11. A loop in an electrical circuit is a closed path starting at a node and proceeding through circuit elements eventually returning to the starting point.

12. Kirchhoff's voltage law (KVL) states that the algebraic sum of the voltages in a loop must equal zero. If the positive polarity of a voltage is encountered first in going around the loop, the voltage carries a plus sign in the sum. On the other hand, if the negative polarity is encountered first, the voltage carries a minus sign.

13. Two elements are in parallel if both ends of one element are directly connected to corresponding ends of the other element. The voltages of parallel elements are identical.

14. The voltage between the ends of an ideal conductor is zero regardless of the current flowing through the conductor. All points in a circuit that are connected by ideal conductors can be considered as a single point.

15. An ideal independent voltage source maintains a specified voltage across its terminals independent of other elements that are connected to it and of the current flowing through it.

16. For a controlled voltage source, the voltage across the source terminals depends on other voltages or currents in the circuit. A voltage-controlled voltage source is a voltage source having a voltage equal to a constant times the voltage across a pair of terminals elsewhere in the network. A current-controlled voltage source is a voltage source having a voltage equal to a constant times the current through some other element in the circuit.

17. An ideal independent current source forces a specified current to flow through itself, independent of other elements that are connected to it and of the voltage across it.

18. For a controlled current source, the current depends on other voltages or currents in the circuit. A voltage-controlled current source produces a current equal to a constant times the voltage across a pair of terminals elsewhere in the network. A current-controlled current source produces a current equal to a constant times the current through some other element in the circuit.

9. For constant resistances, voltage is proportional to current. If the current and voltage references have the passive configuration, Ohm's law states that $v = Ri$. For references opposite to the passive configuration, $v = -Ri$.

Problems

Section 1.1: Overview of Electrical Engineering

P1.1. Broadly speaking, what are the two main objectives of electrical systems?

P1.2. List four reasons why other engineering students need to learn the fundamentals of electrical engineering.

P1.3. List eight subdivisions of electrical engineering.

P1.4. Write a few paragraphs describing an interesting application of electrical engineering in your field. Consult engineering journals and trade magazines such as the *IEEE Spectrum, Automotive Engineering, Chemical Engineering*, or *Civil Engineering* for ideas.

Section 1.2: Circuits, Currents, and Voltages

P1.5. Carefully define or explain the following terms in your own words (give units where appropriate): **a.** Electrical current. **b.** Voltage. **c.** An open switch. **d.** A closed switch. **e.** Direct current. **f.** Alternating current.

P1.6. In the fluid-flow analogy for electrical circuits, what is analogous to **a.** a conductor; **b.** an open switch; **c.** a resistance; **d.** a battery?

P1.7. The charge of an electron is -1.60×10^{-19} C. A current of 1 A flows in a wire carried by electrons. How many electrons pass through a cross section of the wire each second?

***P1.8.** The ends of a length of wire are labeled a and b. If the current in the wire is $i_{ab} = -5$ A, are electrons moving toward a or b? How much charge passes through a cross section of the wire in 3 seconds?

P1.9. The circuit element shown in Figure P1.9 has $v = 12$ V and $i_{ba} = -2$ A. What is the value of v_{ba}? Be sure to give the correct algebraic sign. What is the value of i? Is energy delivered to the element or taken from it?

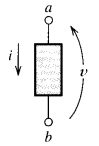

Figure P1.9

P1.10. To stop current from flowing through the headlight circuit of Figure 1.2, should the switch be open or closed? In the fluid-flow analogy for the circuit, would the valve corresponding to the switch be open or closed? What state for a valve, open or closed; is analogous to an open switch?

***P1.11.** The net charge through a cross section of a circuit element is given by $q(t) = 2 + 3t$ C. Find the current through the element.

P1.12. The current through a particular circuit element is given by $i(t) = 10\sin(200\pi t)$ A in which the angle is in radians. **a.** Sketch $i(t)$ to scale versus time. **b.** Determine the net charge that passes through the element between $t = 0$ and $t = 5$ ms. **c.** Repeat for the interval from $t = 0$ to $t = 10$ ms.

