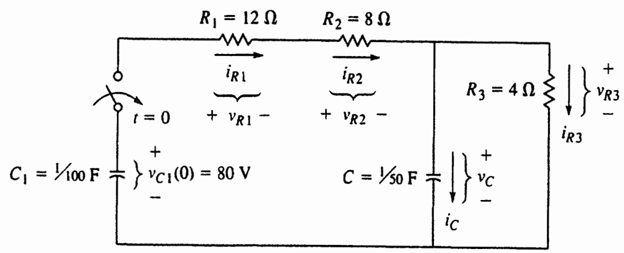


Figure 8.4

THE UNDRIVEN FIRST ORDER NETWORK

8.11: In the network of Fig 8.5, the switch opens instantaneously at $t = 0$. Determine the current response for all $t \geq 0$.

8.12: In the network of Fig 8.6, the switch opens instantaneously at $t = 0$. Determine the voltage response for all $t \geq 0$.

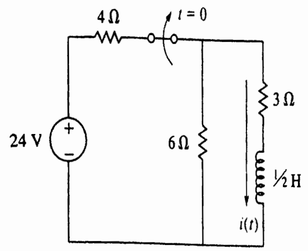


Figure 8.5

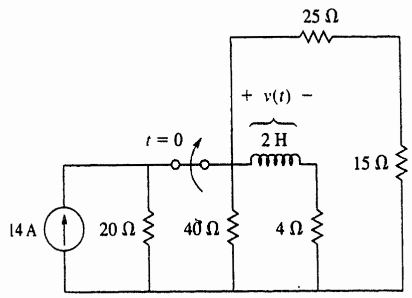


Figure 8.6

8.13: In the network of Fig 8.7, the switch opens instantaneously at $t = 0$. Determine the voltage across the $16\,\Omega$ resistor for all $t \geq 0$.

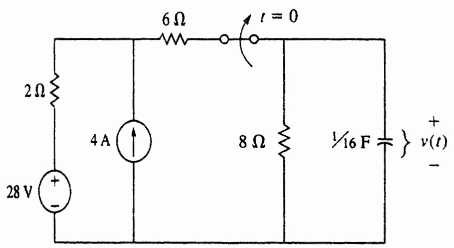


Figure 8.7

8.14: In the network of Fig 8.8, the switch opens instantaneously at $t = 0$. Determine the voltage across the $16\,\Omega$ resistor for all $t \geq 0$.

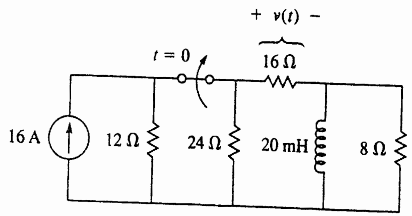


Figure 8.8

8.15: In the network of Fig 8.9, the switch moves from position-1 to position-2 instantaneously at $t = 0$. Determine the voltage response for all $t \geq 0$.

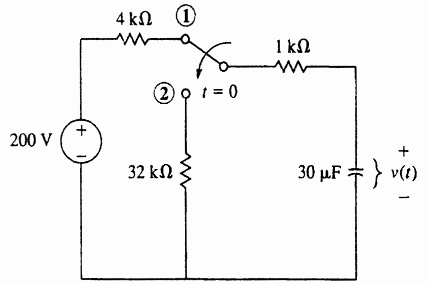


Figure 8.9

8.16: In the network of Fig 8.10, capacitor, C_1 is charged to 28 V and C_2 is uncharged. The switch closes instantaneously at $t = 0$. Determine the current $i(t)$ leaving C_1 for all $t \geq 0$.

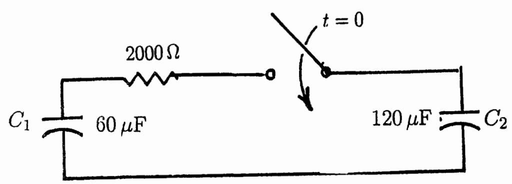


Figure 8.10

8.17: In the network of Fig 8.11, the switch closes instantaneously at $t = 0$. Determine the voltage across the capacitor for all $t \geq 0$.

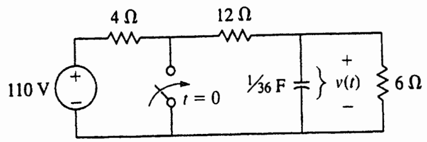


Figure 8.11

8.18: In the network of Fig 8.12, the switch closes instantaneously at $t = 0$. Determine the current through the inductor and the voltage across the $12\,\Omega$ resistor for all $t \geq 0$

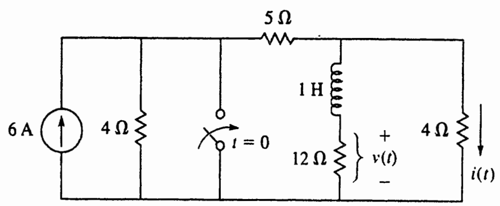


Figure 8.12

THE DRIVEN FIRST ORDER NETWORK

8.19: In the network of Fig 8.13, the switch closes instantaneously at $t = 0$. If the capacitors are initially uncharged, determine $i_1(t)$ and $i_2(t)$ for all $t \geq 0$.

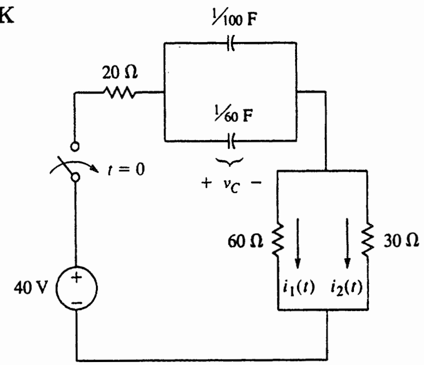


Figure 8.13

8.20: In the network of Fig 8.14, the switch closes instantaneously at $t = 0$. Determine $v_1(t)$ and $v_2(t)$ for all $t \geq 0$.

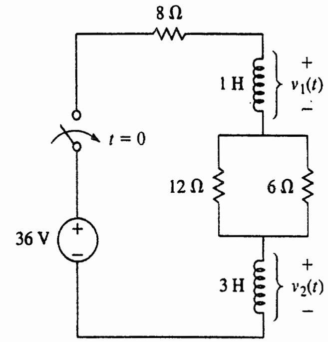


Figure 8.14

8.21: Figure 8.15 shows a network that can be used to control the current through the inductor to values between 1.10 and 1.30 A. Switch-1 (S_1) closes at $t = 0$ and Switch-2 (S_2) opens at $t = t_1$ when $i(t) = 1.3$ A. Switch-2 then remains open until $t = t_2$ when $i(t) = 1.1$ A at which time it closes and remains closed until $t = t_3$ when, once again, $i(t) = 1.3$ A. Determine the times, t_1, t_2 and t_3 and the steady-operation ratio of switch-2 *open time* to *closed time*.

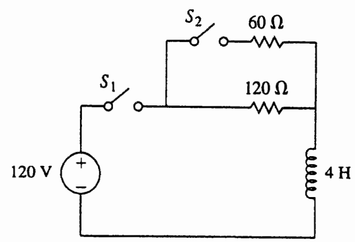


Figure 8.15

8.22: The purpose of the network in Fig 8.16 is to use switch-1 and R_1 to permit the capacitor to charge during a specified time interval and to use switch-2 and R_2 to hold the charge at the specified level. Select a value for R_1 to make the capacitor charge to 16 V in 20 ms and then select the value of R_2 to hold the capacitor voltage to 16 V.

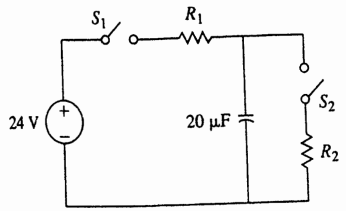


Figure 8.16

8.23: In the network of Fig 8.17, both switches close instantaneously at $t = 0$. Determine the voltage across the capacitor for all $t \geq 0$.

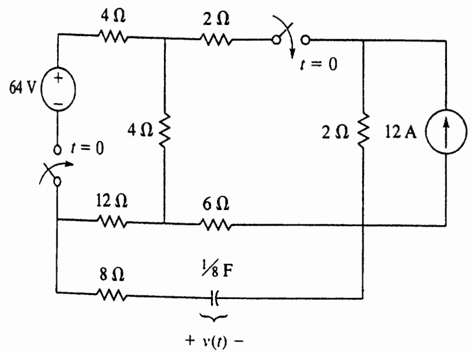


Figure 8.17

8.24: In the network of Fig 8.18, the switch moves instantaneously from position-1 to position-2 at $t = 0$. Determine the voltage across the inductor for all $t \geq 0$

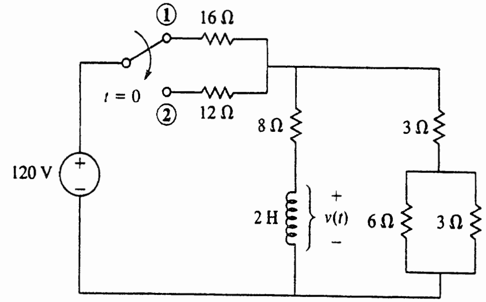


Figure 8.18

8.25: In the network of Fig 8.19, the switch closes instantaneously at $t = 0$. Determine the current through the inductor for all $t \geq 0$.

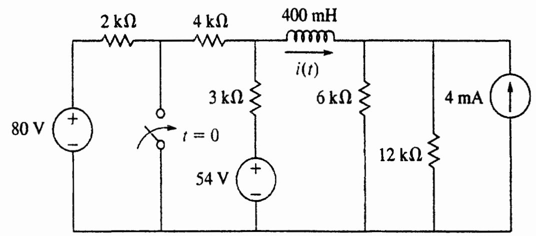


Figure 8.19

THE DRIVEN FIRST ORDER NETWORK - ALTERNATE SOLUTIONS

8.26: Provide an alternate solution to Problem 8.19 that is based on initial and final values of the response and the time constant.

8.27: Provide an alternate solution to Problem 8.20 that is based on initial and final values of the response and the time constant.

8.28: Provide an alternate solution to Problem 8.23 that is based on initial and final values of the response and the time constant.

8.29: Provide an alternate solution to Problem 8.24 that is based on initial and final values of the response and the time constant.

8.30: Provide an alternate solution to Problem 8.25 that is based on initial and final values of the response and the time constant.

OPERATIONAL AMPLIFIERS

8.31: In the ideal operational amplifier configuration shown in Fig 8.20, determine the value of the capacitor if the input voltage is $-12u(t)$, the initial charge on the capacitor is 0 V and the output voltage is required to be $48r(t)$.

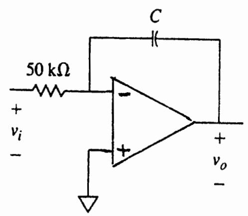


Figure 8.20

8.32: In the ideal operational amplifier configuration shown in Fig 8.21, the initial voltage across each capacitor is zero. If the input voltage, v_1, is a 4 V step. determine the output voltage v_o.

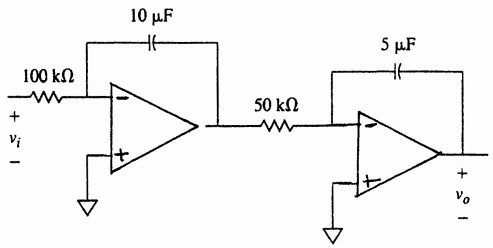


Figure 8.21

8.33: In the ideal operational amplifier configuration shown in Fig 8.22, the initial voltage across each capacitor is zero. If the input voltage, $v_{s1} = 12 \sin 400t$ V and $v_{s2} = 12 \sin 400t$ V, determine the output voltage v_o.

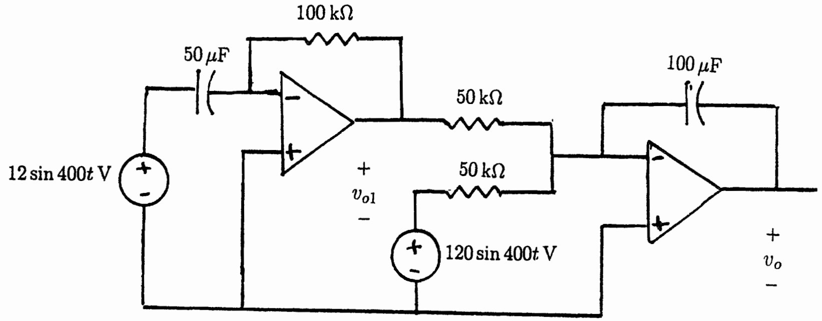


Figure 8.22

8.34: The set of simultaneous differential equations

$$\frac{dv_1}{dt} + 5v_1 - 2v_2 = 18$$

and

$$-2v_1 + 2\frac{dv_2}{dt} + 2v_2 = 0$$

is to be programmed for an analog computer. Draw a circuit diagram using ideal operational amplifiers and specifying values for all R's and C's and considering no initial voltages on any of the capacitors to accomplish this program.

8.35: The differential equation

$$\frac{d^2i}{dt^2} + 10\frac{di}{dt} + 16i = 40t$$

is to be programmed for an analog computer. Draw a circuit diagram using ideal operational amplifiers and specifying values for all R's and C's, a separate function generator for the $40t$ input and considering no initial voltages on any of the capacitors to accomplish this program.

CHAPTER NINE

SECOND ORDER RL AND RC CIRCUITS

THE SINUSOID

9.1: A sinusoidal voltage that has a frequency of 80 Hz and an amplitude of 120 V passes through 0 V with a positive slope at $t = 0.80$ ms. Find V, ω and ϕ in

$$v(t) = V\cos(\omega t + \phi)$$

9.2 A sinusoidal current has a period of $40\mu s$ and passes through a maximum of 40 ma at $t = 4\mu$s. Find I, ω and ϕ in

$$i(t) = I\cos(\omega t + \phi)$$

9.3: A sinusoidally varying charge reaches a maximum of $20\,\mu$C at $t = 8$ ms and the next negative maximum of at $t = 16$ ms. Find Q, ω and ϕ in

$$q(t) = Q\cos(\omega t + \phi)$$

9.4: A sinusoidally varying voltage has a positive maximum of 208 V at $t = 0$ and decreases to a value of 120 V at $t = 0.125$ ms. Find V, ω and ϕ in

$$v(t) = V\cos(\omega t + \phi)\,\mathrm{V}$$

9.5 Determine the frequency and the period of a sinusoidally varying voltage that has a value of 60 V at $t = 0$ and reaches its first maximum of 120 V at $t = 2.5$ ms.

9.6 A sinusoidally varying current passes through a negative maximum of 20 mA at $t = 2$ ms and then passes through the next positive maximum at $t = 12$ ms. Find I, ω and ϕ in

$$i(t) = I\cos(\omega t + \phi)\,\mathrm{V}$$

FORMS OF RESPONSE

9.7: The current in an RLC series network is governed by the differential equation

$$L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = 0$$

If $R = 4\,\Omega$ and $C = 1/40$ F, determine the value of L to make the response critically damped?

