Chapter 11: Electricity and Its Production

Mini Investigation: Building an LED Circuit, page 503

A. When one cell was connected to the LED, the LED did not light no matter which way they were connected.
B. When two cells and the LED were connected, the LED did light but only when connected in one way.
C. The electricity does flow in a particular direction. If it flowed in either direction, the LED would have lit regardless of the way it was connected. Step 2 of the investigation supported my statements.

Section 11.1: Electrical Energy and Power Plants

Tutorial 1 Practice, page 505

1. Given: ΔE = 120 J; Δt = 25 s
Required: P
Analysis: $P = \dfrac{\Delta E}{\Delta t}$
Solution:

$$\begin{aligned} P &= \frac{\Delta E}{\Delta t} \\ &= \frac{120\ \text{J}}{25\ \text{s}} \\ P &= 4.8\ \text{W} \end{aligned}$$

Statement: The power rating of the digital camera is 4.8 W.
2. Given: ΔE = 198 000 J; Δt = 15 min
Required: P
Analysis: $P = \dfrac{\Delta E}{\Delta t}$
Solution: First convert time to seconds to get the answer in joules per second (J/s), or watts (W):

$$\Delta t = 15\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}}$$
$$\Delta t = 900\ \text{s}$$

$$\begin{aligned} P &= \frac{\Delta E}{\Delta t} \\ &= \frac{198\ 000\ \text{J}}{900\ \text{s}} \\ P &= 220\ \text{W} \end{aligned}$$

Statement: The power required for the hair dryer to transform the energy is 220 W.

Tutorial 2 Practice, page 506

1. Given: P = 7.0 W; Δt = 24 h
Required: ΔE
Analysis: $P = \dfrac{\Delta E}{\Delta t}$

$$\Delta E = P\Delta t$$

Solution: Convert time to seconds to get the answer in joules:

$$\Delta t = 24\ \cancel{\text{h}} \times \frac{3600\ \text{s}}{1\ \cancel{\text{h}}}$$
$$\Delta t = 86\ 400\ \text{s}$$

$$\begin{aligned} \Delta E &= (7.0\ \text{W})(86\ 400\ \text{s}) \\ &= \left(7.0\frac{\text{J}}{\cancel{\text{s}}}\right)(86\ 400\ \cancel{\text{s}}) \\ &= 6.048 \times 10^5\ \text{J}\ \text{(two extra digits carried)} \\ \Delta E &= 6.0 \times 10^5\ \text{J} \end{aligned}$$

Statement: The compact fluorescent light bulb needs 6.0×10^5 J of energy to operate for 24 h.
2. To convert the answer from Question 1 to kilowatt hours, convert from joules:

$$6.048 \times 10^5\ \cancel{\text{J}} \times \frac{1\ \text{kWh}}{3.6 \times 10^6\ \cancel{\text{J}}} = 0.17\ \text{kWh}$$

The compact fluorescent light bulb needs 0.17 kWh of energy to operate for 24 h.

Research This: Power Plant Efficiency, page 507

A. Answers may vary. Sample answer:
I chose wind power plant technology for electricity generation. It has a thermal efficiency of 40%.
B. Improvements in the types of materials that can be used create wind turbines has increased the output of wind power technology plants. Lighter materials allow for larger blades and taller supports. Increased turbine height means the turbines can catch the stronger, higher altitude, winds. These changes have increased thermal energy output.
C. By building bigger and lighter turbines, other but similar plants could be improved. Fewer turbines would be needed to generate more electricity.