***P1.13.** The current through a given circuit element is given by

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

* Denotes that answers can be found on the OrCAD CD and on the website www.myengineeringlab.com

Find the net charge that passes through the element in the interval from $t = 0$ to $t = \infty$. (*Hint:* Current is the rate of flow of charge. Thus, to find charge, we must integrate current with respect to time.)

P1.14. The net charge through a cross section of a certain circuit element is given by

$$q(t) = 3 - 3e^{-2t} \text{ C}$$

Determine the current through the element.

P1.15. A copper wire has a diameter of 2.05 mm and carries a current of 15 A due solely to electrons. (These values are common in residential wiring.) Each electron has a charge of -1.60×10^{-19} C. Assume that the free-electron (these are the electrons capable of moving through the copper) concentration in copper is 10^{29} electrons/m^3. Find the average velocity of the electrons in the wire.

***P1.16.** A certain lead acid storage battery has a mass of 30 kg. Starting from a fully charged state, it can supply 5 amperes for 24 hours with a terminal voltage of 12 V before it is totally discharged. **a.** If the energy stored in the fully charged battery is used to lift the battery with 100-percent efficiency, what height is attained? Assume that the acceleration due to gravity is 9.8 m/s^2 and is constant with height. **b.** If the energy stored is used to accelerate the battery with 100-percent efficiency, what velocity is attained? **c.** Gasoline contains about 4.5×10^7 J/kg. Compare this with the energy content per unit mass for the fully charged battery.

P1.17. A circuit element having terminals a and b has $v_{ab} = 10$ V and $i_{ba} = 2$ A. Over a period of 20 seconds, how much charge moves through the element? If electrons carry the charge, which terminal do they enter? How much energy is transferred? Is it delivered to the element or taken from it?

P1.18. An electron moves through a voltage of 9 V from the positive polarity to the negative polarity. How much energy is transferred? Does the electron gain or lose energy?

***P1.19.** A typical "deep-cycle" battery (used for electric trolling motors for fishing boats) is capable of delivering 12 V and 5 A for a period of 10 hours. How much charge flows through the battery in this interval? How much energy is delivered by the battery?

Section 1.3: Power and Energy

P1.20. Define the term *passive reference configuration*. When do we have this configuration when using double subscript notation?

***P1.21.** Compute the power for each element shown in Figure P1.21. For each element, state whether energy is being absorbed by the element or supplied by it.

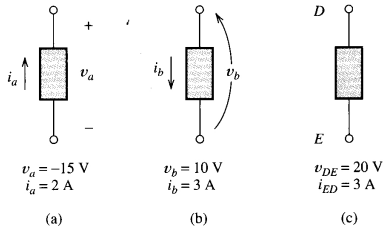

Figure P1.21

P1.22. The terminals of an electrical device are labeled a and b. If $v_{ab} = -10$ V, how much energy is exchanged when a charge of 3 C moves through the device from a to b? Is the energy delivered to the device or taken from the device?

***P1.23.** The terminals of a certain battery are labeled a and b. The battery voltage is $v_{ab} = 12$ V. To increase the chemical energy stored in the battery by 600 J, how much charge must move through the battery? Should electrons move from a to b or from b to a?

P1.24. The element shown in Figure P1.24 has $v(t) = 10$ V and $i(t) = 2e^{-t}$ A. Compute the power for the circuit element. Find the energy transferred between $t = 0$ and $t = \infty$. Is this energy absorbed by the element or supplied by it?

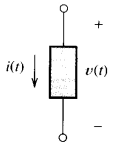

Figure P1.24

P1.25. The current and voltage of an electrical device are $i_{ab}(t) = 5$ A and $v_{ab}(t) = 10\sin(200\pi t)$ V in which the angle is in radians. **a.** Find the power delivered to the device and sketch it to scale versus time. **b.** Determine the energy delivered to the device for the interval from $t = 0$ to $t = 5$ ms. **c.** Repeat for the interval from $t = 0$ to $t = 10$ ms.

