CHAPTER 1

Exercises

E1.1 Charge = Current × Time = (2 A) × (10 s) = 20 C

E1.2 $i(t) = \dfrac{dq(t)}{dt} = \dfrac{d}{dt}(0.01\sin(200t) = 0.01 \times 200\cos(200t) = 2\cos(200t)$ A

E1.3 Because i_2 has a positive value, positive charge moves in the same direction as the reference. Thus, positive charge moves downward in element *C*.

Because i_3 has a negative value, positive charge moves in the opposite direction to the reference. Thus positive charge moves upward in element *E*.

E1.4 Energy = Charge × Voltage = (2 C) × (20 V) = 40 J

Because v_{ab} is positive, the positive terminal is *a* and the negative terminal is *b*. Thus the charge moves from the negative terminal to the positive terminal, and energy is removed from the circuit element.

E1.5 i_{ab} enters terminal *a*. Furthermore, v_{ab} is positive at terminal *a*. Thus the current enters the positive reference, and we have the passive reference configuration.

E1.6 (a) $p_a(t) = v_a(t)i_a(t) = 20t^2$

$$w_a = \int_0^{10} p_a(t)dt = \int_0^{10} 20t^2 dt = \left.\frac{20t^3}{3}\right|_0^{10} = \frac{20t^3}{3} = 6667 \text{ J}$$

(b) Notice that the references are opposite to the passive sign convention. Thus we have:

$$p_b(t) = -v_b(t)i_b(t) = 20t - 200$$

$$w_b = \int_0^{10} p_b(t)dt = \int_0^{10} (20t - 200)dt = 10t^2 - 200t\Big|_0^{10} = -1000 \text{ J}$$

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E1.7 (a) Sum of currents leaving = Sum of currents entering

$i_a = 1 + 3 = 4$ A

(b) $2 = 1 + 3 + i_b \quad \Rightarrow \quad i_b = -2$ A

(c) $0 = 1 + i_c + 4 + 3 \quad \Rightarrow \quad i_c = -8$ A

E1.8 Elements *A* and *B* are in series. Also, elements *E*, *F*, and *G* are in series.

E1.9 Go clockwise around the loop consisting of elements *A*, *B*, and *C*:

$-3 - 5 + v_c = 0 \quad \Rightarrow \quad v_c = 8$ V

Then go clockwise around the loop composed of elements *C*, *D* and *E*:

$- v_c - (-10) + v_e = 0 \quad \Rightarrow \quad v_e = -2$ V

E1.10 Elements *E* and *F* are in parallel; elements *A* and *B* are in series.

E1.11 The resistance of a wire is given by $R = \frac{\rho L}{A}$. Using $A = \pi d^2 / 4$ and substituting values, we have:

$$9.6 = \frac{1.12 \times 10^{-6} \times L}{\pi (1.6 \times 10^{-3})^2 / 4} \quad \Rightarrow \quad L = 17.2 \text{ m}$$

E1.12 $P = V^2/R \quad \Rightarrow \quad R = V^2 / P = 144\ \Omega \quad \Rightarrow \quad I = V / R = 120 / 144 = 0.833$ A

E1.13 $P = V^2/R \quad \Rightarrow \quad V = \sqrt{PR} = \sqrt{0.25 \times 1000} = 15.8$ V

$I = V / R = 15.8 / 1000 = 15.8$ mA

E1.14 Using KCL at the top node of the circuit, we have $i_1 = i_2$. Then, using KVL going clockwise, we have $-v_1 - v_2 = 0$; but $v_1 = 25$ V, so we have $v_2 = -25$ V. Next we have $i_1 = i_2 = v_2/R = -1$ A. Finally, we have $P_R = v_2 i_2 = (-25) \times (-1) = 25$ W and $P_s = v_1 i_1 = (25) \times (-1) = -25$ W.

E1.15 At the top node we have $i_R = i_s = 2$A. By Ohm's law we have $v_R = R i_R = 80$ V. By KVL we have $v_s = v_R = 80$ V. Then $p_s = -v_s i_s = -160$ W (the minus sign is due to the fact that the references for v_s and i_s are opposite to the passive sign configuration). Also we have $P_R = v_R i_R = 160$ W.

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Problems

P1.1 Broadly, the two objectives of electrical systems are:
1. To gather, store, process, transport, and display information.
2. To distribute, store, and convert energy between various forms.

P1.2 Eight subdivisions of EE are:

1. Communication systems.
2. Computer systems.
3. Control systems.
4. Electromagnetics.
5. Electronics.
6. Photonics.
7. Power systems.
8. Signal Processing.

P1.3 Four important reasons that non-electrical engineering majors need to learn the fundamentals of EE are:

1. To pass the Fundamentals of Engineering Exam.
2. To be able to lead in the design of systems that contain electrical/electronic elements.
3. To be able to operate and maintain systems that contain electrical/electronic functional blocks.
4. To be able to communicate effectively with electrical engineers.

P1.4 Responses to this question are varied.

P1.5 (a) Electrical current is the time rate of flow of net charge through a conductor or circuit element. Its units are amperes, which are equivalent to coulombs per second.
(b) The voltage between two points in a circuit is the amount of energy transferred per unit of charge moving between the points. Voltage has units of volts, which are equivalent to joules per coulomb.
(c) The current through an open switch is zero. The voltage across the switch can be any value depending on the circuit.

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(d) The voltage across a closed switch is zero. The current through the switch can be any value depending of the circuit.
(e) Direct current is constant in magnitude and direction with respect to time.
(f) Alternating current varies either in magnitude or direction with time.

P1.6 (a) A conductor is analogous to a frictionless pipe.
(b) An open switch is analogous to a closed valve.
(c) A resistance is analogous to a constriction in a pipe or to a pipe with friction.
(d) A battery is analogous to a pump.

P1.7* The reference direction for i_{ab} points from *a* to *b*. Because i_{ab} has a negative value, the current is equivalent to positive charge moving opposite to the reference direction. Finally, since electrons have negative charge, they are moving in the reference direction (i.e., from *a* to *b*).
For a constant (dc) current, charge equals current times the time interval. Thus, $Q = (3\ A) \times (3\ s) = 9\ C$.