9.8: The current in an RLC series network is governed by the differential equation

$$L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = 0$$

If $R = 8\,\Omega$ and $C = 1/100\,\text{F}$, determine the value of L to make the response underdamped with a damped natural frequency of $6\,\text{rad/s}$. Then, determine the natural frequency and the damping factor.

9.9: The voltage in an RLC parallel network is governed by the differential equation

$$C\frac{d^2v}{dt^2} + \frac{1}{R}\frac{dv}{dt} + \frac{1}{L}v = 0$$

If $R = 4\,\Omega$ and $L = 1/8\,\text{H}$, determine the value of C to make the response overdamped with a damping factor of 2.0.

9.10: The voltage in an RLC parallel network is governed by the differential equation

$$C\frac{d^2v}{dt^2} + \frac{1}{R}\frac{dv}{dt} + \frac{1}{L}v = 0$$

If $R = 4\,\Omega$ and $L = 70.82\,\text{mH}$, determine the value of C required to yield a damped natural frequency of $36\,\text{rad/s}$. What is the damping factor?

9.11: The voltage in the network shown in Fig 9.1 is governed by the differential equation

$$C\frac{d^2v}{dt^2} + \frac{1}{R}\frac{dv}{dt} + \frac{1}{L}v = 0$$

Determine the value of R to make the response overdamped with a damping factor of $\zeta = 2.50$.

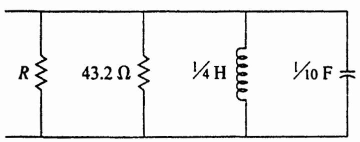


Figure 9.1

9.12: The current in the network shown in Fig 9.2 is governed by the differential equation

$$L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = 0$$

Determine the value of C to make the response critically damped.

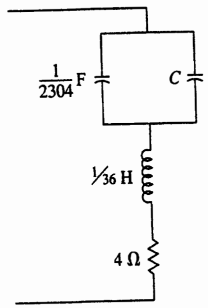


Figure 9.2

UNDRIVEN SECOND ORDER NETWORKS

9.13: In the network of Fig 9.3, the switch closes instantaneously at $t = 0$. Find the current response for $t \geq 0$.

9.14: In the network of Fig 9.4, the switch opens instantaneously at $t = 0$. Find the voltage response for $t \geq 0$.

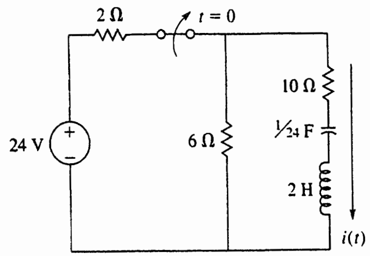


Figure 9.3

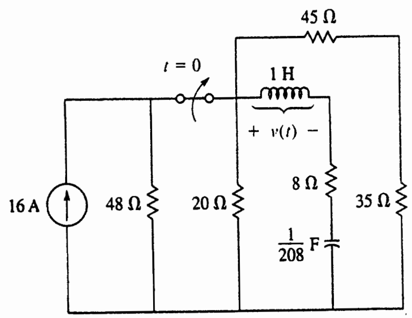


Figure 9.4

9.15: In the network of Fig 9.5, the switch moves instantaneously from position-1 to position-2 at $t = 0$. Find the voltage response for $t \geq 0$.

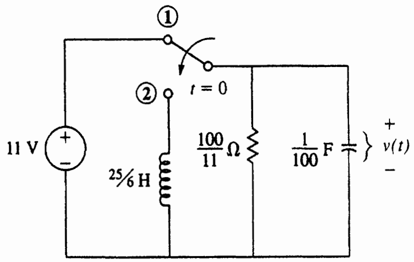


Figure 9.5

9.16: In the network of Fig 9.6, the switch opens instantaneously at $t = 0$. Find the current response for $t \geq 0$.

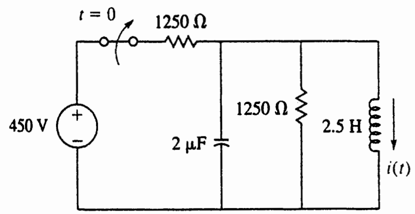


Figure 9.6

9.17: In the network of Fig 9.7 the switch goes from position-1 to position-2 instantaneously at $t = 0$. Determine the voltage across the capacitor for $t \geq 0$ if the capacitor is initially uncharged.

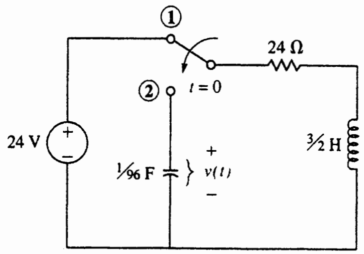


Figure 9.7

9.18: In the network of Fig 9.8 the switch goes from position-1 to position-2 instantaneously at $t = 0$. Determine the voltage across the capacitor for $t \geq 0$ if the capacitor is initially uncharged.

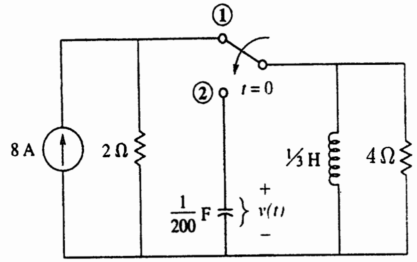


Figure 9.8

DRIVEN SECOND ORDER NETWORKS

9.19: In Fig 9.9, the current is applied to the network instantaneously at $t = 0$ when the voltage across the capacitor is 16 V and no current is flowing in the network. With $R = 4/5\,\Omega$, $L = 1/3\,\text{H}$, $C = 1/8\,\text{F}$ and $i_s = 6\,\text{A}$, determine $v(t)$ for all $t \geq 0$.

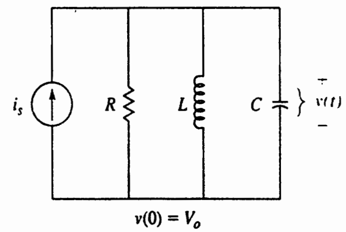


Figure 9.9

9.20: In Fig 9.10, the voltage is applied to the network instantaneously at $t = 0$ when there is no current flowing in the network. With the voltage across the capacitor at 2 V, $R = 2\,\Omega$, $L = 1\,\text{H}$, $C = 1/5\,\text{F}$ and $v_s = 20\,\text{V}$, determine $i(t)$ for all $t \geq 0$.

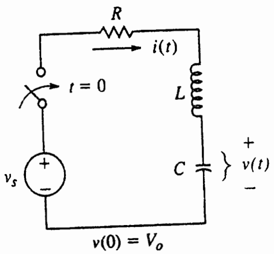


Figure 9.10

9.21: In Fig 9.9, the current is applied to the network instantaneously at $t = 0$ when the voltage across the capacitor is 12 V and no current is flowing in the network. With $R = 5/8\,\Omega, L = 1/5\,\text{H}$, $C = 1/5\,\text{F}$ and $i_s = 20\,\text{A}$, determine $v(t)$ for all $t \geq 0$.

9.22: In Fig 9.10, the voltage is applied to the network instantaneously at $t = 0$ when there is no current flowing in the network. With the voltage across the capacitor at 8 V, $R = 2\,\Omega, L= 1/2\,\text{H}$, $C = 1/2\,\text{F}$ and $v_s = 12\,\text{V}$, determine $i(t)$ for all $t \geq 0$.

9.23: In Fig 9.9, the current is applied to the network instantaneously at $t = 0$ when the voltage across the capacitor is 8 V and no current is flowing in the network. With $R = 1\,\Omega, L = 1\,\text{H}$, $C = 1/4\,\text{F}$ and $i_s = 36\,\text{A}$, determine $v(t)$ for all $t \geq 0$.

9.24: In Fig 9.10, the voltage is applied to the network instantaneously at $t = 0$ when there is no current flowing in the network. With the voltage across the capacitor at 48 V, $R = 7\,\Omega, L= 1\,\text{H}$, $C = 1/12\,\text{F}$ and $v_s = 24\,\text{V}$, determine $i(t)$ for all $t \geq 0$.

CHAPTER TEN

SINUSOIDAL STEADY STATE ANALYSIS BY PHASOR METHODS

COMPLEX NUMBER ALGEBRA

10.1: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = N_1 + N_2 + N_3$$

10.2: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = \frac{N_1 N_2}{N_3}$$

10.3: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = (N_1 - N_2)^2 N_3$$

10.4: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = 3N_1 N_2 N_3$$

10.5: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = \frac{N_1}{N_2} + \frac{N_1}{N_3}$$

10.6: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = (\sqrt{N_1 N_2} - N_3)(N_1)$$

10.7: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = \frac{N_1 + N_2}{N_1 - N_2}$$

10.8: If $N_1 = 4 - \jmath 3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = (N_1 + N_2 + N_3)(N_1 N_2 N_3)^2$$

10.9: If $N_1 = 4 - j3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = N_1^3 + N_2^2 + N_3$$

10.10: If $N_1 = 4 - j3, N_2 = 2\sqrt{2}\underline{/45^\circ}$ and $N_3 = 5e^{90^\circ}$, determine

$$N = N_1N_2 + N_2N_3 + N_1N_3$$

IMPEDANCE AND ADMITTANCE

10.11: If $\omega = 400\,\text{rad/s}$, find the driving point impedance at terminal-a and -b in the network of Fig 10.1.

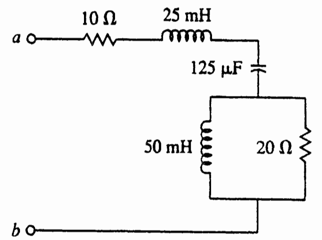


Figure 10.1

10.12: If $\omega = 200\,\text{rad/s}$, find the driving point impedance at terminal-a and -b in the network of Fig 10.2.

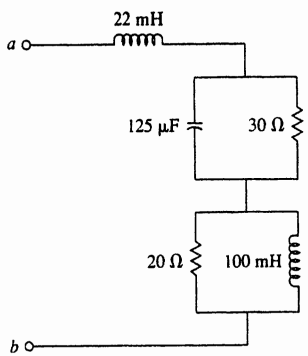


Figure 10.2

10.13: If $\omega = 100\,\text{rad/s}$, find the driving point admittance at terminal-a and -b in the network of Fig 10.3.

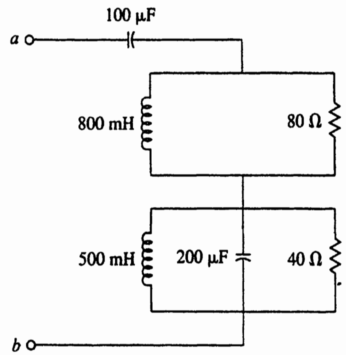


Figure 10.3

10.14: If $\omega = 500\,\text{rad/s}$, find the driving point admittance at terminal-a and -b in the network of Fig 10.4.

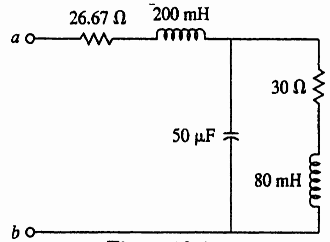


Figure 10.4

10.15: If $\omega = 1000\,\text{rad/s}$, find the driving point admittance at terminal-a and -b in the network of Fig 10.5.

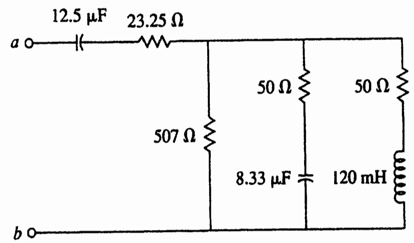


Figure 10.5

PHASORS

10.16: If, in the form

$$f(t) = A\cos\omega t + B\sin\omega t$$

$$A = -4 \quad \text{and} \quad B = 4$$

determine F and ϕ in

$$f(t) = F\cos(\omega t + \phi)$$

10.17: If, in the form

$$f(t) = A\cos\omega t + B\sin\omega t$$

$$A = -64 \quad \text{and} \quad B = 120$$

determine F and ϕ in

$$f(t) = F\cos(\omega t + \phi)$$

10.18: If, in the form

$$f(t) = A\cos\omega t + B\sin\omega t$$

$$A = -60 \quad \text{and} \quad B = -45$$

determine F and ϕ in

$$f(t) = F\cos(\omega t + \phi)$$

10.19: If, in the form

$$f(t) = A\cos\omega t + B\sin\omega t$$

$$A = -70 \quad \text{and} \quad B = -168$$

determine F and ϕ in

$$f(t) = F\cos(\omega t + \phi)$$

10.20: If, in the form

$$f(t) = A\cos\omega t + B\sin\omega t$$

$$A = 28 \quad \text{and} \quad B = -96$$

determine F and ϕ in

$$f(t) = F\cos(\omega t + \phi)$$

10.21: If $F = 275$ and $\phi = -143.13°$ in the instantaneous form

$$f(t) = F\cos(\omega t + \phi)$$

determine A and B in

$$f(t) = A\cos\omega t + B\sin\omega t$$

10.22: If $F = 390$ and $\phi = 112.62°$ in the instantaneous form

$$f(t) = F\cos(\omega t + \phi)$$

determine A and B in

$$f(t) = A\cos\omega t + B\sin\omega t \Leftarrow$$

10.23: If $F = 800$ and $\phi = -196.26°$ in the instantaneous form

$$f(t) = F\cos(\omega t + \phi)$$

determine A and B in

$$f(t) = A\cos\omega t + B\sin\omega t \Leftarrow$$

10.24: If $F = 120$ and $\phi = -150°$ in the instantaneous form

$$f(t) = F\cos(\omega t + \phi)$$

determine A and B in

$$f(t) = A\cos\omega t + B\sin\omega t \Leftarrow$$

10.25: If $F = 1000$ and $\phi = -135°$ in the instantaneous form

$$f(t) = F\cos(\omega t + \phi)$$

determine A and B in

$$f(t) = A\cos\omega t + B\sin\omega t \Leftarrow$$

10.26: If a voltage is given by

$$v(t) = 208\cos(377t + 60°)$$

determine the voltage phasor in rectangular, polar and exponential form.

10.27: If a current is given by

$$i(t) = 4\sqrt{2}\cos(400t - 135°)$$

determine the current phasor in rectangular, polar and exponential form.

10.28: If a current is given by

$$i(t) = 120\sqrt{3}\cos(600t + 15°)$$

determine the current phasor in rectangular, polar and exponential form.

10.29: If a voltage is given by

$$v(t) = 1750\cos(200t - 163.74^\circ)$$

determine the voltage phasor in rectangular, polar and exponential form.

10.30: If a voltage is given by

$$v(t) = 400\cos(1200t + 90^\circ)$$

determine the voltage phasor in rectangular, polar and exponential form.

10.31: Two elements are connected in parallel as indicated in Fig 10.6. The line current is $i(t) = 10\sqrt{2}\cos(377t + 135)^\circ$ A and $i_1(t) = 6\cos(377t + 30)^\circ$ Express $i_2(t)$ instantaneous form.