***P1.26.** Suppose that the cost of electrical energy is \$0.12 per kilowatt hour and that your electrical bill for 30 days is \$60. Assume that the power delivered is constant over the entire 30 days. What is the power in watts? If this power is supplied by a voltage of 120 V, what current flows? Part of your electrical load is a 60 W light that is on continuously. By what percentage can your energy consumption be reduced by turning this light off?

P1.27. Figure P1.27 shows an ammeter (AM) and voltmeter (VM) connected to measure the current and voltage, respectively, for circuit element A. When current actually enters the + terminal of the ammeter, the reading is positive, and when current leaves the + terminal, the reading is negative. If the actual voltage polarity is positive at the + terminal of the VM, the reading is positive; otherwise, it is negative. (Actually, for the connection shown, the ammeter reads the sum of the current in element A and the very small current taken by the voltmeter. For purposes of this problem, assume that the current taken by the voltmeter is negligible.) Find the power for element A and state whether energy is being delivered to element A or taken from it if **a.** the ammeter reading is +2 A and the voltmeter reading is +30 V; **b.** the ammeter

*P1.19. A typical "deep-cycle" battery (used for electric trolling motors for fishing boats) is capable of delivering 12 V and 5 A for a period of 10 hours. How much charge flows through the battery in this interval? How much energy is delivered by the battery?

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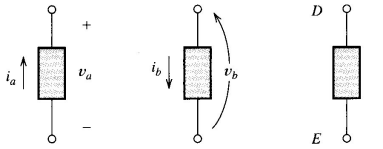

Figure P1.21

P1.22. The terminals of an electrical device are labeled a and b. If $v_{ab} = -10$ V, how much energy is exchanged when a charge of 3 C moves through the device from a to b? Is the energy delivered to the device or taken from the device?

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P1.24. The element shown in Figure P1.24 has $v(t) = 10$ V and $i(t) = 2e^{-t}$ A. Compute the power for the circuit element. Find the energy transferred between $t = 0$ and $t = \infty$. Is this energy absorbed by the element or supplied by it?

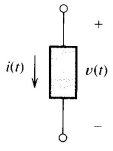

Figure P1.24

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P1.27. Figure P1.27 shows an ammeter (AM) and voltmeter (VM) connected to measure the current and voltage, respectively, for circuit element A. When current actually enters the + terminal of the ammeter, the reading is positive, and when current leaves the + terminal, the reading is negative. If the actual voltage polarity is positive at the + terminal of the VM, the reading is positive; otherwise, it is negative. (Actually, for the connection shown, the ammeter reads the sum of the current in element A and the very small current taken by the voltmeter. For purposes of this problem, assume that the current taken by the voltmeter is negligible.) Find the power for element A and state whether energy is being delivered to element A or taken from it if **a.** the ammeter reading is +2 A and the voltmeter reading is +30 V; **b.** the ammeter reading is −2 A and the voltmeter reading is +30 V; **c.** the ammeter reading is −2 A and the voltmeter reading is −30 V.

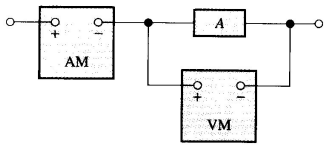

Figure P1.27

*P1.28. Repeat Problem P1.27 with the meters connected as shown in Figure P1.28.

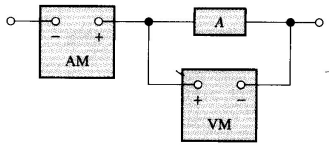

Figure P1.28

P1.29. A certain type of D-cell battery that costs \$0.50 is capable of producing 1.2 V and a current of 0.1 A for a period of 75 hours. Determine the cost of the energy delivered by this battery per kilowatt hour. (For comparison, the approximate cost of energy purchased from electric utilities in the United States is \$0.12 per kilowatt hour.)

P1.30. The electronics aboard a certain sailboat consume 50 W when operated from a 12.6-V source. If a certain fully charged deep-cycle lead acid storage battery is rated for 12.6 V and 100 ampere hours, for how many hours can the electronics be operated from the battery without recharging? (The ampere-hour rating of the battery is the operating time to discharge the battery multiplied by the current.) How much energy in kilowatt hours is initially stored in the battery? If the battery costs \$75 and has a life of 300 charge-discharge cycles, what is the cost of the energy in dollars per kilowatt

hour? Neglect the cost of recharging the battery.