P1.8* $i(t) = \dfrac{dq(t)}{dt} = \dfrac{d}{dt}\left(2t + t^2\right) = 2 + 2t\ A$

P1.9* $Q = \int_0^\infty i(t)dt = \int_0^\infty 2e^{-t}dt = -2e^{-t}\ |_0^\infty = 2$ coulombs

P1.10* The charge flowing through the battery is

$$Q = (5 \text{ amperes}) \times (24 \times 3600 \text{ seconds}) = 432 \times 10^3 \text{ coulombs}$$

The stored energy is

$$\text{Energy} = QV = (432 \times 10^3) \times (12) = 5.184 \times 10^6 \text{ joules}$$

(a) Equating gravitational potential energy, which is mass times height times the acceleration due to gravity, to the energy stored in the battery and solving for the height, we have

$$h = \frac{\text{Energy}}{mg} = \frac{5.184 \times 10^6}{30 \times 9.8} = 17.6 \text{ km}$$

(b) Equating kinetic energy to stored energy and solving for velocity, we have

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$$v = \sqrt{\frac{2 \times \text{Energy}}{m}} = 587.9 \text{ m/s}$$

(c) The energy density of the battery is

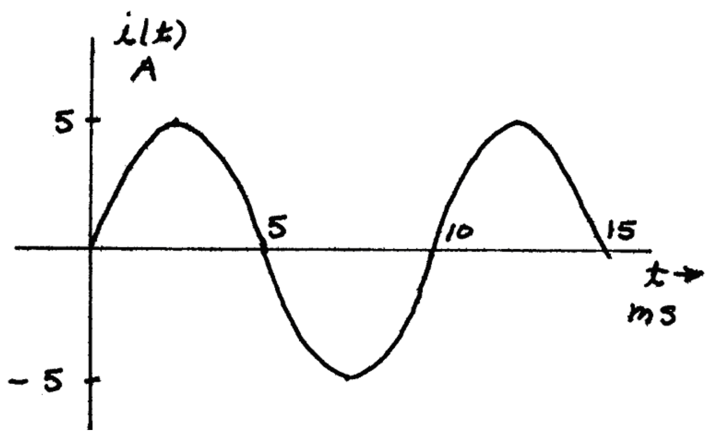
$$\frac{5.184 \times 10^6}{30} = 172.8 \times 10^3 \text{ J/kg}$$

which is about 0.384% of the energy density of gasoline.

P1.11* $Q = \text{current} \times \text{time} = (10 \text{ amperes}) \times (36{,}000 \text{ seconds}) = 3.6 \times 10^5 \text{ coulombs}$

$\text{Energy} = QV = (3.6 \times 10^5) \times (12.6) = 4.536 \times 10^6 \text{ joules}$

P1.12 (a) The sine function completes one cycle for each 2π radian increase in the angle. Because the angle is $200\pi t$, one cycle is completed for each time interval of 0.01 s. The sketch is:



(b) $Q = \int_0^{0.01} i(t)dt = \int_0^{0.01} 5\sin(200\pi t)dt = (5/200\pi)\cos(200\pi t)\Big|_0^{0.01}$

$= 0 \ C$

(b) $Q = \int_0^{0.015} i(t)dt = \int_0^{0.015} 5\sin(200\pi t)dt = (5/200\pi)\cos(200\pi t)\Big|_0^{0.015}$

$= 0.0159 \ C$

P1.13 To cause current to flow, we make contact between the conducting parts of the switch, and we say that the switch is closed. The corresponding fluid analogy is a valve that allows fluid to pass through. This corresponds to an open valve. Thus, an open valve is analogous to a closed switch.

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P1.14 $\text{Electrons per second} = \dfrac{5\text{ coulomb/s}}{1.60 \times 10^{-19}\text{ coulomb/electron}} = 3.125 \times 10^{19}$

P1.15 The positive reference for v is at the head of the arrow, which is terminal a. The positive reference for v_{ba} is terminal b. Thus, we have $v_{ba} = -v = -15$ V. Also, i is the current entering terminal a, and i_{ba} is the current leaving terminal a. Thus, we have $i_{ba} = -i = 3$ A. The true polarity is positive at terminal a, and the true current direction is entering terminal b. Thus, current enters the negative reference and energy is being taken from the device.

P1.16 $i(t) = \dfrac{dq(t)}{dt} = \dfrac{d}{dt}\left(2t + 3t^2\right) = 2 + 6t \text{ A}$

P1.17 The number of electrons passing through a cross section of the wire per second is

$$N = \frac{15\sqrt{2}}{1.6 \times 10^{-19}} = 1.326 \times 10^{20}\text{ electrons/second}$$

The volume of copper containing this number of electrons is

$$\text{volume} = \frac{1.326 \times 10^{20}}{10^{29}} = 1.326 \times 10^{-9}\ \text{m}^3$$

The cross sectional area of the wire is

$$A = \frac{\pi d^2}{4} = 3.301 \times 10^{-6}\ \text{m}^2$$

Finally, the average velocity of the electrons is

$$u = \frac{\text{volume}}{A} = 401.7\ \mu\text{m/s}$$

P1.18 The electron gains $1.6 \times 10^{-19} \times 120 = 19.2 \times 10^{-18}$ joules

P1.19 $Q = \text{current} \times \text{time} = (3\text{ amperes}) \times (2\text{ seconds}) = 6\text{ coulombs}$

The magnitude of the energy transferred is

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$\text{Energy} = QV = (6) \times (12) = 72 \text{ joules}$

Notice that i_{ab} is positive. If the current were carried by positive charge, it would be entering terminal *a*. Thus, electrons enter terminal *b*. The energy is taken from the element.

P1.20 If the current is referenced to flow into the positive reference for the voltage, we say that we have the passive reference configuration. Using double subscript notation, if the order of the subscripts are the same for the current and voltage, either *ab* or *ba*, we have a passive reference configuration.

P1.21* (a) $P = -v_a i_a = 30$ W   Energy is being absorbed by the element.

(b) $P = v_b i_b = 30$ W   Energy is being absorbed by the element.

(c) $P = -v_{DE} i_{ED} = -60$ W   Energy is being supplied by the element.

P1.22* $Q = w/V = (600 \text{ J})/(12 \text{ V}) = 50\ C$.

To increase the chemical energy stored in the battery, positive charge should move through the battery from the positive terminal to the negative terminal, in other words from *a* to *b*. Electrons move from *b* to *a*.

P1.23 The amount of energy is $W = QV = (4\ C) \times (25 \text{ V}) = 100$ J. Because the reference polarity for v_{ab} is positive at terminal *a* and v_{ab} is positive in value, terminal *a* is actually the positive terminal. Because the charge moves from the positive terminal to the negative terminal, energy is delivered to the device.

P1.24 Notice that the references are opposite to the passive configuration, so we have

$p(t) = -v(t)i(t) = 45e^{-2t}$ W

$$\text{Energy} = \int_0^\infty p(t)dt = (-45/2)e^{-2t} \Big|_0^\infty = 22.5 \text{ joules}$$

Because the energy is positive, the energy is delivered to the element.