10.32: Three elements are connected in series as indicated in Fig 10.7. The line voltage is $v(t) = 120\cos(377t + 90)^\circ$ V, $v_1(t) = 40\sqrt{2}\cos(377t + 45)^\circ$ V and $v_3(t) = 60\cos(377t - 53.13)^\circ$ V. Express $v_2(t)$ instantaneous form.

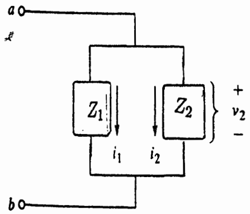


Figure 10.6

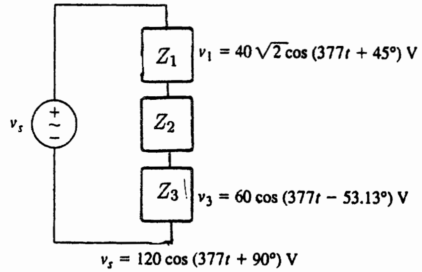


Figure 10.7

10.33: In Fig 10.8, $\mathbf{I}_1 = 2\sqrt{2}\underline{/45^\circ}$ and $\mathbf{V}_2 = 120\underline{/53.13^\circ}$ V. If the line current is $i = 4\cos(\omega t + 90^\circ)$ A and the frequency is $f = 250/2\pi$ Hz, Determine the four components that comprise the parallel combination.

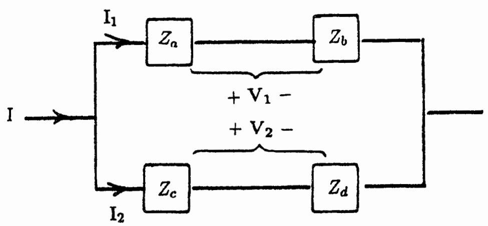


Figure 10.8

10.34: In Fig 10.9, $i_s(t) = 8\cos(400t + 90^\circ)$ A, $v_{s1}(t) = 200\cos(400t + 36.87^\circ)$ V and $v_{s2}(t) = 200\sqrt{2}\cos(400t + 135^\circ)$ A. Combine the three sources to a single voltage source connected across terminals a-b.

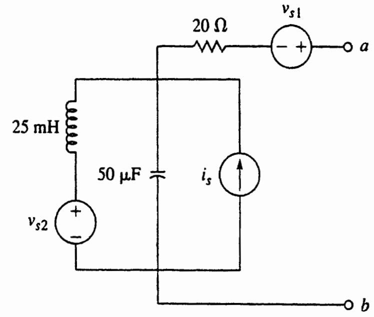


Figure 10.9

LADDER NETWORKS AND PHASOR DIAGRAMS

10.35: Determine all branch currents and branch voltages in the network of Fig 10.10 and then draw a phasor diagram.

10.36: Determine all branch currents and branch voltages in the network of Fig 10.11 and then draw a phasor diagram.

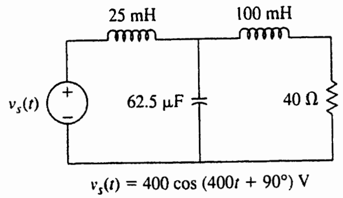


Figure 10.10

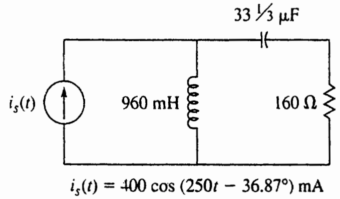
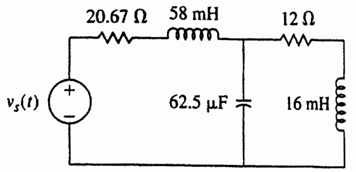


Figure 10.11

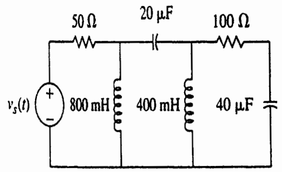
10.37: Determine all branch currents and branch voltages in the network of Fig 10.12 and then draw a phasor diagram.

10.38: Determine all branch currents and branch voltages in the network of Fig 10.13 and then draw a phasor diagram.



$v_s(t) = 336\sqrt{2}\cos(1000t + 135°)$ V

Figure 10.12



$v_s(t) = 500\sqrt{2}\cos(250t + 45°)$ V

Figure 10.13

NETWORK ANALYSIS

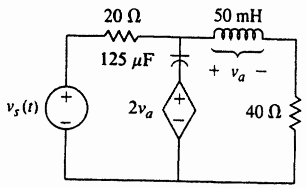
10.39: Rework Problem 10.35 (Fig 10.10) using a nodal analysis to determine the current through the 25 mH inductor and the voltage across the 62.5 μF capacitor.

10.40: Rework Problem 10.36 (Fig 10.11) using a nodal analysis to determine the current through the 960 mH inductor and the voltage across the 160 Ω resistor.

10.41: Rework Problem 10.38 (Fig 10.13) using a nodal analysis to determine the current through the 800 mH inductor and the voltage across the 40 μF capacitor.

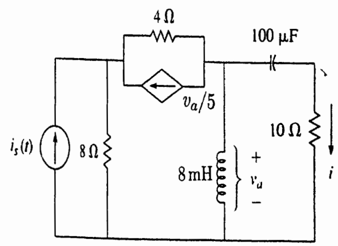
10.42: Use nodal analysis to find the current through the 50 mH inductor and the voltage across the 40 Ω resistor in Fig 10.14.

10.43: Use nodal analysis to find the current through the 10 Ω resistor in Fig 10.15.



$v_s(t) = 400\cos(400t + 90°)$ V

Figure 10.14



$i_s(t) = 4\cos 2000t$ A

Figure 10.15

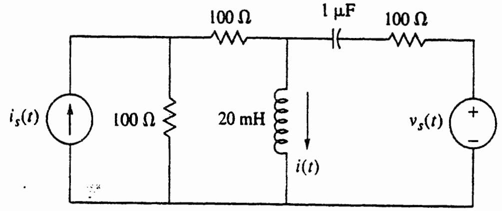
10.44: Rework Problem 10.35 (Fig 10.10) using a mesh analysis to determine the current through the 25 mH inductor and the voltage across the 62.5 μF capacitor.

10.45: Rework Problem 10.36 (Fig 10.11) using a mesh analysis to determine the current through the 960 mH inductor and the voltage across the 160 Ω resistor.

10.46: Rework Problem 10.42 (Fig 10.14) using a mesh analysis to find the current through the 50 mH inductor and the voltage across the 40 Ω resistor.

10.47: Rework Problem 10.43 (Fig 10.15) using mesh analysis to find the current through the 10 Ω resistor in Fig 10.15.

10.48: Use mesh analysis to determine the current through the 20 mH inductor in Fig 10.16.



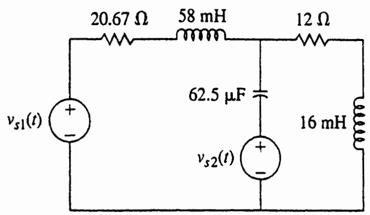
$v_s(t) = 400\sqrt{2}\cos(10{,}000t + 45°)$ V
$i_s(t) = 8\cos(10{,}000t + 0°)$ A

Figure 10.16

10.49: Rework Problem 10.48 (Fig 10.16) using superposition to determine the current through the 20 mH inductor.

10.50: Use superposition to determine the voltage across the 58 mH inductor in Fig 10.17.

10.51: Use superposition to determine the voltage across the 50 μF capacitor in Fig 10.18.



$v_{s1}(t) = 336\sqrt{2}\cos(1000t + 135°)$ V
$v_{s2}(t) = 260\cos(1000t + 67.38°)$ V

Figure 10.17

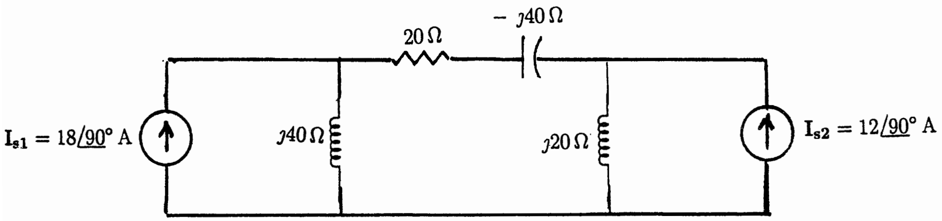
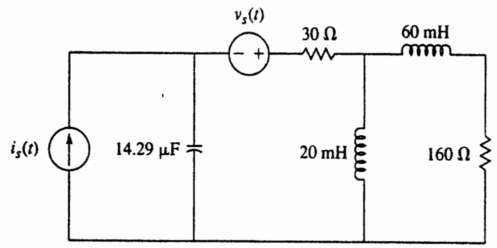


Figure 10.18

10.52: Use superposition to determine the current through the 20 mH inductor in Fig 10.19.



$v_{s(t)} = 210\cos(2000t + 90°)$ V

$i_{s(t)} = 16\cos(2000t + 0°)$ mA

Figure 10.19

10.53: Rework Problem 10.35 (Fig 10.10) using Thevenin's theorem to determine the current through the 40 Ω resistor.

10.54: Rework Problem 10.51 (Fig 10.18) using Thevenin's theorem to determine the current through the 50 μF capacitor.

10.55: Rework Problem 10.43 (Fig 10.15) using Thevenin's theorem to determine the current through the 10 Ω resistor.

10.56: Rework Problem 10.37 (Fig 10.12) using Thevenin's theorem to determine the current through the 16 mH inductor.

10.57: Rework Problem 10.38 (Fig 10.13) using Thevenin's theorem to determine the current through the 40 μF capacitor.

CHAPTER ELEVEN

SINUSOIDAL STEADY STATE POWER CALCULATIONS

AVERAGE AND EFFECTIVE VALUES

11.1: If the period, $T = 10$ s, determine the average and effective values for the voltage wave shown in Fig 11.1.

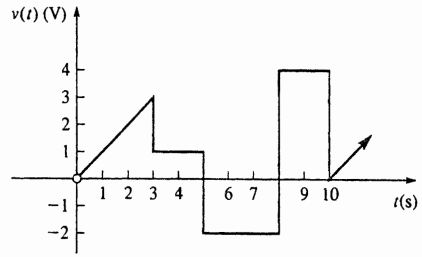


Figure 11.1

11.2: If the period, $T = 10$ s, determine the average and effective values for the current wave shown in Fig 11.2.

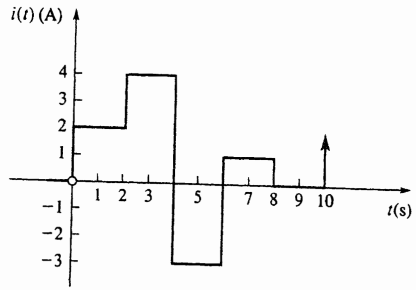


Figure 11.2

11.3: If the period, $T = 10\,\text{s}$, determine the average and effective values for the voltage wave shown in Fig 11.3.

11.4: If the period, $T = 10\,\text{s}$, determine the average and effective values for the current wave shown in Fig 11.4.

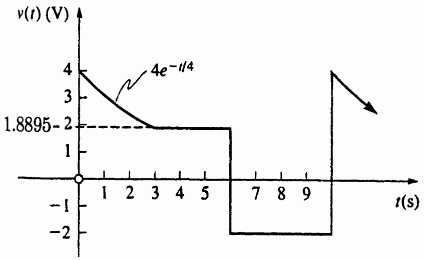


Figure 11.3

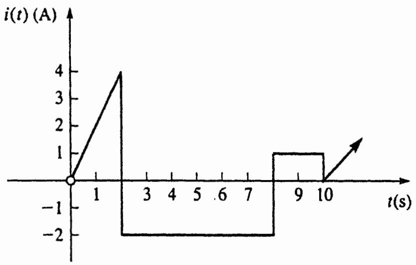


Figure 11.4

11.5: If the period, $T = 40\,\text{ms}$, determine the average and effective values for the voltage wave shown in Fig 11.5.

11.6: If the period, $T = 6\,\text{s}$, determine the average and effective values for the voltage wave shown in Fig 11.6.

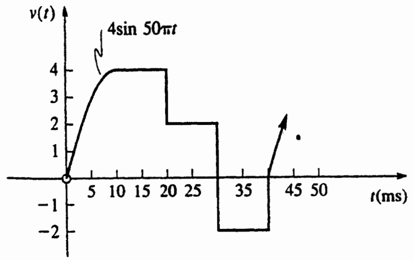


Figure 11.5

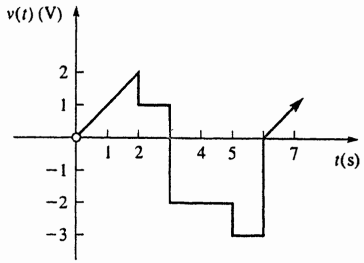


Figure 11.6

SINUSOIDAL STEADY STATE

11.7: Determine the average power and the power factor for an *RLC* series network operating at 400 Hz with $R = 100\,\Omega, L = 39.79\,\text{mH}$ and $C = 15.92\,\mu\text{F}$ if the network is subjected to a sinusoidal voltage with a maximum amplitude of 180 V.

11.8: Determine the average power and the power factor for an *RLC* parallel network operating at 250 Hz with $R = 50\,\Omega, L = 50.93\,\text{mH}$ and $C = 21.22\,\mu\text{F}$ if the network is subjected to a sinusoidal current with a maximum amplitude of 16 A.

11.9 Two impedances, $Z_1 = 40\sqrt{2}\underline{/45^\circ}\,\Omega$ and $Z_2 = 80 - j60\,\Omega$ are connected in parallel and the combination is then connected in series with a $24\,\Omega$ resistor. If the combination is connected across a source having an rms value of 120 V, how much power is drawn and what is the power factor?

11.10: Two impedances, $Z_1 = 25\underline{/53.13^\circ}\,\Omega$ and $Z_2 = 39\underline{/67.38^\circ}\,\Omega$ are connected in parallel and the combination is then connected in series with an impedance of $17\underline{/28.07^\circ}\,\Omega$. If the combination is connected across a source having an rms value of 20 A, how much power is drawn and what is the power factor?

11.11: An *RLC* series network is subjected to an rms voltage of

$$v(t) = 200\cos 400t\ \text{V}$$

An impedance meter has measured the impedance angle as 36.87°. If, $R = 40\,\Omega, L = 387.5\,\text{mH}$ and the power dissipated is 640 W, determine the value of C.

11.12: A series *RC* circuit absorbs 22.15 W at a power factor of 0.9231 when it is connected to an rms voltage source of

$$v(t) = 120\cos 400t\ \text{V}$$

Determine the values of R and C.

11.13: Determine the total power dissipated by all of the resistors in the phasor domain network of Fig 11.7.

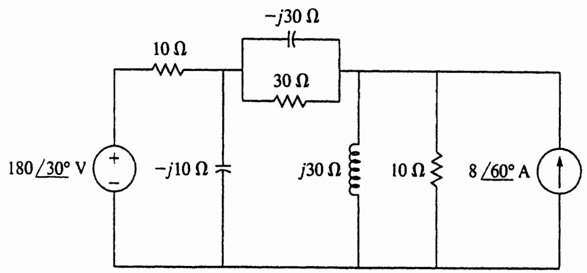


Figure 11.7

11.14: Determine the complex power delivered to the phasor domain network in Fig 11.8.