Section 1.4: Kirchhoff's Current Law

P1.31. What is a *node* in an electrical circuit? Identify the nodes in the circuit of Figure P1.31. Keep in mind that all points connected by ideal conductors are considered to be a single node in electrical circuits.

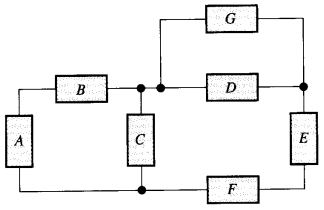

Figure P1.31

P1.32. State Kirchhoff's current law.

P1.33. Two electrical elements are connected in series. What can you say about the currents through the elements?

P1.34. Suppose that in the fluid-flow analogy for an electrical circuit the analog of electrical current is volumetric flow rate with units of cm^3/s. For a proper analogy to electrical circuits, must the fluid be compressible or incompressible? Must the walls of the pipes be elastic or inelastic? Explain your answers.

***P1.35.** Identify elements that are in series in the circuit of Figure P1.31.

P1.36. Consider the circuit shown in Figure P1.36. **a.** Which elements are in series? **b.** What is the relationship between i_d and i_c? **c.** Given that $i_a = 3$ A and $i_c = 1$ A, determine the values of i_b and i_d.

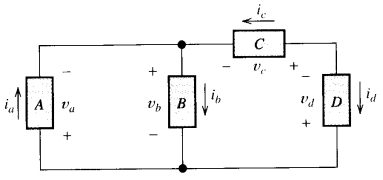

Figure P1.36

***P1.37.** Use KCL to find the values of i_a, i_c, and i_d for the circuit of Figure P1.37. Which elements are connected in series in this circuit?

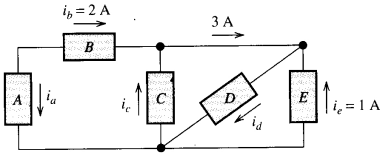

Figure P1.37

***P1.38.** Find the values of the other currents in Figure P1.38 if $i_a = 2$ A, $i_b = 3$ A, $i_d = -5$ A, and $i_h = 4$ A.

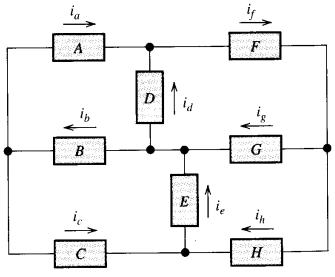

Figure P1.38

P1.39. Find the values of the other currents in Figure P1.38 if $i_a = -1$ A, $i_c = 3$ A, $i_g = 5$ A, and $i_h = 1$ A.

tion 1.5: Kirchhoff's Voltage Law

40. State Kirchhoff's voltage law.

41. Consider the circuit shown in Figure P1.36. **a.** Which elements are in parallel? **b.** What is the relationship between v_a and v_b? **c.** Given that $v_a = 2$ V and $v_d = -5$ V, determine the values of v_b and v_c.

42. Use KVL to solve for the voltages v_a, v_b, and v_c in Figure P1.42.

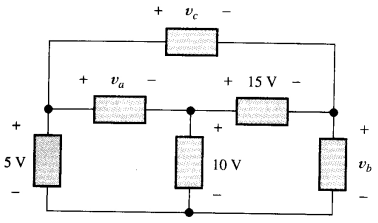

Figure P1.42

43. Solve for the other voltages shown in Figure P1.43 given that $v_a = 5$ V, $v_b = 7$ V, $v_f = -10$ V, and $v_h = 6$ V.

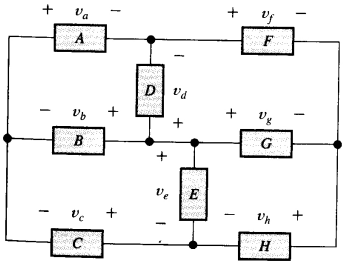

Figure P1.43

44. Use KVL and KCL to solve for the labeled currents and voltages in Figure P1.44. Compute the power for each element and show that power is conserved (i.e., the algebraic sum of the powers is zero).