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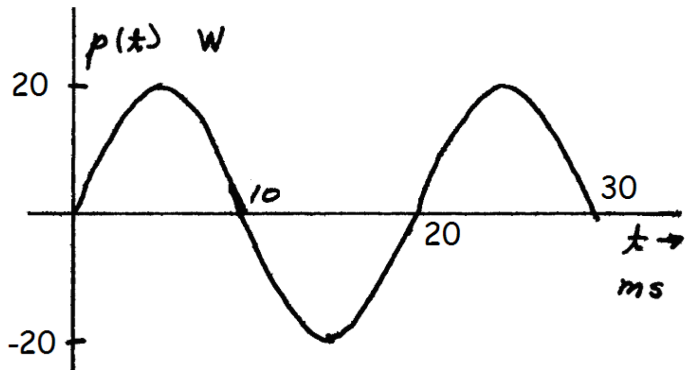
P1.25* $\text{Energy} = \dfrac{\text{Cost}}{\text{Rate}} = \dfrac{\$60}{0.12\ \$/\text{kWh}} = 500\ \text{kWh}$

$$P = \frac{\text{Energy}}{\text{Time}} = \frac{500\ \text{kWh}}{30 \times 24\ \text{h}} = 694.4\ \ \text{W} \qquad I = \frac{P}{V} = \frac{694.4}{120} = 5.787\ \ A$$

$$\text{Reduction} = \frac{60}{694.4} \times 100\% = 8.64\%$$

P1.26 (a) $p(t) = v_{ab} i_{ab} = 20\sin(100\pi t)\ \ \text{W}$



(b) $w = \int_0^{0.010} p(t)dt = \int_0^{0.010} 20\sin(100\pi t)dt = -(20/100\pi)\cos(100\pi t)\Big|_0^{0.010}$

$= 127.3\ \ \text{mJ}$

(c) $w = \int_0^{0.02} p(t)dt = \int_0^{0.02} 20\sin(100\pi t)dt = -(20/100\pi)\cos(100\pi t)\Big|_0^{0.02}$

$= 0\ \ \text{J}$

P1.27 The current supplied to the electronics is $i = p/v = 30/12.6 = 2.381\ A$. The ampere-hour rating of the battery is the operating time to discharge the battery multiplied by the current. Thus, the operating time is $T = 100/2.381 = 42\ \text{h}$. The energy delivered by the battery is $W = pT = 30(42) = 1260\ \text{Wh} = 1.26\ \text{kWh}$. Neglecting the cost of recharging, the cost of energy for 250 discharge cycles is $Cost = 95/(250 \times 1.26) = 0.302\ \$/\text{kWh}$.

***P1.28** (a) $P =$ 50 W taken from element A.
(b) $P =$ 50 W taken from element A.
(c) $P = 50$ W delivered to element A.

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P1.29 (a) $P = 50$ W delivered to element A.
(b) $P = 50$ W delivered to element A.
(c) $P =$ 50 W taken from element A.

P1.30 The power that can be delivered by the cell is $p = vi = 0.45$ W. In 10 hours, the energy delivered is $W = pT = 4.5$ Whr $= 0.0045$ kWhr. Thus, the unit cost of the energy is $Cost = (1.95)/(0.0045) = 433.33$ \$/kWhr which is 3611 times the typical cost of energy from electric utilities.

P1.31 A node is a point that joins two or more circuit elements. All points joined by ideal conductors are electrically equivalent. Thus, there are five nodes in the circuit at hand:

1: Joining elements A, B, C, and F
2: Joining elements B and D
3: Joining elements D and G
4: Joining elements E, F, and G
5: Joining elements A, C, and E

P1.32* At the node joining elements A and B, we have $i_a + i_b = 0$. Thus, $i_a = -2$ A. For the node at the top end of element C, we have $i_b + i_c = 3$. Thus, $i_c = 1$ A. Finally, at the top right-hand corner node, we have $3 + i_e = i_d$. Thus, $i_d = 4$ A. Elements A and B are in series.

P1.33 The currents in series-connected elements are equal.

P1.34 The sum of the currents entering a node equals the sum of the currents leaving. It is true because charge cannot collect at a node in an electrical circuit.

P1.35* Elements B, D and G are in series.

P1.36 For a proper fluid analogy to electric circuits, the fluid must be incompressible. Otherwise the fluid flow rate out of an element could be more or less than the inward flow. Similarly the pipes must be inelastic so the flow rate is the same at all points along each pipe.

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P1.37* We are given $i_a = 2$ A, $i_b = 3$ A, $i_d = -5$ A, and $i_h = 4$ A. Applying KCL, we find

$$i_c = i_b - i_a = 1\text{ A} \qquad i_e = i_c + i_h = 5\text{ A}$$

$$i_f = i_a + i_d = -3\text{ A} \qquad i_g = i_f - i_h = -7\text{ A}$$

P1.38 We are given $i_a = 2$ A, $i_c = -3$ A, $i_g = 6$ A, and $i_h = 1$ A. Applying KCL, we find

$$i_b = i_c + i_a = -1\text{ A} \qquad i_e = i_c + i_h = -2\text{ A}$$

$$i_d = i_f - i_a = 5\text{ A} \qquad i_f = i_g + i_h = 7\text{ A}$$

P1.39 (a) Elements *A* and *E* are in series, and elements *C* and *D* are in series.
(b) Because elements *C* and *D* are in series, the currents are equal in magnitude. However, because the reference directions are opposite, the algebraic signs of the current values are opposite. Thus, we have $i_c = -i_d$.
(c) At the node joining elements *A*, *B*, and *C*, we can write the KCL equation $i_b = i_a + i_c = 6 - 2 = 4$ A. Also, we found earlier that $i_d = -i_c = 2$ A.

P1.40 If one travels around a closed path adding the voltages for which one enters the positive reference and subtracting the voltages for which one enters the negative reference, the total is zero. KVL must be true for the law of conservation of energy to hold.

P1.41* Applying KCL and KVL, we have

$$i_c = i_a - i_d = 1\text{ A} \qquad i_b = -i_a = -2\text{ A}$$

$$v_b = v_d - v_a = -6\text{ V} \qquad v_c = v_d = 4\text{ V}$$

The power for each element is

$$P_A = -v_a i_a = -20\text{ W} \qquad P_B = v_b i_b = 12\text{ W}$$

$$P_C = v_c i_c = 4\text{ W} \qquad P_D = v_d i_d = 4\text{ W}$$

Thus, $P_A + P_B + P_C + P_D = 0$

P1.42* Summing voltages for the lower left-hand loop, we have $-5 + v_a + 10 = 0$, which yields $v_a = -5$ V. Then for the top-most loop, we have $v_c - 15 - v_a = 0$, which yields $v_c = 10$ V. Finally, writing KCL around the outside loop, we have $-5 + v_c + v_b = 0$, which yields $v_b = -5$ V.