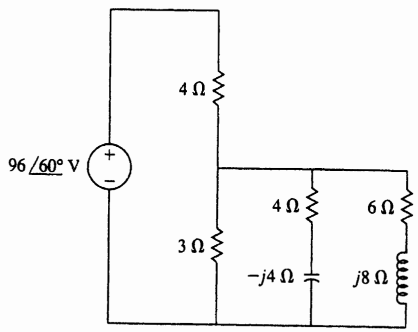


Figure 11.8

11.15: Determine the complex power delivered to the network in Fig 11.9.

11.16: Determine the complex power delivered to the network in Fig 11.10.

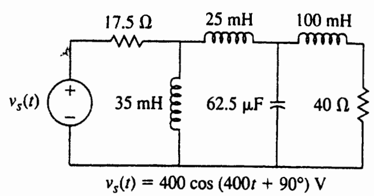


Figure 11.9

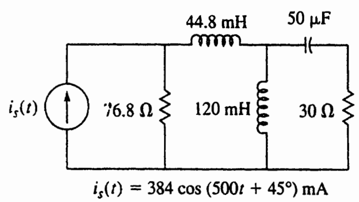


Figure 11.10

11.17: Determine the complex power delivered to the network in Fig 11.11.

11.18: For the phasor domain network shown in Fig 11.12, Determine the real power, the apparent power, the magnitude of the apparent power and the power factor.

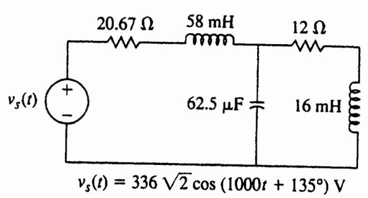


Figure 11.11

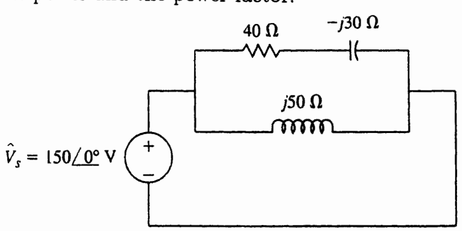


Figure 11.12

POWER FACTOR CORRECTION

11.19: In the power distribution system shown in Fig 11.13, the frequency is 60 Hz. Determine:

(a) The real power
(b) The reactive power
(c) The magnitude of the apparent power
(d) The power factor
(e) The correction necessary to make the power factor 0.950
(f) the component necessary to achieve the correction in part (e)

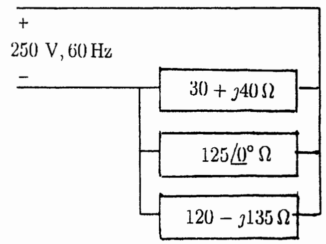


Figure 11.13

11.20: In the power distribution system shown in Fig 11.14, the frequency is 60 Hz. Determine:

(a) The real power
(b) The reactive power
(c) The magnitude of the apparent power
(d) The power factor
(e) The correction necessary to make the power factor 0.935
(f) the component necessary to achieve the correction in part (e)

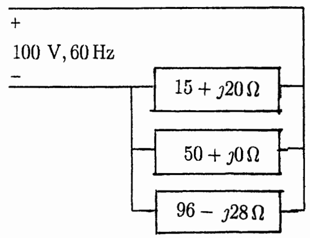


Figure 11.14

11.21: In the power distribution system shown in Fig 11.15, the frequency is 60 Hz. Determine:

(a) The real power
(b) The reactive power
(c) The magnitude of the apparent power
(d) The power factor
(e) The correction necessary to make the power factor 0.920
(f) the component necessary to achieve the correction in part (e)

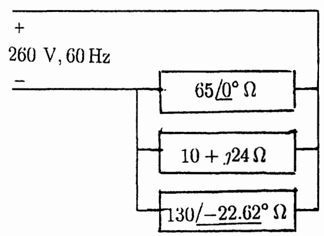


Figure 11.15

11.22: In the power distribution system shown in Fig 11.16, the frequency is 100 Hz. Determine:

(a) The real power
(b) The reactive power
(c) The magnitude of the apparent power
(d) The power factor
(e) The correction necessary to make the power factor 0.945
(f) the component necessary to achieve the correction in part (e)

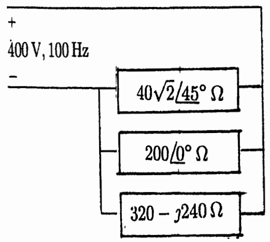


Figure 11.16

MAXIMUM POWER TRANSFER

11.23: In the network of Fig 11.17, determine what elements should be placed across the terminals a-b to make the power factor unity.

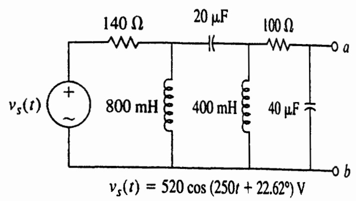


Figure 11.17

11.24: In the phasor domain network of Fig 11.18, determine the load to be placed across terminals a-b to make the power drawn by the load a maximum and then determine the value of this maximum power.

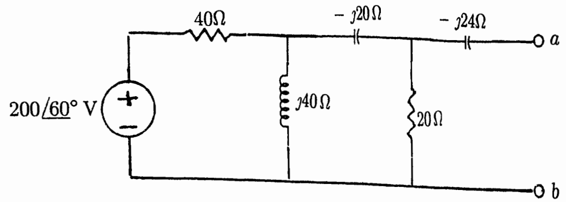


Figure 11.18

11.25: In the phasor domain network of Fig 11.19, determine the load to be placed across terminals a-b to make the power drawn by the load a maximum and then determine the value of this maximum power.

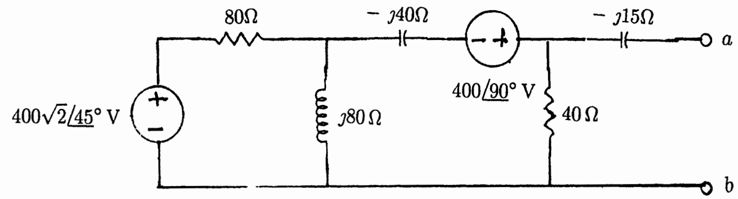


Figure 11.19

11.26: In the phasor domain network of Fig 11.20, determine the load to be placed across terminals a-b to make the power drawn by the load a maximum and then determine the value of this maximum power.

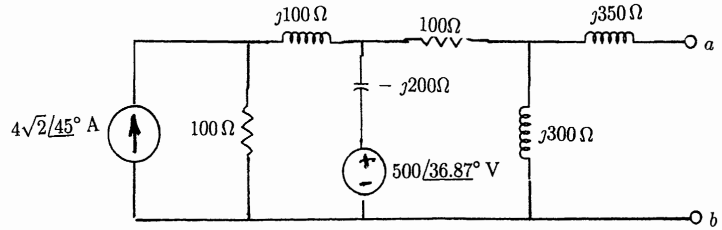


Figure 11.20

CHAPTER TWELVE

THREE PHASE POWER SYSTEMS

BALANCED SYSTEMS

12.1: In Fig 12.1, $\mathbf{V}_{AN} = \mathbf{V}_{NB} = 120\underline{/0^\circ}$ V. If $Z_1 = Z_2 = Z_3 = 40\,\Omega$, determine the total power delivered to the system of loads.

12.2: In Fig 12.1, $\mathbf{V}_{AN} = \mathbf{V}_{NB} = 120\underline{/0^\circ}$ V. If $Z_1 = Z_2 = Z_3 = 30\underline{/16.26^\circ}\,\Omega$, determine the total power delivered to the system of loads.

12.3: For the balanced three phase generator connected as shown in Fig 12.2, the phase voltages have an rms amplitude of 440 V and are connected in the positive sequence. Determine the currents, $\mathbf{I}_a, \mathbf{I}_b$ and $\mathbf{I}_c$ if the load is balanced with all $Z = 44\underline{/0^\circ}\,\Omega$.

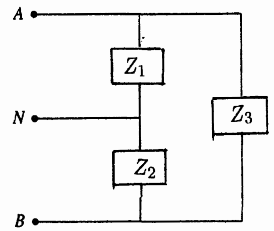


Figure 12.1

12.4: The line voltages in the wye connected generator that supplies the loads shown in Fig 12.3 have a magnititude of 208 V and are in the positive sequence at 60 Hz. Determine all phase and line voltages in instantaneous form.

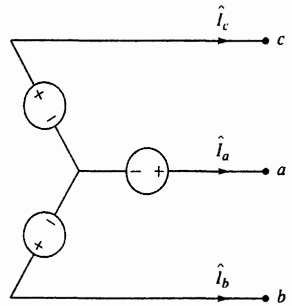


Figure 12.2

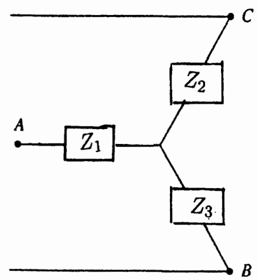


Figure 12.3

12.5: The line voltages in the wye connected generator that supplies the loads shown in Problem 12.4 (Fig 12.3) have a magnititude of 208 V and are in the *negative sequence* at 60 Hz. Determine all phase and line voltages in instantaneous form.

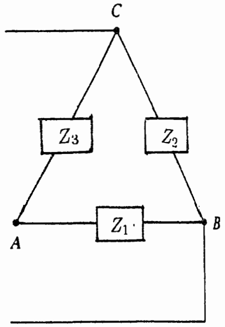


Figure 12.4

12.6: The line voltages in the delta connected generator that supplies the loads shown in Fig 12.4 have a magnititude of 208 V and are in the positive sequence at 60 Hz. Determine all phase and line voltages in instantaneous form.

12.7: The line voltages in the delta connected generator that supplies the loads shown in Problem 12.6 (Fig 12.4) have a magnititude of 208 V and are in the *negative sequence* at 60 Hz. Determine all phase and line voltages in instantaneous form.

12.8: The line-to-line voltages in Fig 12.5 have a magnititude of 440 V and are in the positive sequence at 60 Hz. The loads are balanced with $Z = Z_1 = Z_2 = Z_3 = 25\underline{/36.87^\circ}\,\Omega$. Determine all phase and line and phase voltages and load currents in instantaneous form.

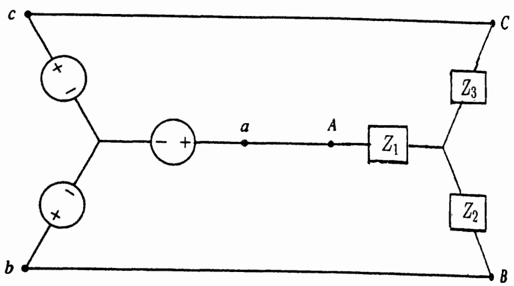


Figure 12.5

12.9 In Problem 12.8, determine the power drawn by the load.

12.10: In Fig 12.5, the rms amplitude of the line-to-line voltages in the three phase source is 240 V. The source is connected in the positive sequence and operates at 60 Hz. If the balanced load consists of $Z = Z_1 = Z_2 = Z_3 = 30\underline{/36.87^\circ}\,\Omega$, determine the phase voltages and currents and the power delivered to the load.

12.11: In Fig 12.5, the rms amplitude of the line-to-line voltages in the three phase source is 240 V. The source is connected in the positive sequence and operates at 60 Hz. If the balanced load consists of $Z = Z_1 = Z_2 = Z_3 = 40\underline{/53.13^\circ}\,\Omega$, determine the phase voltages and currents and the power delivered to the load.

12.12: In Fig 12.6, the rms amplitude of the line-to-line voltages in the three phase source is 240 V. The source is connected in the positive sequence and operates at 60 Hz. If the balanced load consists of $Z = Z_1 = Z_2 = Z_3 = 30\underline{/36.87^\circ}\,\Omega$, determine the line and phase voltages, the line currents and the power delivered to the load.

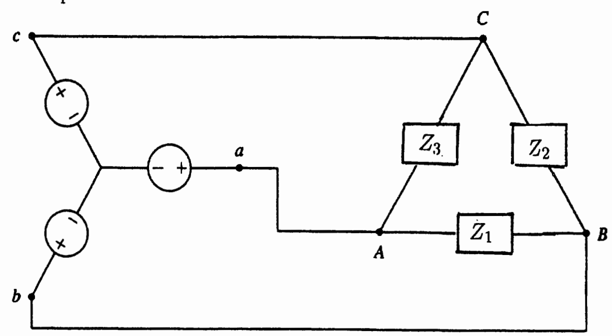


Figure 12.6

12.13: In Problem 12.12 (Fig 12.6), determine the phase currents and the power delivered to the balanced load if $Z = Z_1 = Z_2 = Z_3 = 50\underline{/16.26^\circ}\,\Omega$ V.

12.14: In Fig 12.7, the rms amplitude of the line-to-line voltages in the three phase source is 240 V. The source is connected in the positive sequence and operates at 60 Hz. If the balanced load consists of $Z = Z_1 = Z_2 = Z_3 = 30\underline{/36.87^\circ}\,\Omega$, determine the line voltages and currents and the power delivered to the load.

12.15: Rework Problem 12.14 (Fig 12.7) to determine the power delivered to the load with the balanced load consisting of $Z = Z_1 = Z_2 = Z_3 = 40\underline{/53.13^\circ}\,\Omega$.

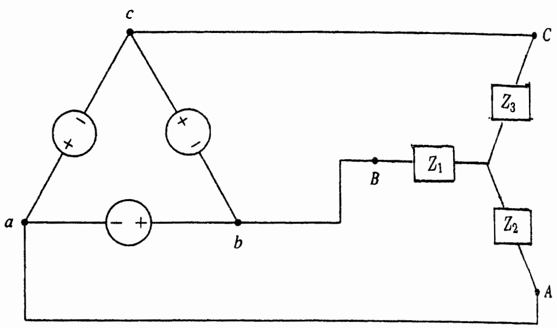


Figure 12.7

12.16: In Fig 12.8, the rms amplitude of the line-to-line voltages in the three phase source is 240 V. The source is connected in the positive sequence and operates at 60 Hz. If the balanced load consists of $Z = Z_1 = Z_2 = Z_3 = 30\underline{/36.87^\circ}\,\Omega$, determine the phase voltages and currents and the power delivered to the load.

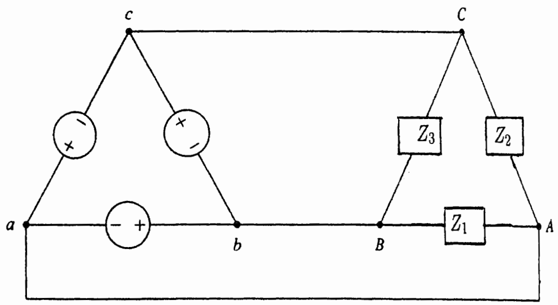


Figure 12.8

12.17: Rework Problem 12.16 (Fig 12.8) to determine the power delivered to the load with the balanced load consisting of $Z = Z_1 = Z_2 = Z_3 = 50\underline{/16.26^\circ}\,\Omega$.