*P1.60. Which of the following are self-contradictory combinations of circuit elements? **a.** A 12-V voltage source in parallel with a 2-A current source. **b.** A 2-A current source in series with a 3-A current source. **c.** A 2-A current source in parallel with a short circuit. **d.** A 2-A current source in series with an open circuit. **e.** A 5-V voltage source in parallel with a short circuit.

P1.61. Consider the circuit shown in Figure P1.61. Find the power for the voltage source and for the current source. Which source is absorbing power?

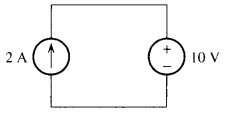

Figure P1.61

*P1.62. Consider the circuit shown in Figure P1.62. Find the current i_R flowing through the resistor. Find the power for each element in the circuit. Which elements are absorbing power?

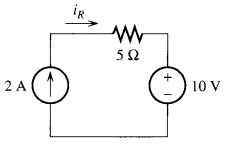

Figure P1.62

P1.63. Consider the circuit shown in Figure P1.63. Find the current i_R flowing through the resistor. Find the power for each element in the circuit. Which elements are receiving power?

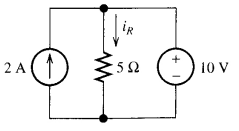

Figure P1.63

P1.64. Consider the circuit shown in Figure P1.64. Use Ohm's law, KVL, and KCL to find V_x.

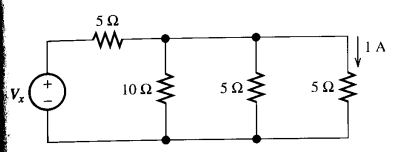

Figure P1.64

P1.65. Determine the value of I_x in the circuit shown in Figure P1.65.

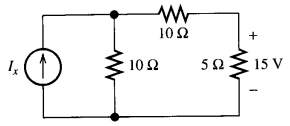

Figure P1.65

P1.66. Consider the circuit shown in Figure P1.66. **a.** Which elements are in series? **b.** Which elements are in parallel? **c.** Apply Ohm's and Kirchhoff's laws to solve for V_x.

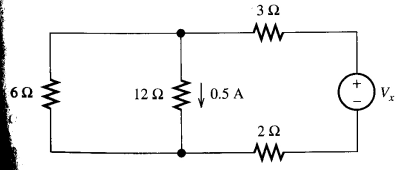

Figure P1.66

P1.67. The circuit shown in Figure P1.67 is the electrical model for an electronic megaphone, in which the 8-Ω resistance models a loudspeaker, the source V_x and the 5-kΩ resistance represent a microphone, and the remaining elements model an amplifier. Given that the power delivered to the 8-Ω resistance is 8 W, determine the current circulating in the right-hand loop of the circuit. Also, determine the value of the microphone voltage V_x.

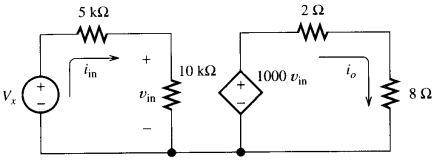

Figure P1.67

P1.68. Consider the circuit shown in Figure P1.68. **a.** Which elements are in series? **b.** Which elements are in parallel? **c.** Apply Ohm's and Kirchhoff's laws to solve for R_x.

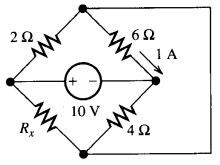

Figure P1.68

P1.69. Solve for the currents shown in Figure P1.69.

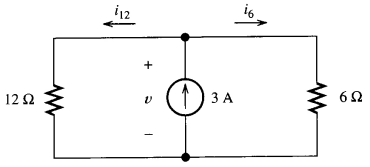

Figure P1.69

*P1.70. The circuit shown in Figure P1.70 contains a voltage-controlled voltage source. **a.** Use KVL to write an equation relating the voltages and solve for v_x. **b.** Use Ohm's law to find the current i_x. **c.** Find the power for each element in the circuit and verify that power is conserved.