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P1.43 We are given $v_a = 10$ V, $v_b = -3$ V, $v_f = 12$ V, and $v_h = 5$ V. Applying KVL, we find

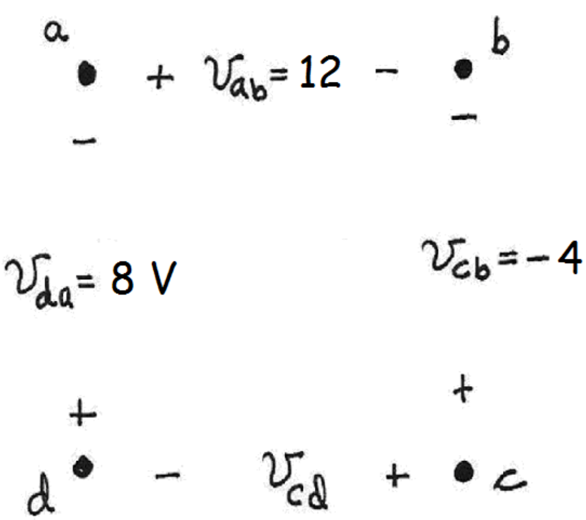
$$v_d = v_a + v_b = 7 \text{ V} \qquad v_c = -v_a - v_f - v_h = -27 \text{ V}$$
$$v_e = -v_a - v_c + v_d = 24 \text{ V} \qquad v_g = v_e - v_h = 19 \text{ V}$$

P1.44 (a) Elements *A* and *C* are in parallel.
(b) Because elements *A* and *C* are in parallel, the voltages are equal in magnitude. However because the reference polarities are opposite, the algebraic signs of the voltage values are opposite. Thus, we have $v_A = -v_C$.
(c) Writing a KVL equation while going clockwise around the loop composed of elements *A, E,* and *F*, we obtain $v_A + v_F - v_E = 0$. Solving for v_F and substituting values, we find $v_F = -5$ V. Also, we have $v_C = -v_A = -4$ V.

P1.45 (a) In Figure P1.32, elements *C*, *D*, and *E* are in parallel.
(b) In Figure P1.43, no element is in parallel with another element.

P1.46 There are two nodes; one at the center of the diagram and the other at the outer periphery of the circuit. Elements *A*, *B*, *C*, and *D* are in parallel. No elements are in series.

P1.47 The points and the voltages specified in the problem statement are:



Applying KVL to the loop *abca*, substituting values and solving, we obtain:

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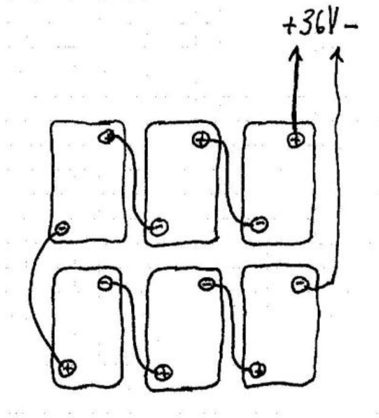
$$v_{ab} - v_{cb} - v_{ac} = 0$$
$$12 + 4 - v_{ac} = 0 \qquad v_{ac} = 16 \text{ V}$$

Similiarly, applying KVL to the loop *abcda*, substituting values and solving, we obtain:

$$v_{ab} - v_{cb} + v_{cd} + v_{da} = 0$$
$$12 + 4 + v_{cd} + 8 = 0$$
$$v_{cd} = -24 \text{ V}$$

P1.48 Six batteries are needed and they need to be connected in series. A typical configuration looking down on the tops of the batteries is shown:



P1.49 Provided that the current reference points into the positive voltage reference, the voltage across a resistance equals the current through the resistance times the resistance. On the other hand, if the current reference points into the negative voltage reference, the voltage equals the negative of the product of the current and the resistance.

P1.50 (a) The voltage between any two points of an ideal conductor is zero regardless of the current flowing.

(b) An ideal voltage source maintains a specified voltage across its terminals.

(c) An ideal current source maintains a specified current through itself.

(d) The voltage across a short circuit is zero regardless of the current flowing. When an ideal conductor is connected between two points, we say that the points are shorted together.

(e) The current through an open circuit is zero regardless of the voltage.

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P1.51 Four types of dependent sources and the units for their gain constants are:

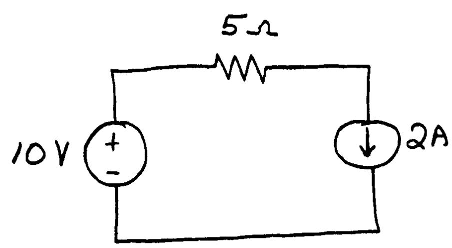
1. Voltage-controlled voltage sources. V/V or unitless.
2. Voltage-controlled current sources. A/V or siemens.
3. Current-controlled voltage sources. V/A or ohms.
4. Current-controlled current sources. A/A or unitless.

P1.52 (a) The resistance of the copper wire is given by $R_{Cu} = \rho_{Cu} L/A$, and the resistance of the aluminum wire is $R_{Al} = \rho_{Al} L/A$. Taking the ratios of the respective sides of these equations yields $R_{Al}/R_{Cu} = \rho_{Al}/\rho_{Cu}$.

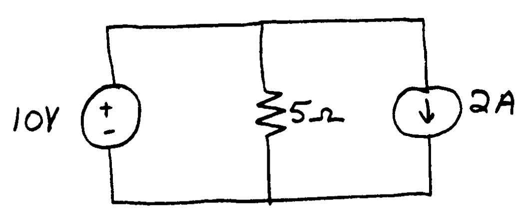
(b) Solving for R_{Al} and substituting values, we have

$$\begin{aligned} R_{Al} &= R_{Cu}\rho_{Al}/\rho_{Cu} \\ &= (1.5)\times(2.73\times10^{-8})/(1.72\times10^{-8}) \\ &= 2.38\ \Omega \end{aligned}$$

P1.53*



P1.54



P1.55 Equation 1.10 gives the resistance as

$$R = \frac{\rho L}{A}$$

(a) Thus, if the length of the wire is doubled, the resistance doubles to $20\,\Omega$.

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(b) If the diameter of the wire is doubled, the cross sectional area A is increased by a factor of four. Thus, the resistance is decreased by a factor of four to 2.5 Ω.

P1.56 The resistance is proportional to the resistivity and inversely proportional to the square of the wire diameter. Thus, the diameter of the aluminum wire must be

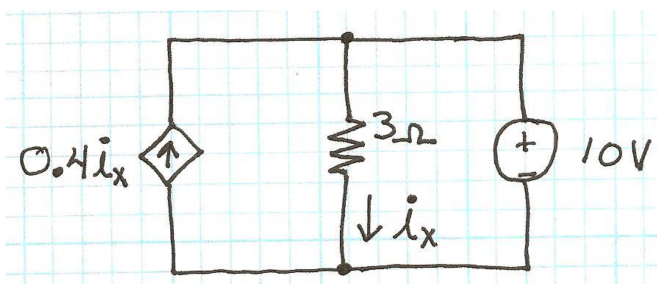
$$\sqrt{\rho_{Al} / \rho_{Cu}} = \sqrt{(2.73 \times 10^{-8}) / (1.72 \times 10^{-8})} = 1.250$$

times the diameter of the copper wire.