UNBALANCED SYSTEMS

12.18: In Fig 12.1, $\mathbf{V}_{AN} = \mathbf{V}_{NB} = 120\underline{/0^\circ}$ V. If $Z_1 = 8 + j6\,\Omega$, $Z_2 = 8 - j6\,\Omega$ and $Z_3 = 4 - j20\,\Omega$, determine the total power delivered to the system of loads.

12.19: In Fig 12.1, $\mathbf{V}_{AN} = \mathbf{V}_{NB} = 120\underline{/0^\circ}$ V. If $Z_1 = 20\underline{/30^\circ}$, $Z_2 = 30\underline{/36.87^\circ}$ and $Z_3 = 30\underline{/45^\circ}\,\Omega$, determine the total power delivered to the system of loads.

12.20: In the system of Fig 12.9, the line voltages are 240 V and are in the positve sequence. Determine $\mathbf{I}_b$.

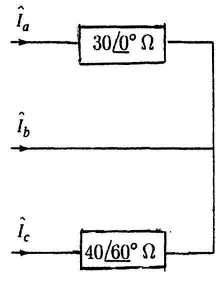


Figure 12.9

12.21: In Fig 12.10, determine the line currents. $\mathbf{I}_1, \mathbf{I}_2$ and $\mathbf{I}_3$ if the line-to-line voltages all have a magnitude of 300 V and are connected in the positive sequence.

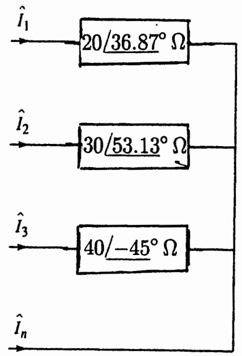


Figure 12.10

12.22: In Fig 12.10, determine the line currents. I_1, I_2 and I_3 if the line-to-line voltages all have a magnitude of 300 V and are connected in the *negative sequence.*

12.23: In Fig 12.11, the rms amplitude of the line-to-line voltages in the three phase source is 440 V. The source is connected in the positive sequence and operates at 60 Hz. If the unbalanced load consists of $Z_1 = 88\underline{/0^\circ}\,\Omega$, $Z_2 = 44\sqrt{2}\underline{/45^\circ}\,\Omega$ and $Z_3 = 44\underline{/36.87^\circ}\,\Omega$, determine the power delivered to the load.

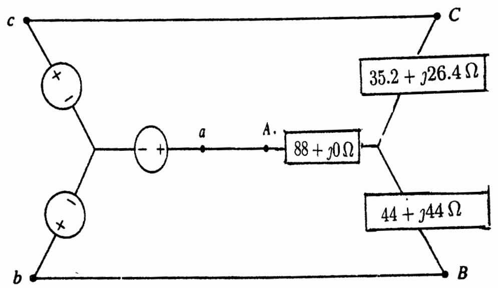


Figure 12.11

12.24: Determine the overall power factor for the system treated in Problem 12.23.

12.25: In Fig 12.12, the rms amplitude of the line-to-line voltages in the three phase source is 300 V. The source is connected in the positive sequence and operates at 60 Hz. If the unbalanced load consists of $Z_1 = 60\underline{/0^\circ}\,\Omega$, $Z_2 = 75\sqrt{2}\underline{/-45^\circ}\,\Omega$, and $Z_3 = 50\underline{/36.87^\circ}\,\Omega$, determine the power delivered to the load.

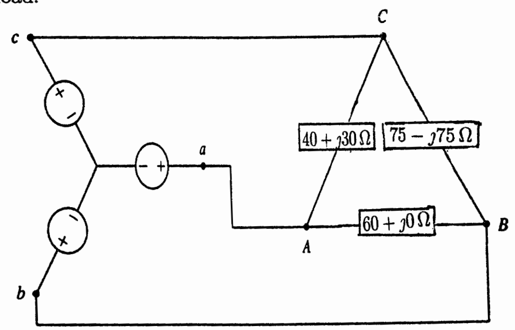


Figure 12.12

12.26: Determine the overall power factor for the system treated in Problem 12.25.

12.27: Figure 12.13 shows a wye-connected generator delivering power to a wye-connected load in a four wire system. The rms amplitude of the line-to-line voltages in the three phase source is 240 V. The source is connected in the positive sequence and operates at 60 Hz. If the unbalanced load consists of three impedances, $Z_1 = 48\underline{/0^\circ}\,\Omega$, $Z_2 = 24\sqrt{2}\underline{/-135^\circ}\,\Omega$ and $Z_3 = 60\underline{/36.87^\circ}\,\Omega$, determine the power delivered to the load.

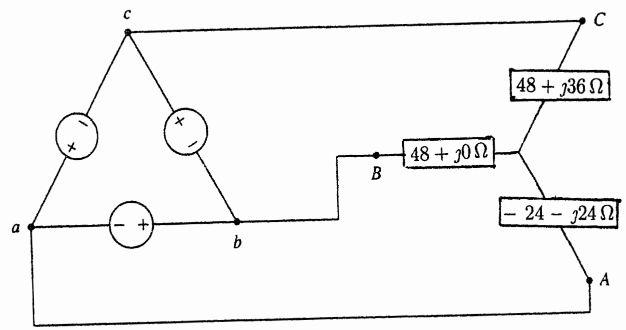


Figure 12.13

PROBLEM ANSWERS

CHAPTER ONE

INTRODUCTION AND BASIC CONCEPTS

CHARGE AND CURRENT

1.1:	1.248×10^{21} electrons
1.2:	$I = 20\,\text{A}$
1.3:	$I = 32.04\,\text{A}$
1.4:	$Q = 164\,\text{C}$

ENERGY, POWER, VOLTAGE, CURRENT AND CHARGE

1.5:	$W = 5.44 \times 10^{-3}\,\text{J}$
1.6:	$V = 29\,\text{V}$
1.7:	$W = 400\,\text{J}$
1.8:	$Q = 1.914\,\text{C}$
1.9:	$W = 17.904\,\text{MJ}$
1.10:	$4500\,\text{C}$, 28.09×10^{21} electrons
1.11:	$7.26
1.12:	$I = 14\,\text{A}$
1.13:	$W = 44\,\text{J}$
1.14:	$W = 0\,\text{J}$

RESISTANCE

1.15:	$V = 25.98\,\text{V}$
1.16:	$R = 3.48\,\Omega$
1.17:	$R = 8.105 \times 10^{-4}\,\Omega$
1.18:	$L = 0.2031\,\text{m}$
1.19:	$L = 123.48\,\text{m}$
1.20:	$T = 81.99°\text{C}$, $T = -31.42°\text{C}$
1.21:	$\alpha = 0.00360°\text{C}^{-1}$
1.22:	$R(T) = 250\,\Omega\text{-}°\text{C}^{-1}$, $T = 1895°\text{C}$
1.23:	$I = 15\,\text{A}$, $R = 8\,\Omega$
1.24:	$R = 5\,\Omega$

APPLICATIONS OF OHM'S LAW

1.25: $I_1/I_2 = 0.711$, $P_1/P_2 = 0.506$

1.26: $V_1/V_2 = 0.711$, $P_1/P_2 = 0.360$

1.27: $I = 12\,\text{A}$, $P_R = 72\,\text{W}$, $P_{\text{source}} = 72\,\text{W}$

1.28: $L = 39.35\,\text{m}$

1.29: $R = 48\,\Omega$, $P_{\text{source}} = 60\,\text{W}$

1.30: $R = 4\,\Omega$

1.31: $V_{30} = 150\,\text{V}$, $V_3 = 75\,\text{V}$, $I_4 = 18.75\,\text{A}$, $I_{12} = 6.25\,\text{A}$

1.32: $V_5 = 15\,\text{V}$, $V_1 = 3\,\text{V}$, $I_3 = 2\,\text{A}$, $I_6 = 1\,\text{A}$

CONTROLLED SOURCES

1.33: $\beta = 4$

1.34: $|V_{\text{out}}/V_{\text{in}}| = 8$, $|P_{\text{out}}/P_{\text{in}}| = 32$

1.35: $R_1 = 8\,\Omega$

1.36: $|I_2/I_1| = 5$

1.37: $|V_{\text{out}}/V_{\text{in}}| = 16$, $|P_{\text{out}}/P_{\text{in}}| = 128$

1.38: $|I_3/I_{\text{in}}| = 12$

CHAPTER TWO
KIRCHHOFF'S CURRENT AND VOLTAGE LAWS AND SERIES-PARALLEL RESISTIVE CIRCUITS

KCL PROBLEMS

2.1: $i_1 = -7\,\text{A}$, $i_2 = 6\,\text{A}$, $i_3 = -3\,\text{A}$

2.2: $i_1 = 5\,\text{A}$, $i_2 = 8\,\text{A}$, $i_3 = 3\,\text{A}$, $i_4 = 1\,\text{A}$, $i_5 = 3\,\text{A}$

2.3: $i_1 = 2\,\text{A}$, $i_2 = 0\,\text{A}$, $i_3 = 2\,\text{A}$, $i_4 = -5\,\text{A}$

KVL PROBLEMS

2.4: $v_1 = 6\,\text{V}$, $v_2 = -4\,\text{V}$, $v_3 = 12\,\text{V}$, $v_4 = 2\,\text{V}$, $v_5 = 13\,\text{V}$

2.5: $v_1 = 10\,\text{V}$, $v_2 = 20\,\text{V}$, $v_3 = 20\,\text{V}$, $v_4 = 18\,\text{V}$,
$v_5 = 18\,\text{V}$, $v_6 = 26\,\text{V}$, $v_7 = 12\,\text{V}$

2.6: $v_1 = -30\,\text{V}$, $v_2 = -20\,\text{V}$, $v_3 = -36\,\text{V}$, $v_4 = 32\,\text{V}$,
$v_5 = 36\,\text{V}$, $v_6 = -12\,\text{V}$

EQUIVALENT RESITANCE PROBLEMS

2.7: (a) $R_{\text{eq}} = 10\,\Omega$, (b) $R_{\text{eq}} = 16\,\Omega$, (c) $R_{\text{eq}} = 20\,\Omega$
(d) $R_{\text{eq}} = 0\,\Omega$, (e) $R_{\text{eq}} = 14.29\,\Omega$

2.8: $R = 21\,\Omega$

2.9: $R_{\text{eq}} = 48\,\Omega$

2.10: $R_{\text{eq}} = 19\,\Omega$

2.11: $R_{\text{eq}} = 25\,\Omega$

2.12: $R_{\text{eq}} = 110\,\Omega$

OHM'S LAW PROBLEMS

2.13: (a) $I_4 = I_{12} = 3/2\,\text{A}$, (b) $V_4 = 6\,\text{V}$, $V_{12} = 18\,\text{V}$

2.14: $P_4 = 9\,\text{W}$, $P_{12} = 27\,\text{W}$

2.15: $V_4 = 6\,\text{V}$, $V_{12} = 18\,\text{V}$

2.16: (a) $V = 36\,\text{V}$, (b) $I_4 = 9\,\text{A}$, $I_{12} = 3\,\text{A}$

2.17: $P_4 = 324\,\text{W}$, $P_{12} = 108\,\text{W}$

2.18: $I_4 = 9\,\text{A}$, $I_{12} = 3\,\text{A}$

2.19: $I_3 = I_9 = 2\,\text{A}$, $I_4 = 6\,\text{A}$, $I_6 = 4\,\text{A}$,

2.20: $P_3 = 12\,\text{W}$, $P_4 = 144\,\text{A}$, $P_6 = 96\,\text{W}$, $P_9 = 36\,\text{W}$

2.21: $R_1 = 3\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 1\,\Omega$

OHM'S LAW PROBLEMS (Cont'd)

2.22: $I_1 = 4\,A$, $I_3 = 4/3\,A$, $I_2 = I_4 = 2/3\,A$
$V_1 = 4\,V$, $V_2 = 4/3\,V$, $V_3 = 4\,V$, $V_4 = 8/3\,V$

2.23: $I_4 = 3\,A$, $I_5 = 4\,A$, $I_6 = 8\,A$, $I_8 = 4\,A$, $I_{12} = 1\,A$
$V_4 = 12\,V$, $V_5 = 20\,V$, $V_6 = 48\,V$, $V_8 = 32\,V$, $V_{12} = 12\,V$

2.24: $I_1 = 6\,A$, $I_2 = 2\,A$, $V_6 = 18\,V$

2.25: $I_1 = 6\,A$, $I_2 = 2\,A$, $V_6 = 18\,V$

2.26: $I_4 = 9/2\,A$, $I_9 = 12\,A$, $V_7 = 21/2\,V$

2.27: $I_4 = 9/2\,A$, $I_9 = 12\,A$, $V_7 = 21/2\,V$

2.28: $I_3 = 18\,A$, $I_4 = 3\,A$, $V_{12} = 24\,V$, $V_{14} = 14\,V$

2.29: $I_6 = 2\,A$, $I_{10} = 2\,A$, $V_2 = 8/3\,V$

2.30: $I_9 = 9\,A$, $I_{40} = 9/20\,A$, $V_7 = 63/5\,V$

2.31: $I_{13} = 1\,A$, $I_{14} = 1\,A$, $V_6 = 6\,V$, $V_7 = 21\,V$

2.32: $I_5 = 5/4\,A$, $V_{20} = 100\,V$, $P_{24} = 9.375\,W$

CHAPTER THREE
NODAL AND LOOP ANALYSES

SINGLE NODE PROBLEMS

3.1: $V_1 = 24\,V$

3.2: $V_1 = 64/3\,V$

3.3: $V_1 = 400\,V$

3.4: $I_2 = -5/2\,A$

3.5: $I_5 = -20/7\,A$

3.6: $V_1 = 3\,V$, $V_2 = 6\,V$

3.7: $I_4 = 0.590\,A$

3.8:
$$\begin{bmatrix} 14 & -4 & -2 & 0 & 0 \\ -4 & 16 & -6 & 0 & -5 \\ -2 & -6 & 12 & -4 & 0 \\ 0 & 0 & -4 & 20 & -16 \\ 0 & -5 & 0 & -16 & 33 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{bmatrix} = \begin{bmatrix} -6 \\ -2 \\ 14 \\ -11 \\ 8 \end{bmatrix}$$