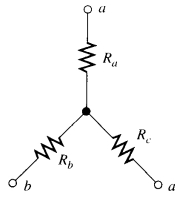

Figure P2.20

Section 2.2: Network Analysis by Using Series and Parallel Equivalents

P2.21. What are the steps in solving a circuit by network reduction (series/parallel combinations)? Does this method always provide the solution? Explain.

***P2.22.** Find the voltages v_1 and v_2 for the circuit shown in Figure P2.22 by combining resistances in series and parallel.

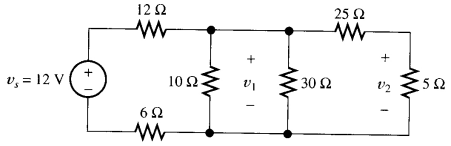

Figure P2.22

P2.23. Consider the circuit shown in Figure P2.22. Suppose that the value of v_s is adjusted until $v_2 = 5$ V. Determine the new value of v_s.

P2.24. Find the voltage v and the currents i_1 and i_2 for the circuit shown in Figure P2.24.

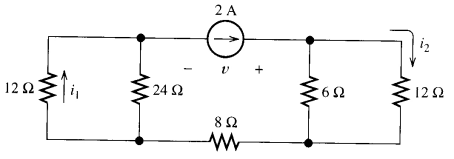

Figure P2.24

***P2.25.** Find the values of v and i in Figure P2.25.

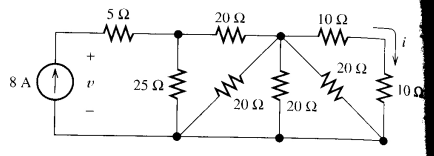

Figure P2.25

***P2.26.** Find the values of i_1 and i_2 in Figure P2.26.

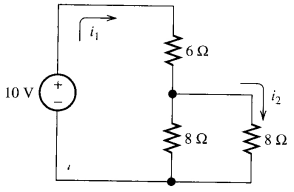

Figure P2.26

P2.27. Find the values of i_1 and i_2 in Figure P2.27.

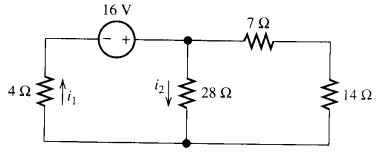

Figure P2.27

P2.28. Consider the circuit shown in Figure P2.28. Find the values of v_1, v_2, and v_{ab}.

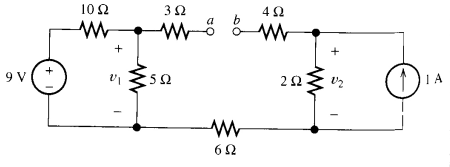

Figure P2.28

P2.29. Find the values of v_s, v_1, and i_2 in Figure P2.29.

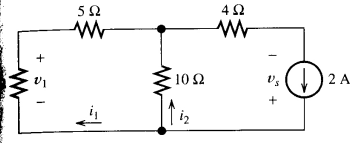

Figure P2.29

P2.30. The circuit of Figure P2.30 continues indefinitely to the right. Find the values of i_1, i_2, i_3, i_4, and i_{18}. (*Hint:* See Problem P2.9.)

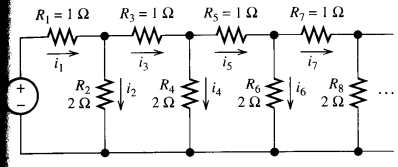

Figure P2.30

P2.31. Solve for the values of i_1, i_2, and the powers for the sources in Figure P2.31. Is the current source absorbing energy or delivering energy? Is the voltage source absorbing energy or delivering it?

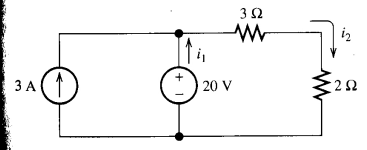

Figure P2.31

P2.32. Refer to the circuit shown in Figure P2.32. With the switch open, we have $v_2 = 5$ V. On

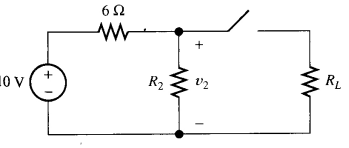

Figure P2.32