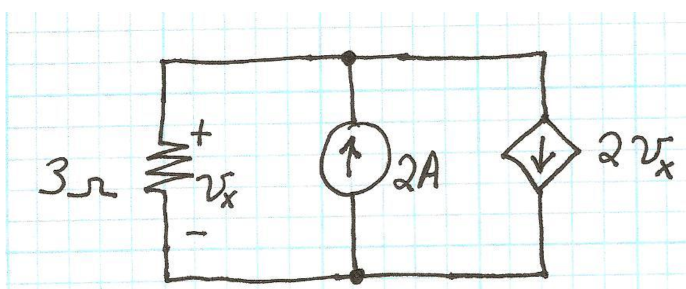
P1.57* $R = \dfrac{(V_1)^2}{P_1} = \dfrac{100^2}{100} = 100\ \Omega$

$P_2 = \dfrac{(V_2)^2}{R} = \dfrac{90^2}{100} = 81\text{ W}$ for a 19% reduction in power

P1.58



P1.59



P1.60 The power delivered to the resistor is

$$p(t) = i^2(t)R = 1000\exp(-4t)$$

and the energy delivered is

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$$w = \int_0^\infty p(t)dt = \int_0^\infty 1000 \exp(-4t)dt = \left[-250 \exp(-4t)\right]_0^\infty = 250 \text{ J}$$

P1.61 The power delivered to the resistor is

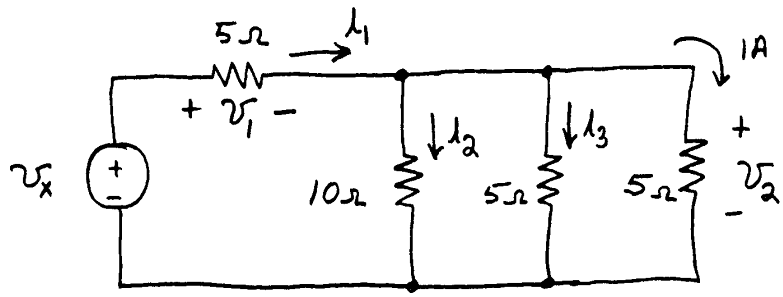
$$p(t) = v^2(t)/R = 48\cos^2(2\pi t) = 24 + 24\cos(4\pi t)$$

and the energy delivered is

$$w = \int_0^2 p(t)dt = \int_0^2 [24 + 24\cos(4\pi t)]dt = \left[24t + \frac{24}{4\pi}\sin(4\pi t)\right]_0^2 = 48 \text{ J}$$

P1.62* (a) Not contradictory.
(b) A 2-A current source in series with a 3-A current source is contradictory because the currents in series elements must be equal.
(c) Not contradictory.
(d) A 2-A current source in series with an open circuit is contradictory because the current through a short circuit is zero by definition and currents in series elements must be equal.
(e) A 5-V voltage source in parallel with a short circuit is contradictory because the voltages across parallel elements must be equal and the voltage across a short circuit is zero by definition.

P1.63*



Applying Ohm's law, we have $v_2 = (5\,\Omega)\times(1\,A) = 5\,V$. However, v_2 is the voltage across all three resistors that are in parallel. Thus, $i_3 = \frac{v_2}{5} = 1\,A$, and $i_2 = \frac{v_2}{10} = 0.5\,A$. Applying KCL, we have $i_1 = i_2 + i_3 + 1 = 2.5\,A$. By Ohm's law: $v_1 = 5i_1 = 12.5\,V$. Finally using KVL, we have $v_x = v_1 + v_2 = 17.5\,V$.

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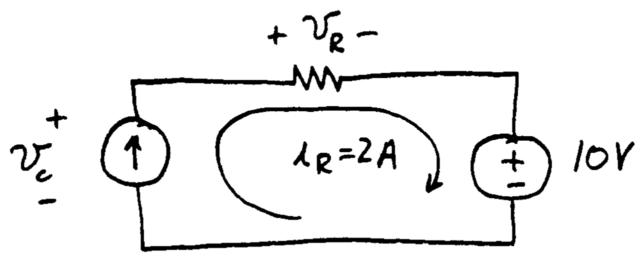
P1.64*



As shown above, the 2 A current circulates clockwise through all three elements in the circuit. Applying KVL, we have

$$v_c = v_R + 10 = 5i_R + 10 = 20\text{ V}$$

$P_{current-source} = -v_c i_R = -40$ W. Thus, the current source delivers power.

$P_R = (i_R)^2 R = 2^2 \times 5 = 20$ W. The resistor absorbs power.

$P_{voltage-source} = 10 \times i_R = 20$ W. The voltage source absorbs power.

P1.65 (a) The voltage across the voltage source is 10 V independent of the current. The reference direction for v_{ab} is opposite to that of the source. Thus, we have $v_{ab} = -10$ which plots as a vertical line in the i_{ab} versus v_{ab} plane.

(b) Ohm's law gives $i_{ab} = v_{ab}/5$.

(c) The current source has $i_{ab} = 1$ A independent of v_{ab}, which plots as a horizontal line in the i_{ab} versus v_{ab} plane.

(d) Applying Ohm's law and KVL, we obtain $v_{ab} = 10i_{ab} + 4$ which is equivalent to $i_{ab} = (v_{ab} - 4)/10$

(e) Applying KCL and Ohm's law, we obtain $i_{ab} = (v_{ab}/5) + 1.5$.