3.9: $I_s = -576\,A$

3.10: $I_{40} = -0.81\,A$

3.11: $V_1 = 224/13\,V$, $V_2 = 96/13\,V$

3.12: $I_{1/8} = 18.49\,A$

3.13: $V_1 = -19.733\,V$, $V_2 = -10.667\,V$, $V_3 = -21.867\,V$

SUPERNODE PROBLEMS

3.14: $V_1 = 2.958\,V$, $V_2 = -17.917\,V$, $V_3 = 10.083\,V$

3.15: $V_1 = 76.952\,V$, $V_2 = 102.095\,V$, $V_3 = 42.667\,V$, $V_4 = 106.667\,V$

3.16: $V_1 = 5.551\,V$, $V_2 = -21.279\,V$,

3.17: $V_1 = 12\,V$, $V_2 = 2\,V$, $V_3 = -8\,V$

A LINK TO CHAPTER TWO

3.18: $I_1 = 4\,A$, $I_3 = 4/3\,A$, $I_2 = I_4 = 2/3\,A$
$V_1 = 4\,V$, $V_2 = 4/3\,V$, $V_3 = 4\,V$, $V_4 = 8/3\,V$

3.19: $I_1 = 6\,A$, $I_2 = 2\,A$, $V_6 = 18\,V$

3.20: $I_3 = 18\,A$, $I_4 = 3\,A$, $V_{12} = 24\,V$, $V_{14} = 14\,V$

3.21: $I_5 = 5/4\,A$, $V_{20} = 100\,V$, $P_{24} = 9.375\,W$

SINGLE LOOP ANALYSIS

3.22: $I = 400\,\text{mA}$

3.23: $I = 40\,\text{mA}$

3.24: $I = 37.5\,\text{mA}$

3.25: $I = 1.50\,\text{A},\ R_{eq} = 68\,\Omega$

3.26: $I_5 = -20/7\,\text{A}$

3.27: $I = 50\,\text{mA}$

MULTIPLE LOOP ANALYSIS

3.28: $I_4 = 0.590\,\text{A}$

3.29:

$$\begin{bmatrix} 32 & -10 & -8 & -2 & 0 \\ -10 & 42 & 0 & -6 & -2 \\ -8 & 0 & 24 & -4 & 0 \\ -2 & -6 & -4 & 22 & -10 \\ 0 & -2 & 0 & -10 & 16 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} 8 \\ -40 \\ 64 \\ 0 \\ 36 \end{bmatrix}$$

3.30: $V_s = 56\,\text{V}$

3.31: $I_{16} = 1.808\,\text{A},\ V_8 = -1.496\,\text{V}$

3.32: $I_6 = 1.819\,\text{A},\ I_4 = 5.455\,\text{A},\ V_{12} = 32.724\,\text{V},\ P_{24} = 401.7\,\text{W}$

3.33: $I_6 = 2.208\,\text{A},\ V_6 = 13.248\,\text{V},\ P_6 = 29.25\,\text{W}$

3.34: $P = 49.96\,\text{W}$

3.35: $I_1 = 4\,\text{A},\ I_3 = 4/3\,\text{A},\ I_2 = I_4 = 2/3\,\text{A}$
$V_1 = 4\,\text{V},\ V_2 = 4/3\,\text{V},\ V_3 = 4\,\text{V},\ V_4 = 8/3\,\text{V}$

3.36: $I_1 = 6\,\text{A},\ I_2 = 2\,\text{A},\ V_6 = 18\,\text{V}$

3.37: $I_3 = 18\,\text{A},\ I_4 = 3\,\text{A},\ V_{12} = 24\,\text{V},\ V_{14} = 14\,\text{V}$

3.38: $I_5 = 5/4\,\text{A},\ V_{20} = 100\,\text{V},\ P_{24} = 9.375\,\text{W}$

CHAPTER FOUR
THE OPERATIONAL AMPLIFIER

ANALYSIS USING THE IDEAL OP-AMP MODEL

4.1: (a) $G = -5, R_{in} = 20\,\text{k}\Omega$, (b) $G = -2, R_{in} = 50\,\text{k}\Omega$,
(c) $G = -0.25, R_{in} = 40\,\text{k}\Omega$

4.2: (a) $G = -1, R_{in} = 50\,\text{k}\Omega$, (b) $G = -3, R_{in} = 25\,\text{k}\Omega$,
(c) $G = -8, R_{in} = 11\,\text{k}\Omega$

4.3: $v_o/v_i = 50$

4.4: $$\frac{v_o}{v_i} = -\frac{R_2R_3(R_4+R_5)}{R_1(R_3R_4+R_3R_5+R_2R_4)}$$

4.5: (a) $G = 10$, (b) $G = 16$, (c) $G = 12$

4.6: $v_o = 24\,\text{V}$

4.7: $$v_o = \left(1+\frac{R_2}{R_1}\right)\left(\frac{R_2}{R_1+R_2}\right)v_{i2} - \frac{R_2}{R_1}v_{i1},\ v_o = v_{i2} - v_{i1}$$

4.8: $$\Delta R = -(R_a+R_b)\frac{v_o}{v_i}$$

4.9: $$v_0 = -\frac{R_a}{R_1}\left[1+\left(\frac{R_a+R_b}{R_b}\right)\right]v_i,\ R_a = 10{,}900\,\Omega$$

4.10: $$R_{in} = -\frac{R}{R_f}R_1$$

4.11: $R_f = 5\,\text{M}\Omega, R_1 = 40{,}000\,\Omega$

4.12: $R == 80\,\text{k}\Omega$

GENERAL SUMMING AMPLIFIER PROBLEMS (THE IDEAL OP-AMP MODEL)

4.13: $v_o = 5\,\text{V}$

4.14: $v_3 = 3\,\text{V}$

4.15: $v_o = 20\,\text{V}$

4.16: $R_f = 20\,\text{k}\Omega,\ R_{1,2} = 2.5\,\text{k}\Omega,\ R_{1,3} = 2\,\text{k}\Omega$

4.17: $i_o = -1.06\,\text{mA}\ P = 2.592\,\text{mW}$

4.18: $v_o = 34.29\,\text{V}$

NON IDEAL OP-AMPS: FINITE OPEN LOOP GAIN

4.19: $v_o = -19.76\,V$
4.20: $A = 74.00$
4.21: $R_f \approx 202,500\,\Omega$
4.22: $R_1 \approx 10,560\,\Omega$

SATURATION EFFECTS

4.23: see sketch in example.
4.24: for negative saturation, 7.85 ms to 23.56 ms
for positive saturation region, 39.27 ms to 54.98 ms
4.25: $-20\text{mV} \le v_d \le 20\,\text{mV}\, v_o = -2.4\,V$
4.26: (a) $v_o = -2.5\,V, v_d = 0\,V$, (b) $v_o = 8\,V, v_d = -0.80\,V$
(c) $v_o = -8\,V, v_d = -1.6\,V$

SELECTION OF OPERATIONAL AMPLIFIER COMPONENTS

4.27: $R_f = 100\text{k}\Omega$, $\Delta R = 16.67\text{k}\Omega$, $R_g = 100\text{k}\Omega$
$R_{a1} = 12.5\text{k}\Omega$, $R_{a2} = 25\text{k}\Omega$, $R_{a3} = 50\text{k}\Omega$
$R_{b1} = 33.33\text{k}\Omega$, $R_{b2} = 16.67\text{k}\Omega$, $R_{b3} = 11.11\text{k}\Omega$
4.28: $v_o = 5\,V$
4.29: $R_f = 100\text{k}\Omega$, $R_g = 12.5\text{k}\Omega$, $R_{a1} = 25\text{k}\Omega$
$R_{a2} = 50\text{k}\Omega$, $R_{a3} = 100\text{k}\Omega$, $R_{a4} = 12.5\text{k}\Omega$
$R_{b1} = 20\text{k}\Omega$, $R_{b2} = 50\text{k}\Omega$
4.30: $v_o = -8\,V$

CHAPTER FIVE

SUPERPOSITION AND SOURCE TRANSFORMATIONS

LINEARITY

5.1: (a) linear, (b) nonlinear
5.2: linear
5.3: linear
5.4: nonlinear
5.5: nonlinear

PROPORTIONALITY

5.6: $I_3 = 18\,A, I_4 = 3\,A\ V_{12} = 24\,V\,V_{14} = 14\,V$
5.7: $I_6 = 3\,A, V_3 = 12\,V$
5.8: $I_4 = 4\,A, I_6 = 4/3\,A\,V_2 = 16/3\,V$
5.9: $I_2 = 1\,A, I_4 = 3\,A\,V_8 = 24\,V$
5.10: $I_9 = 9\,A, I_{40} = 9/20\,A\,V_7 = 63/5\,V$

SOURCE TRANSFORMATION PROBLEMS

5.11: (a) $I = 4\,A, R = 6\,\Omega$, (b) $I = 2\,A, R = 6\,\Omega$
(c) $I = 2I_a\,A\,R = 2\,\Omega$
5.12: (a) $V = 28\,V, R = 7\,\Omega$, (b) $V = 32\,V, R = 4\,\Omega$
(c) $V = 20I_a\,V\,R = 4\,\Omega$
5.13: $V = 18\,V, R = 18\,\Omega$
5.14: $V = 24\,V, R = 8\,\Omega$
5.15: $V = 33\,V, R = 22\,\Omega$

SUPERPOSITION PROBLEMS

5.16: $I = 3\,A$
5.17: $I = 3/4\,A$
5.18: $I = 3.420\,A$
5.19: $I = -0.323\,A$
5.20: $V = -55\,V$
5.21: $I = 5/14\,A$
5.22: $V = -8/11\,V$
5.23: $I = -0.261\,A$
5.24: $V_s = 22\,V$
5.25: $P = 18.14\,\text{mW}$

SUPERPOSITION AND OPERATIONAL AMPLIFIERS

5.26: $v_o = \frac{R_2}{R_1}(v_{i2} - v_{i1})$

5.27: $R = 25\,\text{k}\Omega$

5.28: $v_0 = 6.5\,\text{V}$

5.29: $v_o = \left(\frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_3}{R_4}}\right) v_{i2} - \frac{R_2}{R_1} v_{i1}$

5.30: $R_1 = 50\,\text{k}\Omega$, $R_3 = 40\,\text{k}\Omega$

CHAPTER SIX

THEVENIN, NORTON AND MAXIMUM POWER TRANSFER THEOREMS

THEVENIN AND NORTON THEOREMS FOR NETWORKS WITHOUT CONTROLLED SOURCES

6.1: $R = 12\,\Omega$

6.2: $V_T = 19.51\,\text{V}$ $R_T = 7.63\,\Omega$

6.3: $I = 0.718\,\text{A}$

6.4: $I = 0.352\,\text{A}$

6.5: I_N $0.0965\,\text{A}$ $R_N = 600\,\Omega$

6.6: $V_{320} = 755.53\,\text{V}$

6.7: $R = 8\,\Omega$

6.8: $I_{10} = 3/4\,\text{A}$

THEVENIN AND NORTON THEOREMS FOR NETWORKS WITH CONTROLLED SOURCES

6.9: $P_{12} = 117.6\,\text{W}$

6.10: $I_N = 5.00\,\text{mA}, R_N = 1800\,\Omega$

6.11: $I_{1.6} = 3\,\text{A}$

6.12: $I_4 = 22/7\,\text{A}$

6.13: $I_{16} = 3.71\,\text{A}$

6.14: $P_{300} = 7.68\,\text{W}$

6.15: $I_6 = 5.76\,\text{A}$

6.16: $I_3 = -9.6\,\text{A}$

MAXIMUM POWER TRANSFER

6.17: $R = 3\,\Omega,\ P = 12\,\text{W}$

6.18: $R = 16\,\Omega,\ P = 324\,\text{W}$

6.19: $R = 30/7\,\Omega,\ P = 33.6\,\text{W}$

6.20: $R = 1100\,\Omega,\ P = 16.57\,\text{W}$

6.21: $R = 160\,\Omega,\ P \approx 2007\,\text{W}$

6.22: $R = 3.619\,\Omega,\ P \approx 2763\,\text{W}$

CHAPTER SEVEN

INDUCTORS, CAPACITORS AND DUALITY

INDUCTORS

7.1: $v = 12.5\,\text{V}$

7.2: $L_{eq} = = 0.200\,\text{H}$

7.3: $p = 12,800 \sin 800t\,\text{W}$

7.4: (a) $w_L(t = 0\,\text{s}) = 0\,\text{J}$, (b) $w_L(t = 0.5\,\text{s}) = 0.1823\,\text{J}$
(c) $v_L(t = 0.5\,\text{s}) = 0.2068\,\text{V}$, (d) $p(t = 0.5\,\text{s}) = 0.1974\,\text{J}$

7.5: $L_{eq} = = 2.20\,\text{H}$

7.6: (a) $p_R(t = 5\,\text{s}) = 8000\,\text{W}$ (b) $w_L(t = 5\,\text{s}) = 80\,\text{W}$
(c) $p_s(t = 5\,\text{s}) = 8080\,\text{W}$ (d) $W_R(0 \rightarrow 4\,\text{s}) = 6826.67\,\text{J}$
(e) $W_L(0 \rightarrow 4\,\text{s}) = 128\,\text{J}$ (f) $W_s(0 \rightarrow 4\,\text{s}) = 6954.67\,\text{J}$

7.7: (a) $p(t = \pi/200\,\text{s}) = 0\,\text{W}$ (b) $p(0 \rightarrow \pi/200\,\text{s}) = 0\,\text{J}$

7.8: $W(0 \rightarrow 1.2\,\text{s}) = 22.38\,\text{J}$

7.9: $R = 4\,\Omega$

7.10: $i_1 = 7.5\,\text{A}, i_2 = 5\,\text{A}$

7.11: $L_1 = 4.0\,\text{H}, L_2 = 1.0\,\text{H}$

7.12: see sketch

CAPACITORS

7.13: $i = 1.50 \cos 250t\,\text{A}, q = 6 \sin 250t\,\text{mC}$

7.14: $W = 0.160\,\text{J}$

7.15: $Q_1 = 200\,\mu\text{C}, Q_2 = 400\,\mu\text{C}$

7.16: $C_{eq} = 80\,\mu\text{F}$

7.17: $p = 576 \sin 800t\,\text{W}$

7.18: $C_{eq} = 232\,\mu\text{F}$

7.19: (a) $p_R(t = 4\,\text{s}) = 12.80\,\text{W}$ (b) $p_C(t = 4\,\text{s}) = 8\,\text{W}$
(c) $p_s(t = 4\,\text{s}) = 20.80\,\text{W}$, (d) $W_R(0 \rightarrow 4\,\text{s}) = 29.87\,\text{J}$
(e) $W_C(0 \rightarrow 4\,\text{s}) = 24\,\text{J}$, (f) $W_s(0 \rightarrow 4\,\text{s}) = 53.87\,\text{J}$

7.20: $W_C = -74.91\,\mu\text{J}$ removed.

7.21: $W_C = 4.088\,\text{mJ}$

7.22: $C = 60\,\mu\text{F}$

7.23: $v_1 = 15\,\text{V}, v_2 = 5\,\text{V}$

7.24: see sketch

CHAPTER EIGHT

FIRST ORDER RL AND RC CIRCUITS

THE EXPONENTIAL FUNCTION

8.1: $q(t = 0) = 200\,\mu\text{C}, T = 2.50\,\text{ms},\ q(t = 0.625\,\text{ms}) = 155.76\,\mu\text{C}$

8.2: $v(t = 0) = 1200\,\text{V}, T = 0.20\,\text{s}, v(t = 32.5\,\text{ms}) = 1020\,\text{V}$

8.3: $i(t = 0) = 64.67\,\text{A}, t = 265\,\text{ms}$

8.4: $v(t = 125\,\text{ms}) = 877.9\,\text{V}, v(t = 2.125\,\text{s}) = 5.92\,\text{V}$

8.5: $i(t = 0) = 800\,\text{A}, T = 0.25\,\text{s}$

8.6: $v(t = 0) = 88\,\text{V}, T = 20\,\text{ms}$

EVALUATION OF INITIAL CONDITIONS

8.7:	$i_R(0^-) = 4/3\,\text{A}$	$i_L(0^-) = 4/3\,\text{A}$	$i_C(0^-) = 0\,\text{A}$	$v_C(0^-) = 8/3\,\text{V}$
	$v_L(0^-) = 0\,\text{V}$	$i_R(0^+) = 4/3\,\text{A}$	$i_L(0^+) = 4/3\,\text{A}$	$i_C(0^+) = 0\,\text{A}$
	$v_C(0^+) = 8/3\,\text{V}$	$v_L(0^+) = -32\,\text{V}$	$i'_L(0^+) = -32\,\text{A/s}$	
8.8:	$i_{R1}(0^-) = 4/3\,\text{A}$	$i_L(0^-) = 2\,\text{A}$	$i_C(0^-) = 0\,\text{A}$	$i_{R2}(0^-) = 4/3\,\text{A}$
	$v_L(0^-) = 0\,\text{V}$	$v_{R1}(0^-) = 8\,\text{V}$	$v_C(0^-) = 8/3\,\text{V}$	$v_{R2}(0^-) = 8/3\,\text{V}$
	$i_{R1}(0^+) = 2\,\text{A}$	$i_L(0^+) = 2\,\text{A}$	$i_C(0^+) = 2/3\,\text{A}$	$i_{R2}(0^+) = 4/3\,\text{A}$
	$v_L(0^+) = -8/3\,\text{V}$	$v_{R1}(0^+) = 8\,\text{V}$	$v_C(0^+) = 8/3\,\text{V}$	$v'_C(0^+) = 16/3\,\text{V/s}$
8.9:	$i_{R1}(0^+) = 4\,\text{A}$	$i_L(0^+) = 0\,\text{A}$	$i_C(0^+) = 4\,\text{A}$	$i_{R2}(0^+) = 4\,\text{A}$
	$v_L(0^+) = 24\,\text{V}$	$v_{R1}(0^+) = 16\,\text{V}$	$v_C(0^+) = 40\,\text{V}$	$i'_L(0^+) = 12\,\text{A/s}$
8.10:	$i_{R1}(0^+) = 4\,\text{A}$	$v_{R1}(0^+) = 48\,\text{V}$	$v'_C(0^+) = 200\,\text{V/s}$	$i_{R3}(0^+) = 0\,\text{A}$
	$i_{R2}(0^+) = 4\,\text{A}$	$i_C(0^+) = 4\,\text{A}$	$v_{R3}(0^+) = 0\,\text{V}$	$v_{R2}(0^+) = 32\,\text{V}$
	$v_C(0^+) = 0\,\text{V}$			

THE UNDRIVEN FIRST ORDER NETWORK

8.11: $i(t) = \frac{8}{3} e^{-18t}\,\text{A}$

8.12: $v(t) = -240 e^{-12t}\,\text{V}$

8.13: $v(t) = 18 e^{-2t}\,\text{V}$

8.14: $v_{16} = \frac{128}{9} e^{-1000t/3}\,\text{V}$

8.15: $v(t) = 200 e^{-1.0101t}\,\text{V}$

8.16: $i(t) = 0.014 e^{-12.5t}\,\text{A}$

8.17: $v(t) = 30 e^{-9t}\,\text{V}$

8.18: $i_L = \frac{1}{2} e^{-128t/9}\,\text{A},\ v_{12}(t) = 6 e^{-128t/9}\,\text{V}$

CHAPTER EIGHT

FIRST ORDER *RL* AND *RC* CIRCUITS

THE EXPONENTIAL FUNCTION

8.1: $q(t=0)=200\,\mu\text{C}, T=2.50\,\text{ms}, q(t=0.625\,\text{ms})=155.76\,\mu\text{C}$

8.2: $v(t=0)=1200\,\text{V}, T=0.20\,\text{s}, v(t=32.5\,\text{ms})=1020\,\text{V}$

8.3: $i(t=0)=64.67\,\text{A}, t=265\,\text{ms}$

8.4: $v(t=125\,\text{ms})=877.9\,\text{V}, v(t=2.125\,\text{s})=5.92\,\text{V}$

8.5: $i(t=0)=800\,\text{A}, T=0.25\,\text{s}$

8.6: $v(t=0)=88\,\text{V}, T=20\,\text{ms}$

EVALUATION OF INITIAL CONDITIONS

8.7:	$i_R(0^-)=4/3\,\text{A}$	$i_L(0^-)=4/3\,\text{A}$	$i_C(0^-)=0\,\text{A}$	$v_C(0^-)=8/3\,\text{V}$
	$v_L(0^-)=0\,\text{V}$	$i_R(0^+)=4/3\,\text{A}$	$i_L(0^+)=4/3\,\text{A}$	$i_C(0^+)=0\,\text{A}$
	$v_C(0^+)=8/3\,\text{V}$	$v_L(0^+)=-32\,\text{V}$	$i'_L(0^+)=-32\,\text{A/s}$	
8.8:	$i_{R1}(0^-)=4/3\,\text{A}$	$i_L(0^-)=2\,\text{A}$	$i_C(0^-)=0\,\text{A}$	$i_{R2}(0^-)=4/3\,\text{A}$
	$v_L(0^-)=0\,\text{V}$	$v_{R1}(0^-)=8\,\text{V}$	$v_C(0^-)=8/3\,\text{V}$	$v_{R2}(0^-)=8/3\,\text{V}$
	$i_{R1}(0^+)=2\,\text{A}$	$i_L(0^+)=2\,\text{A}$	$i_C(0^+)=2/3\,\text{A}$	$i_{R2}(0^+)=4/3\,\text{A}$
	$v_L(0^+)=-8/3\,\text{V}$	$v_{R1}(0^+)=8\,\text{V}$	$v_C(0^+)=8/3\,\text{V}$	$v'_C(0^+)=16/3\,\text{V/s}$
8.9:	$i_{R1}(0^+)=4\,\text{A}$	$i_L(0^+)=0\,\text{A}$	$i_C(0^+)=4\,\text{A}$	$i_{R2}(0^+)=4\,\text{A}$
	$v_L(0^+)=24\,\text{V}$	$v_{R1}(0^+)=16\,\text{V}$	$v_C(0^+)=40\,\text{V}$	$i'_L(0^+)=12\,\text{A/s}$
8.10:	$i_{R1}(0^+)=4\,\text{A}$	$v_{R1}(0^+)=48\,\text{V}$	$v'_C(0^+)=200\,\text{V/s}$	$i_{R3}(0^+)=0\,\text{A}$
	$i_{R2}(0^+)=4\,\text{A}$	$i_C(0^+)=4\,\text{A}$	$v_{R3}(0^+)=0\,\text{V}$	$v_{R2}(0^+)=32\,\text{V}$
	$v_C(0^+)=0\,\text{V}$			

THE UNDRIVEN FIRST ORDER NETWORK

8.11: $i(t)=\frac{8}{3}e^{-18t}\,\text{A}$

8.12: $v(t)=-240e^{-12t}\,\text{V}$

8.13: $v(t)=18e^{-2t}\,\text{V}$

8.14: $v_{16}=\frac{128}{9}e^{-1000t/3}\,\text{V}$

8.15: $v(t)=200e^{-1.0101t}\,\text{V}$

8.16: $i(t)=0.014e^{-12.5t}\,\text{A}$

8.17: $v(t)=30e^{-9t}\,\text{V}$

8.18: $i_L=\frac{1}{2}e^{-128t/9}\,\text{A},\ v_{12}(t)=6e^{-128t/9}\,\text{V}$

THE DRIVEN FIRST ORDER NETWORK

8.19: $i_1(t)=\frac{1}{3}e^{-15t/16}\,\text{A},\ i_2(t)=\frac{2}{3}e^{-15t/16}\,\text{A}$

8.20: $v_1(t)=9e^{-3t}\,\text{V}, v_2(t)=27e^{-3t}\,\text{V}$

8.21: $t_1=56.8\,\text{ms}, t_2=36.6\,\text{ms}, t_3=11.1\,\text{ms}$, ratio $=3.29$

8.22: $R_1=910.2\,\Omega,\ R_2=1820.4\,\Omega$

8.23: $v(t)=31.272(e^{-0.595t}-1)\,\text{V}$

8.24: $i(t)=3.061-0.642e^{-5.765t}\,\text{A}$

8.25: $i(t)=2.600+5.178e^{-14{,}285t}\,\text{A}$

THE DRIVEN FIRST ORDER NETWORK - ALTERNATE SOLUTIONS

8.26: $i_1(t)=\frac{1}{3}e^{-15t/16}\,\text{A},\ i_2(t)=\frac{2}{3}e^{-15t/16}\,\text{A}$

8.27: $i(t)=3(1-e^{-3t})\,\text{A}$

8.28: $v(t)=31.272(e^{-0.595t}-1)\,\text{V}$

8.29: $i(t)=3.061-0.642e^{-5.765t}\,\text{A}$

8.30: $i(t)=2.600+5.178e^{-14{,}285t}\,\text{A}$

OPERATIONAL AMPLIFIERS

8.31: $C=5\,\mu\,\text{F}$

8.32: $v_o=8t^2\,\text{V}$

8.33: $v_o=12\sin 400t-6(\cos 400t-1)\,\text{V}$

8.34: see circuit diagram

8.35: see circuit diagram

CHAPTER NINE

SECOND ORDER RL AND RC CIRCUITS

THE SINUSOID

9.1: $V = 120\,\text{V}, \omega = 160\pi\,\text{rad/s}, \phi = -1.973\,\text{rad}$
9.2: $I = 40\,\text{ma}, \omega = 50{,}000\pi\,\text{rad/s}, \phi = -0.20\,\text{rad}$
9.3: $Q = 20\,\mu\text{C}, \omega = 125\pi\,\text{rad/s}, \phi = \pm\pi\,\text{rad}$
9.4: $V = 208\,\text{V}, \omega = 7646.7\pi\,\text{rad/s}, \phi = 0\,\text{rad}$
9.5: $f = 66.67\,\text{Hz}, T = 15\,\text{ms}$
9.6: $I = 20\,\text{mA}, \omega = 100\pi\,\text{rad/s}, \phi = -1.20\,\text{rad}$

FORMS OF RESPONSE

9.7: $L = 0.10\,\text{H}$
9.8: $L = 0.171\,\text{H}, \zeta = 0.967, \omega_n = 24.18\,\text{rad/s}$
$L = 2.067\,\text{H}, \zeta = 0.248, \omega_n = 6.19\,\text{rad/s}$
9.9: $C = 488.3\,\mu\text{F}$
9.10: $C = 0.00125\,\text{F}, \zeta = 0.941$
$C = 0.009645\,\text{F}, \zeta = 0.339$
9.11: $R = 0.319\,\Omega$
9.12: $C = 0.00651\,\text{F}$

UNDRIVEN SECOND ORDER NETWORKS

9.13: $i(t) = \frac{9}{4}\left(e^{-6t} - e^{-2t}\right)\,\text{A}$
9.14: $v_L(t) = 96e^{-12t}(3\sin 8t - 2\cos 8t)\,\text{V}$
9.15: $v(t) = \frac{11}{5}\left(8e^{-8t} - 3e^{-3t}\right), \text{V}$
9.16: $i_L(t) = e^{-200t}(0.180\sin 400t + 0.360\cos 400t)\,\text{A}$
9.17: $v_C(t) = -96te^{-8t}\,\text{V}$
9.18: $v_C(t) = 160(e^{-30t} - e^{-20t})\,\text{V}$

DRIVEN SECOND ORDER NETWORKS

9.19: $v(t) = 24e^{-6t} - 8e^{-4t}\,\text{V}$
9.20: $i(t) = 9e^{-t}\sin 2t\,\text{A}$
9.21: $v(t) = e^{-4t}\left(12\cos 3t + \frac{52}{3}\sin 3t\right)\text{V}$
9.22: $i(t) = 8te^{-2t}\,\text{A}$
9.23: $v(t) = 8e^{-2t} + 128te^{-2t}\,\text{V}$
9.24: $i(t) = 24(e^{-4t} - e^{-3t})\,\text{A}$

CHAPTER TEN

SINUSOIDAL STEADY STATE ANALYSIS BY PHASOR METHODS

COMPLEX NUMBER ALGEBRA

10.1: $6 + j4, 7.211\underline{/33.69}°, 7.211e^{33.69°}$
10.2: $2.828\underline{/-81.87}°, 0.40 - j2.80, 2.828e^{-81.87°}$
10.3: $145.00\underline{/-46.40}°, 100 - j105, 145e^{-46.40°}$
10.4: $100\sqrt{2}\underline{/98.13}°, -20 + j140, 100\sqrt{2}e^{98.13°}$
10.5: $-0.35 - j2.55, 2.574\underline{/-97.82}°, 2.574e^{-97.82°}$
10.6: $30.198\underline{/-88.47}°, 0.804 - j30.187, 30.198e^{-88.47°}$
$32.330\underline{/-162.33}°, -30.804 - j9.813, 32.330e^{-162.33°}$
10.7: $1.130\underline{/58.74}°, 0.586 + j0.966, 1.130e^{58.74°}$
10.8: $36,055\underline{/-130.05}°, -23,200 - j27,600, 36,055e^{-130.05°}$
10.9: $-44 - j104, 112.93\underline{/-112.93}°, 112.93e^{-122.93°}$
10.10: $19 + j32, 37.22\underline{/59.30°}, 37.22e^{59.30°}$

IMPEDANCE AND ADMITTANCE

10.11: $Z(\omega = 400\,\text{rad/s}) = 20\,\Omega$
10.12: $Z(j200\,\text{rad/s}) = 29.2\,\Omega$
10.13: $Y(\omega = j100\,\text{rad/s}) = 0.01\underline{/36.87°}\,℧ = 0.008 + j0.006\,℧$
10.14: $Y(s = j500\,\text{rad/s}) = 0.01\underline{/-36.87°}\,℧ = 0.008 - j0.006\,℧$
10.15: $Z(\omega = 1000\,\text{rad/s}) = 150 - j80\,\Omega = 170\underline{/-28.07°}\,\Omega$

PHASORS

10.16: $f(t) = 4\sqrt{2}\cos(\omega t - 135°)$
10.17: $f(t) = 136\cos(\omega t - 118.07°)$
10.18: $f(t) = 75\cos(\omega t + 143.13°)$
10.19: $f(t) = 182\cos(\omega t + 112.62°)$
10.20: $f(t) = 100\cos(\omega t + 73.74°)$
10.21: $f(t) = -220\cos\omega t + 165\sin\omega t$
10.22: $f(t) = -150\cos\omega t - 360\sin\omega t$
10.23: $f(t) = 768\cos\omega t - 224\sin\omega t$
10.24: $f(t) = -103.92\cos\omega t - 60\sin\omega t$
10.25: $f(t) = -500\sqrt{2}\cos\omega t + 500\sqrt{2}\sin\omega t$

10.26:	$\mathbf{V} = 208\angle 60^\circ$ V, $104 + j180.13$ V, $208e^{60^\circ}$ V
10.27:	$\mathbf{i} = 4\sqrt{2}\angle -135^\circ$ A, $-4 - j4$ A, $4\sqrt{2}e^{-135^\circ}$ A
10.28:	$\mathbf{i} = 120\sqrt{3}\angle 15^\circ$ A, $200.76 + j53.79$ A, $120\sqrt{3}e^{15^\circ}$ A
10.29:	$\mathbf{V} = 1750\angle -163.74^\circ$ V, $1680 - j490$ V, $1750e^{-163.74^\circ}$ V
10.30:	$\mathbf{V} = 400\angle 90^\circ$ V, $0 + j400$ V, $400e^{90^\circ}$ V
10.31:	$i_2(t) = 16.731\cos(377t + 155.27^\circ)$ A
10.32:	$v_2(t) = 148.86\cos(377t + 120.70^\circ)$ V
10.33:	$R_a = 42\,\Omega, L_b = 0.024$ H, $R_c = 6\,\Omega, C_d = 95.24\,\mu$F
10.34:	$\mathbf{V} = 415.93\angle 117.18^\circ, Z_{eq} = 20 + j12.5\,\Omega$

LADDER NETWORKS AND PHASOR DIAGRAMS

10.35:	See solution for phasor diagram.
10.36:	See solution for phasor diagram.
10.37:	See solution for phasor diagram.
10.38:	See solution for phasor diagram.
10.39:	See solution for phasor diagram.