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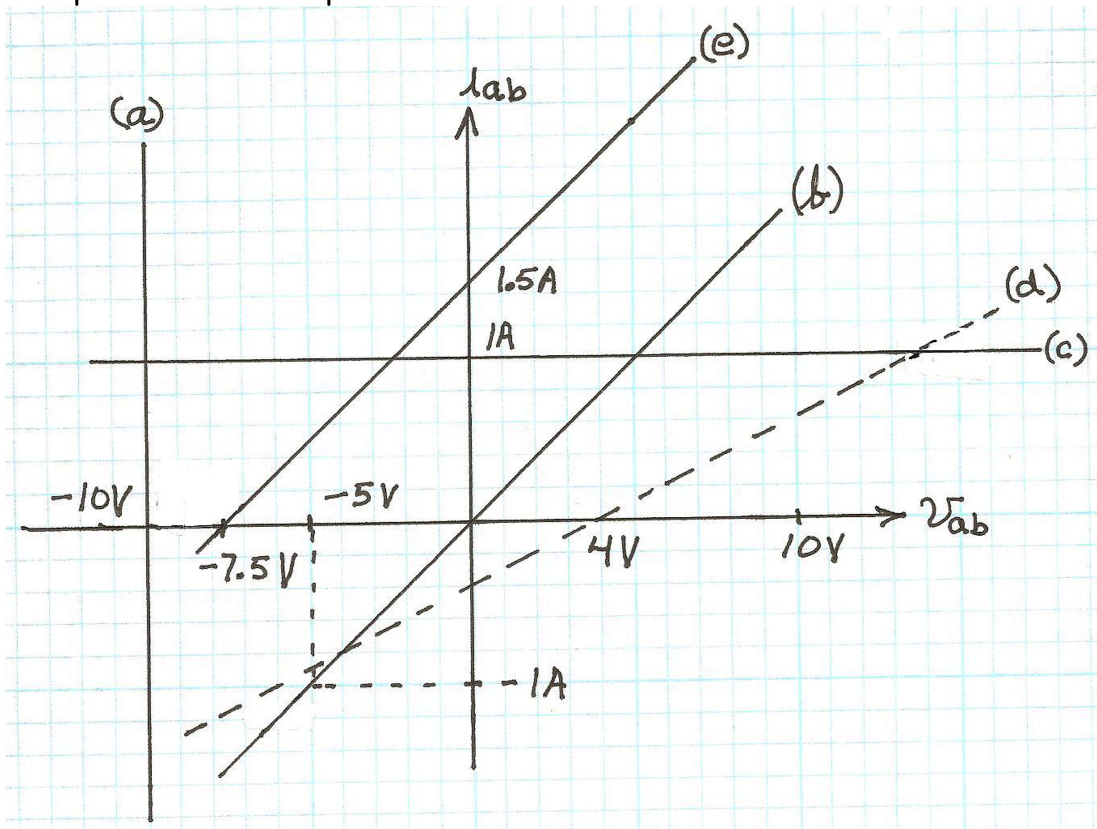
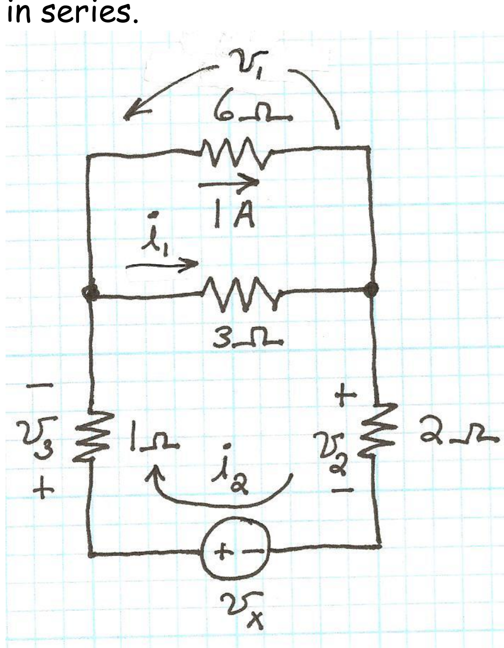
The plots for all five parts are shown.



P1.66 (a) The 1-Ω resistance, the 2-Ω resistance, and the voltage source v_x are in series.



(b) The 6-Ω resistance and the 3-Ω resistance are in parallel.

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(c) Refer to the sketch of the circuit. Applying Ohm's law to the 6-Ω resistance, we determine that $v_1 = 6$ V. Then, applying Ohm's law to the 3-Ω resistance, we have $i_1 = 2$ A. Next, KCL yields $i_2 = 3$ A. Continuing, we use Ohm's law to find that $v_2 = 6$ V and $v_3 = 3$ V. Finally, applying KVL, we have $v_x = v_3 + v_1 + v_2 = 15$ V.

P1.67 The power for each element is 120 W in magnitude. The voltage source absorbs power and the current source delivers it.

P1.68 This is a parallel circuit, and the voltage across each element is 12 V positive at the bottom end. Thus, the current flowing through the resistor is

$$i_R = -\frac{12\text{ V}}{8\,\Omega} = -1.5\text{ A}$$

(Notice that current actually flows upward through the resistor.) Applying KCL, we find that the current through the voltage source is 5.5 A flowing downward. Computing power for each element, we find

$$P_{current-source} = 48\text{ W}$$

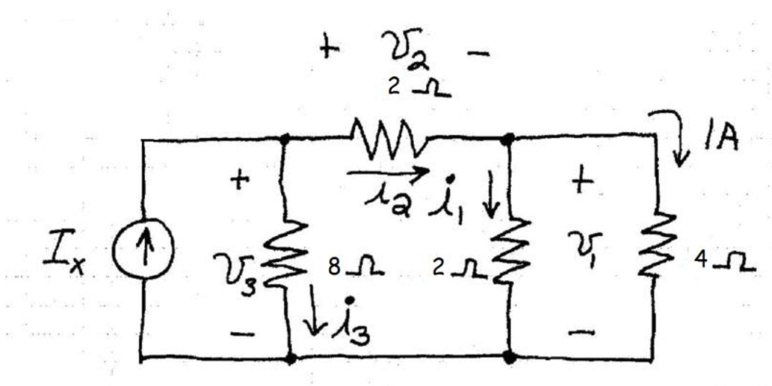
$$P_R = (i_R)^2 R = 18\text{ W}$$

Thus, the current source and the resistance absorb power.

$$P_{voltage-source} = -66\text{ W}$$

The voltage source delivers power.

P1.69



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Ohm's law for the 4-Ω resistor yields: $v_1 = 4$ V. Then, we have $i_1 = v_1 / 2 = 2$ A. Next, KCL yields $i_2 = i_1 + 1 = 3$ A. Then for the top 2-Ω resistor, we have $v_2 = 2i_2 = 6$ V. Using KVL, we have $v_3 = v_1 + v_2 = 10$ V. Next, applying Ohms law, we obtain $i_3 = v_3 / 8 = 1.25$ A. Finally applying KCL, we have $I_x = i_2 + i_3 = 4.25$ A.

P1.70* (a) Applying KVL, we have $10 = v_x + 5v_x$, which yields $v_x = 10/6 = 1.667$ V

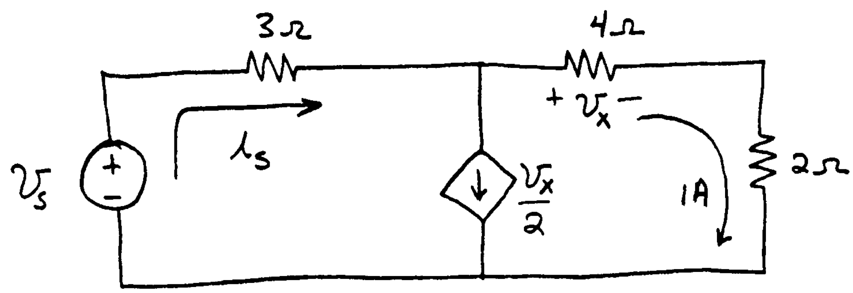
(b) $i_x = v_x / 3 = 0.5556$ A

(c) $P_{voltage-source} = -10i_x = -5.556$ W. (This represents power delivered by the voltage source.)

$$P_R = 3(i_x)^2 = 0.926 \text{ W (absorbed)}$$

$$P_{controlled-source} = 5v_x i_x = 4.63 \text{ W (absorbed)}$$

P1.71* We have a voltage-controlled current source in this circuit.



$v_x = (4\,\Omega) \times (1\text{ A}) = 4$ V $\qquad i_s = v_x / 2 + 1 = 3$ A

Applying KVL around the outside of the circuit, we have:

$$v_s = 3i_s + 4 + 2 = 15 \text{ V}$$

P1.72 (a) No elements are in series.