NETWORK ANALYSIS

10.39:	$\mathbf{i}_L = 8\angle 126.87^\circ$ A, $\mathbf{V}_C = 320\sqrt{2}\angle 81.87^\circ$ V
10.40:	$\mathbf{V}_R = 76.80\angle 16.26^\circ$ V, $I_L = 400\angle -110.61^\circ$ mA
10.41:	$\mathbf{i}_L = 2\sqrt{2}\angle -45^\circ$ A, $\mathbf{V}_C = 400\angle 90^\circ$ A
10.42:	$\mathbf{V}_R = 160\angle 53.13^\circ$ A, $\mathbf{i}_L = 4\angle 53.13^\circ$ V
10.43:	$\mathbf{i}_R = 0.973\angle 46.85^\circ$ A
10.44:	$\mathbf{i}_L = 8\angle 126.87^\circ$ A, $\mathbf{V}_C = 452.54\angle 81.87^\circ$ V
10.45:	$\mathbf{i}_L = 400\angle -110.61^\circ$ mA, $V_R = 76.80\angle 16.26^\circ$ V
10.46:	$\mathbf{i}_L = 4\angle 53.13^\circ$ mA, $\mathbf{V}_R = 76.80\angle 16.26^\circ$ V
10.47:	$\mathbf{i}_R = 0.973\angle 46.85^\circ$ A
10.48:	$2\sqrt{2}\angle -45^\circ$ A
10.49:	$2\sqrt{2}\angle -45^\circ$ A
10.50:	$\mathbf{V}_L = 118.89\angle -117.16^\circ$ V
10.51:	$\mathbf{V}_C = 480\sqrt{2}\angle 45^\circ$ V
10.52:	$\mathbf{i}_L = 8.34\angle -98.13^\circ$ A
10.53:	$\mathbf{i}_R = 8\angle 36.87^\circ$ A
10.54:	$\mathbf{V}_C = 480\sqrt{2}\angle 45^\circ$ V
10.55:	$\mathbf{i}_R = 0.973\angle 46.84^\circ$ A
10.56:	$\mathbf{i}_L = 10.67\angle 0^\circ$ A
10.57:	$\mathbf{i}_C = 4\angle 180^\circ$ A

CHAPTER ELEVEN

SINUSOIDAL STEADY STATE POWER CALCULATIONS

AVERAGE AND EFFECTIVE VALUES

11.1:	$V_{avg} = 0.850$ V, $V_{eff} = 2.345$ V
11.2:	$I_{avg} = 0.800$ V, $V_{eff} = 2.450$ A
11.3:	$V_{avg} = 0.611$ V, $V_{eff} = 2.271$ V
11.4:	$I_{avg} = -0.600$ A, $I_{eff} = 1.915$ V
11.5:	$V_{avg} = 1.637$ V, $V_{eff} = 2.828$ V
11.6:	$V_{avg} = 2/3$ V, $V_{eff} = 1.856$ V

AVERAGE POWER IN THE SINUSOIDAL STEADY STATE

11.7:	$P_{avg} = 103.68$ W, $PF = 0.800$
11.8:	$P_{avg} = 3075$ W, $PF = 0.6932$
11.9:	$P_{avg} = 230.6$ W, $PF = 0.9027$
11.10:	$P_{avg} = 9192$ W, $PF = 0.7365$
11.11:	$C = 20\,\mu$ F
11.12:	$R = 600\,\Omega, C = 10\,\mu$F
11.13:	$P_{10\,\Omega} = 1141.7$ W, $P_{10\,\Omega} = = 933.9$ W, $P_{30\,\Omega} = 306.8$ W
11.14:	$\mathbf{S} = 1556.9\angle -1.61^\circ$ VA
11.15:	$\mathbf{S} = 5971.4\angle 35.84^\circ$ VA
11.16:	$\mathbf{S} = 12.21\angle 8.42^\circ$ VA
11.17:	$\mathbf{S} = 2688\sqrt{2}\angle 45^\circ$ VA
11.18:	$P = 360$ W, $\mathbf{S} = 402.49\angle 26.57^\circ$ VA $\lvert S\rvert = 402.49$ VA, $PF = 0.8944$

POWER FACTOR CORRECTION

11.19:	$P = 1479.85$ W, $Q = 741.41$ VAR, $\lvert S\rvert = 1655.19$ VA $PF = 0.8941, Q_{corr} = -255$ VAR, $C = 10.82\,\mu$F
11.20:	$P = 536$ W, $Q = 292$ VAR, $\lvert S\rvert = 610.38$ VA $PF = 0.8781, Q_{corr} = -88.7$ VAR, $C = 23.53\,\mu$F
11.21:	$P = 2520$ W, $Q = 2200$ VAR, $\lvert S\rvert = 3345.2$ VA $PF = 0.7533, Q_{corr} = -1126.5$ VAR , $C = 44.20\,\mu$F
11.22:	$P = 3120$ W, $Q = 1760$ VAR, $\lvert S\rvert = 3582.2$ VA $PF = 0.8710, Q_{corr} = -680.1$ VAR, $C = 6.77\,\mu$F

MAXIMUM POWER TRANSFER

11.23: $Z_o = 50 + j108.22\,\Omega$

11.24: $Z_o = 10 + j24\,\Omega$, $P_o = 125\,\text{W}$

11.25: $Z_o = 20 + j15\,\Omega$, $P_o = 2000\,\text{W}$

11.26: $Z_o = 150 - j200\,\Omega$, $P_o = 341.6\,\text{W}$

CHAPTER TWELVE

THREE PHASE POWER SYSTEMS

BALANCED SYSTEMS

12.1: $P = 2160\,\text{W}$

12.2: $P = 2764.8\,\text{W}$

12.3: $\mathbf{i}_a = 30\angle 0^\circ\,\text{A}$, $\mathbf{i}_b = 30\angle -120^\circ\,\text{A}$, $\mathbf{i}_c = 30\angle 120^\circ\,\text{A}$

12.4: $v_{an}(t) = 120.09\cos(377t + 0^\circ)\,\text{V}$, $v_{bn}(t) = 120.09\cos(377t - 120^\circ)\,\text{V}$
$v_{cn}(t) = 120.09\cos(377t + 120^\circ)\,\text{V}$, $v_{ab}(t) = 208\cos(377t + 30^\circ)\,\text{V}$
$v_{bc}(t) = 208\cos(377t - 90^\circ)\,\text{V}$, $\mathbf{V}_{ca} = 208\cos(377t + 150^\circ)\,\text{V}$

12.5: $v_{an}(t) = 120.09\cos(377t + 0^\circ)\,\text{V}$, $v_{bn}(t) = 120.09\cos(377t + 120^\circ)\,\text{V}$
$v_{cn}(t) = 120.09\cos(377t - 120^\circ)\,\text{V}$, $v_{ab}(t) = 208\cos(377t - 30^\circ)\,\text{V}$
$v_{bc}(t) = 208\cos(377t + 90^\circ)\,\text{V}$, $v_{ca}(t) = 208\cos(377t - 150^\circ)\,\text{V}$

12.6: $v_{ab}(t) = 208\cos(377t + 0^\circ)\,\text{V}$, $v_{bc}(t) = 208\cos(377t + 120^\circ)\,\text{V}$
$\mathbf{V}_{ca} = 208\cos(377t - 120^\circ)\,\text{V}$

12.7: $v_{ab}(t) = 208\cos(377t + 0^\circ)\,\text{V}$,
$v_{bc}(t) = 208\cos(377t + 120^\circ)\,\text{V}$
$v_{ca}(t) = 208\cos(377t - 120^\circ)\,\text{V}$

12.8: $v_{an}(t) = 254\cos(377t + 0^\circ)\,\text{V}$, $v_{bn}(t) = 254\cos(377t - 120^\circ)\,\text{V}$
$v_{cn}(t) = 254\cos(377t + 120^\circ)\,\text{V}$, $v_{ab}(t) = 440\cos(377t + 30^\circ)\,\text{V}$
$v_{bc}(t) = 440\cos(377t - 90^\circ)\,\text{V}$, $v_{ca}(t) = 440\cos(377t + 150^\circ)\,\text{V}$
$i_{AN}(t) = 10.16\cos(377t - 36.87^\circ)\,\text{A}$, $i_{BN}(t) = 10.16\cos(377t - 156.87^\circ)\,\text{A}$,
$i_{CN}(t) = 10.16\cos(377t + 83.13^\circ)\,\text{A}$

12.9: $P = 6193.5\,\text{W}$

12.10: $\mathbf{V}_{AN} = \mathbf{V}_{an} = 138.6\angle 0^\circ\,\text{V}$, $\mathbf{V}_{BN} = \mathbf{V}_{bn} = 138.6\angle -120^\circ\,\text{V}$
$\mathbf{V}_{CN} = \mathbf{V}_{cn} = 138.6\angle 120^\circ\,\text{V}$, $\mathbf{i}_{AN} = 4.62\angle -36.87^\circ\,\text{A}$
$\mathbf{i}_{BN} = 4.62\angle -156.87^\circ\,\text{A}$, $\mathbf{i}_{CN} = 4.62\angle -83.13^\circ\,\text{A}$
$P = 1536.8\,\text{W}$

12.11: $\mathbf{V}_{AN} = \mathbf{V}_{an} = 138.6\angle 0^\circ\,\text{V}$, $\mathbf{V}_{BN} = \mathbf{V}_{bn} = 138.6\angle -120^\circ\,\text{V}$
$\mathbf{V}_{CN} = \mathbf{V}_{cn} = 138.6\angle 120^\circ\,\text{V}$, $\mathbf{i}_{AN} = 3.47\angle -53.13^\circ\,\text{A}$
$\mathbf{i}_{BN} = 3.47\angle -172.13^\circ\,\text{A}$, $\mathbf{i}_{CN} = 4.47\angle 66.87^\circ\,\text{A}$
$P = 865.7\,\text{W}$

12.12: $\mathbf{V}_{AN} = 138.6\angle 0^\circ\,\text{V}$, $\mathbf{V}_{BN} = 138.6\angle -120^\circ\,\text{V}$
$\mathbf{V}_{CN} = 138.6\angle 120^\circ\,\text{V}$, $\mathbf{V}_{AB} = 240\angle 30^\circ\text{V}$
$\mathbf{V}_{bc} = 240\angle -90^\circ\text{V}$, $\mathbf{V}_{AB} = 240\angle 30^\circ\text{V}$, $\mathbf{V}_{CA} = 240\angle 160^\circ\text{V}$
$\mathbf{i}_{AB} = 8\angle -6.87^\circ\,\text{A}$, $\mathbf{i}_{BC} = 8\angle -126.87^\circ\,\text{A}$,
$\mathbf{i}_{CA} = 8\angle 113.13^\circ\,\text{A}$, $P = 4608\,\text{W}$

12.13: $\mathbf{i}_{AB} = 4.80\underline{/13.74^\circ}$ A, $\mathbf{i}_{BC} = 4.80\underline{/-106.26^\circ}$ A
$\mathbf{i}_{CA} = 4.80\underline{/133.74^\circ}$ A, $P = 3317.8$ W

12.14: $\mathbf{V}_{an} = 138.6\underline{/0^\circ}$ V, $\mathbf{V}_{bn} = 138.6\underline{/-120^\circ}$ V
$\mathbf{V}_{an} = 138.6\underline{/120^\circ}$ V, $\mathbf{V}_{AB} = 240\underline{/30^\circ}$ V,
$\mathbf{V}_{BC} = 240\underline{/-90^\circ}$ V, $\mathbf{V}_{CA} = 240\underline{/150^\circ}$ V
P 2660.4 W

12.15: $P = 1496.5$ W

12.16: $\mathbf{V}_{AB} = 240\underline{/0^\circ}$ V, $\mathbf{V}_{BC} = 240\underline{/-120^\circ}$ V
$\mathbf{V}_{CA} = 240\underline{/120^\circ}$ V, $\mathbf{i}_{AB} = 8\underline{/-36.87^\circ}$ A,
$\mathbf{V}_{BC} = 8\underline{/-156.87^\circ}$ A, $\mathbf{V}_{CA} = 8\underline{/153.13^\circ}$ A
$P = 4608$ W

12.17: $P = 3317.8$ W

UNBALANCED SYSTEMS

12.18: $P = 2857.2$ W

12.19: $P = 1346.9$ W

12.20: $\mathbf{i}_b = 24.25\underline{/-150^\circ}$ A

12.21: $\mathbf{i}_1 = 15\underline{/-36.87^\circ}$ A, $\mathbf{i}_2 = 10\underline{/-173.13^\circ}$ A,
$\mathbf{i}_3 = 7.5\underline{/165^\circ}$ A, $\mathbf{i}_n = 9.74\underline{/57.96^\circ}$ A

12.22: $\mathbf{i}_1 = 15\underline{/-36.87^\circ}$ A. $\mathbf{i}_2 = 10\underline{/66.87^\circ}$ A,
$\mathbf{i}_3 = 7.5\underline{/-75^\circ}$ A, $\mathbf{i}_n = 19.21\underline{/158.47^\circ}$ A,

12.23: $P = 2694.3$ W

12.24: $PF = 0.8861$

12.25: $P = 3540$ W

12.26: $PF = 0.9909$

12.27: $P = 1055.9$ W