(b) R_x and the 2-Ω resistor are in parallel. Also, the 4-Ω resistor and the 8-Ω resistor are in parallel. The voltages across the parallel elements are the same as shown in this figure:

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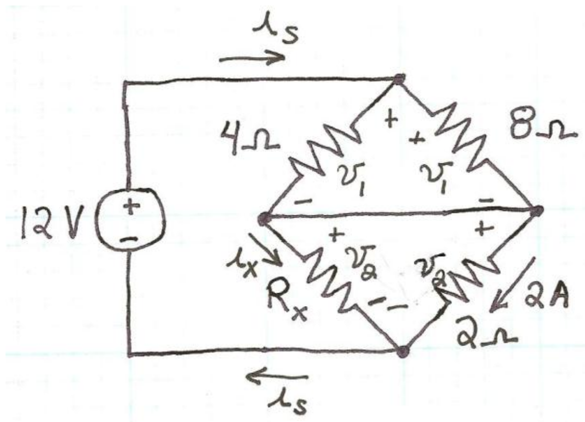
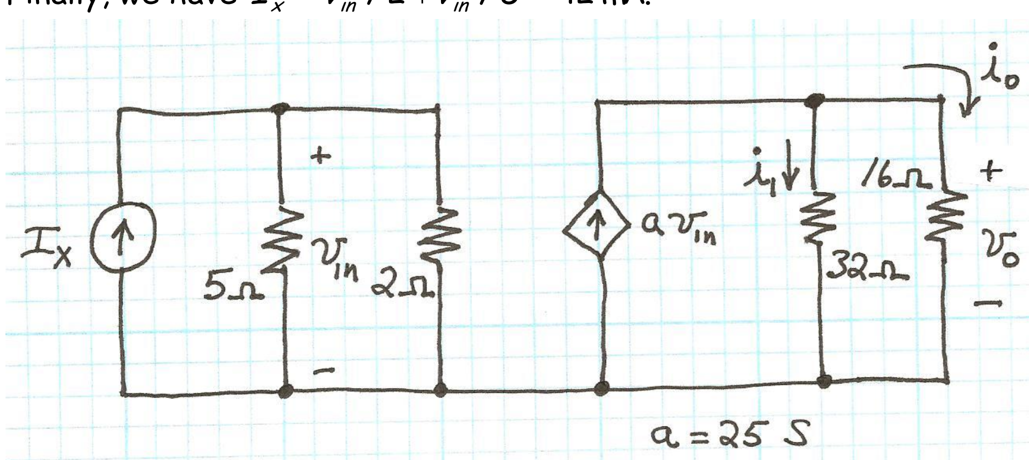


(c) $v_2 = 2 \times 2 = 4$ V
$v_1 = 12 - v_2 = 8$ V

$$i_s = \frac{v_1}{4} + \frac{v_1}{8} = 3\,A$$
$i_x = i_s - 2 = 1\,A$
$R_x = v_2 / i_x = 4\,\Omega$

P1.73 $i_2 = v/2$ $\quad i_8 = v/8$ $\quad i_2 + i_8 = v/2 + v/8 = 10$
$v = 16$ V $\quad i_2 = 8\,A$ $\quad i_8 = 2\,A$

P1.74 This is a voltage-controlled current source. First, we have $v_o = \sqrt{P_o 16} = 16$ V. Then, we have $i_1 = v_o / 32 = 0.5\,A$ and $i_o = v_o / 8 = 1\,A$. KCL gives $25 v_{in} = i_1 + i_o = 1.5$ A. Thus, we have $v_{in} = 1.5 / 25 = 60$ mV.
Finally, we have $I_x = v_{in}/2 + v_{in}/5 = 42$ mA.



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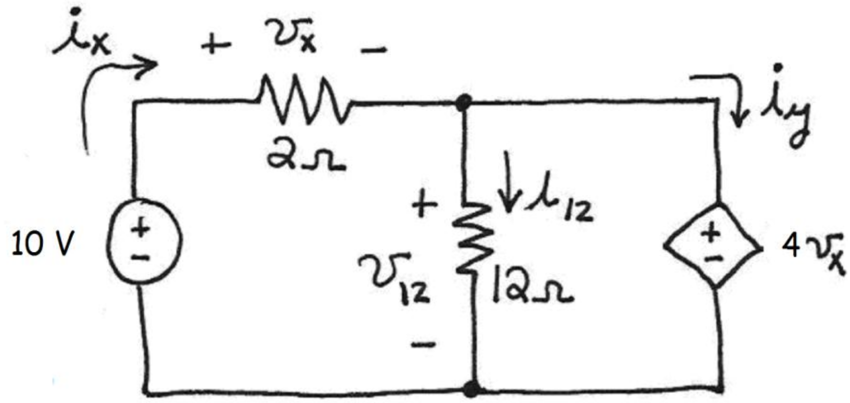
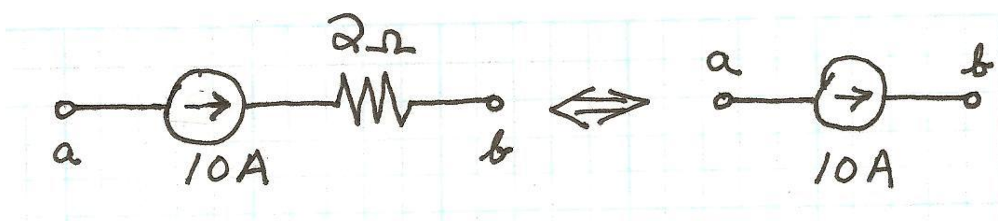
P1.75 This circuit contains a voltage-controlled voltage source.



Applying KVL around the periphery of the circuit, we have $-10 + v_x + 4v_x = 0$, which yields $v_x = 2$ V. Then, we have $v_{12} = 4v_x = 8$ V. Using Ohm's law we obtain $i_{12} = v_{12}/12 = 0.667$ A and $i_x = v_x/2 = 1$ A. Then KCL applied to the node at the top of the 12-Ω resistor gives $i_x = i_{12} + i_y$ which yields $i_y = 0.333$ A.

P1.76 Consider the series combination shown below on the left. Because the current for series elements must be the same and the current for the current source is 10 A by definition, the current flowing from *a* to *b* is 10 A. Notice that the current is not affected by the 2-Ω resistance in series. Thus, the series combination is equivalent to a simple current source as far as anything connected to terminals *a* and *b* is concerned. The voltage v_{ab} depends on what else is connected between *a* and *b*.



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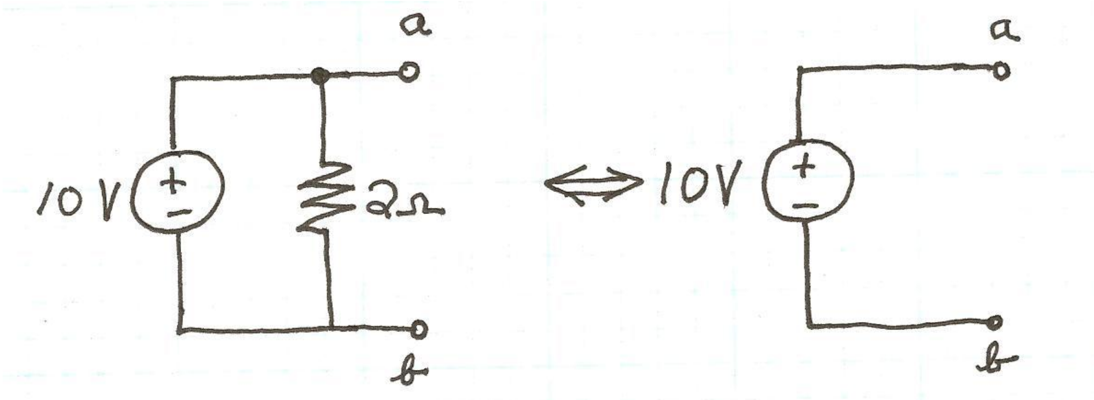
P1.77 Consider the parallel combination shown below on the left. Because the voltage for parallel elements must be the same, the voltage v_{ab} must be 10 V. Notice that v_{ab} is not affected by the resistance. Thus, the parallel combination is equivalent to a simple voltage source as far as anything connected to terminals *a* and *b* is concerned. The current i_{ab} depends on what else is connected between *a* and *b*.



P1.78 (a) $4 = i_1 + i_2$

(b) $i_1 = v/15$

$i_2 = v/10$

(c) $4 = v/15 + v/10$

$v = 24\text{ V}$

(d) $P_{currentsource} = -I_s v = -96\text{ W}$ (Power is supplied by the source.)

$P_1 = v^2/R_1 = 38.4\text{ W}$ (Power is absorbed by R_1.)

$P_2 = v^2/R_2 = 57.6\text{ W}$ (Power is absorbed by R_2.)

P1.79 (a) $v = v_1 + v_2$

(b) $v_1 = R_1 I_s = 6\text{ V}$

$v_2 = R_2 I_s = 8\text{ V}$

(c) $v = 14\text{ V}$

(d) $P_{current-source} = -vI_s = -28\text{ W}$. (Power delivered by the source.)

$P_1 = R_1 I_s^2 = 12\text{ W}$ (Power absorbed by R_1.)

$P_2 = R_2 I_s^2 = 16\text{ W}$ (Power absorbed by R_2.)

Notice that power is conserved.

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P1.80 The source labeled I_s is an independent current source. The source labeled ai_x is a current-controlled current source. Applying ohm's law to the 20-Ω resistance gives:

$$i_x = 20\text{ V}/20\ \Omega = 1\text{ A}$$

Applying KCL for the node at the top end of the controlled current source:

$$I_s = 0.5i_x + i_x = 1.5i_x = 1.5\text{ A}$$

Then KVL around the outside of the circuit yields

$$v = 15I_s + 10i_x + 20 = 52.5\text{ V}$$

P1.81 (a) $i_3 = i_1 + i_2$

(b) $-v_1 i_3 + v_2 i_3 + v_4 i_1 + v_3 i_2 + v_5 i_2 = 0$

(c) $(-v_1 + v_2 + v_4)i_1 + (-v_1 + v_2 + v_3 + v_5)i_2 = 0$

(d) Setting the coefficients of i_1 and i_2 to zero, we have

$$-v_1 + v_2 + v_4 = 0 \quad \text{and} \quad -v_1 + v_2 + v_3 + v_5 = 0$$

which are the KVL equations written around the left-hand loop and around the outside of the network, respectively.

P1.82 The source labeled 24 V is an independent voltage source. The source labeled ai_x is a current-controlled voltage source.
Applying Ohm's law and KVL, we have $-24 + 5i_x + 3i_x = 0$. Solving, we obtain $i_x = 3\text{ A}$.

Practice Test

T1.1 (a) 4; (b) 7; (c) 16; (d) 18; (e) 1; (f) 2; (g) 8; (h) 3; (i) 5; (j) 15; (k) 6; (l) 11;

(m) 13; (n) 9; (o) 14.

T1.2 (a) The current $I_s = 3$ A circulates clockwise through the elements entering the resistance at the negative reference for v_R. Thus, we have $v_R = -I_s R = -6$ V.
(b) Because I_s enters the negative reference for V_s, we have $P_V = -V_s I_s = -30$ W. Because the result is negative, the voltage source is delivering energy.
(c) The circuit has three nodes, one on each of the top corners and one along the bottom of the circuit.

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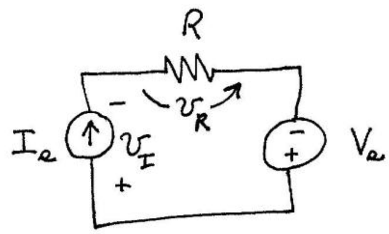
(d) First, we must find the voltage v_I across the current source. We choose the reference shown:



Then, going around the circuit counterclockwise, we have $-v_I + V_s + v_R = 0$, which yields $v_I = V_s + v_R = 10 - 6 = 4$ V. Next, the power for the current source is $P_I = I_s v_I = 12$ W. Because the result is positive, the current source is absorbing energy.

Alternatively, we could compute the power delivered to the resistor as $P_R = I_s^2 R = 18$ W. Then, because we must have a total power of zero for the entire circuit, we have $P_I = -P_V - P_R = 30 - 18 = 12$ W.

T1.3 (a) The currents flowing downward through the resistances are v_{ab}/R_1 and v_{ab}/R_2. Then, the KCL equation for node a (or node b) is

$$I_2 = I_1 + \frac{v_{ab}}{R_1} + \frac{v_{ab}}{R_2}$$

Substituting the values given in the question and solving yields $v_{ab} = -8$ V.
(b) The power for current source I_1 is $P_{I1} = v_{ab} I_1 = -8 \times 3 = -24$ W. Because the result is negative we know that energy is supplied by this current source.
The power for current source I_2 is $P_{I2} = -v_{ab} I_2 = 8 \times 1 = 8$ W. Because the result is positive, we know that energy is absorbed by this current source.
(c) The power absorbed by R_1 is $P_{R1} = v_{ab}^2 / R_1 = (-8)^2 / 12 = 5.33$ W. The power absorbed by R_2 is $P_{R2} = v_{ab}^2 / R_2 = (-8)^2 / 6 = 10.67$ W.

T1.4 (a) Applying KVL, we have $-V_s + v_1 + v_2 = 0$. Substituting values given in the problem and solving we find $v_1 = 8$ V.
(b) Then applying Ohm's law, we have $i = v_1 / R_1 = 8 / 4 = 2$ A.
(c) Again applying Ohm's law, we have $R_2 = v_2 / i = 4 / 2 = 2\,\Omega$.

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T1.5 Applying KVL, we have $-V_s + v_x = 0$. Thus, $v_x = V_s = 15$ V. Next Ohm's law gives $i_x = v_x / R = 15/10 = 1.5$ A. Finally, KCL yields
$i_{sc} = i_x - av_x = 1.5 - 0.3 \times 15 = -3$ A.

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