D. Answers may vary. Students' reports could include:
Hydro power plant efficiency could be improved by upgrading or "uprating" existing hydro power plants in the mechanics of generating the electricity and the electronics of operating the plant. Taller dams or water reservoirs would increase output of electricity. Heat capture mechanisms could be connected to cooling towers to convert heat energy to power other parts of the plant or to be used elsewhere.
Fossil fuel (such as coal) power plant efficiency could be improved by directing steam into pipes and increasing its pressure, allowing it to reach much higher temperatures. The higher temperatures make the transfer of energy more efficient.
Nuclear power plant efficiency could be improved by redesigning important components in the energy production process. For example, the uranium cylinders could become hollow tubes. The increased surface area would allow water to flow in and out of the cylinders, increasing heat transfer.
Solar power plant efficiency could be improved by using solar power towers instead of solar troughs to capture sun energy. In a trough system, many parabolic (half cylindrical troughs) solar panels, placed at a fixed angle, capture sun energy which is transferred to synthetic oil circulating through pipes. In a tower system, the sun energy is captured and reflected directly by movable solar panels to a tower that transmits the energy to a fluid. As with both systems, the heat is used to generate steam to run a turbine. The tower system is more efficient because it requires fewer solar panels than a trough system for the same energy output. Unused energy can be stored with the tower system, unlike the trough system.

Section 11.1 Questions, page 507

1. Answers may vary. Sample answer:
The statement "My washing machine consumes a large amount of electricity." uses the word electricity incorrectly. The statement should be "My washing machine requires a large amount of electrical energy per second in order to operate." Electricity refers to electrical energy and the movement of charge.

2. Given: ΔE = 19 200 J; Δt = 2.0 s
Required: P
Analysis: $P = \frac{\Delta E}{\Delta t}$
Solution:
$$\begin{aligned} P &= \frac{\Delta E}{\Delta t} \\ &= \frac{19\ 200 \text{ J}}{2.0 \text{ s}} \\ P &= 9600 \text{ W} \end{aligned}$$
Statement: The power of the starter is 9600 W.

3. Given: P = 1200 W; $\Delta E = 1.8 \times 10^5$ J
Required: Δt
Analysis: $P = \frac{\Delta E}{\Delta t}$
Solution:
$$\begin{aligned} P &= \frac{\Delta E}{\Delta t} \\ \Delta t &= \frac{\Delta E}{P} \\ &= \frac{1.8 \times 10^5 \cancel{\text{J}}}{1200 \frac{\cancel{\text{J}}}{\text{s}}} \\ \Delta t &= 150 \text{ s} \end{aligned}$$
To find the answer in minutes, convert from seconds:
$$\Delta t = 150 \cancel{\text{s}} \times \frac{1 \text{ min}}{60 \cancel{\text{s}}}$$
$$\Delta t = 2.5 \text{ min}$$
Statement: The food was in the microwave for 2.5 min.

4. Given: P = 380 W; Δt = 110 h
Required: ΔE
Analysis: $P = \frac{\Delta E}{\Delta t}$
$$\Delta E = P\Delta t$$
Solution: Convert time to seconds to get the answer in joules:
$$\Delta t = 110 \cancel{\text{h}} \times \frac{3600 \text{ s}}{1 \cancel{\text{h}}}$$
$$\Delta t = 396\ 000 \text{ s}$$

$$\begin{aligned} \Delta E &= (380 \text{ W})(396\ 000 \text{ s}) \\ &= \left(380 \ \frac{\text{J}}{\cancel{\text{s}}}\right)(396\ 000 \cancel{\text{s}}) \\ \Delta E &= 1.505 \times 10^8 \text{ J (two extra digits carried)} \end{aligned}$$

To find the answer in kilowatt hours, convert from joules:
$$1.505 \times 10^8 \cancel{\text{J}} \times \frac{1 \text{ kWh}}{3.6 \times 10^6 \cancel{\text{J}}} = 42 \text{ kWh}$$

Statement: The plasma television needs 1.5×10^8 J or 42 kWh of energy to operate for one month.

5. Given: P = 380 W; Δt = 110 h/month for 12 months

Required: ΔE

Analysis: $P = \frac{\Delta E}{\Delta t}$

$$\Delta E = P\Delta t$$

Solution: First find the total amount of television watched in hours. Then convert time to seconds to get the answer in joules:

$$\begin{aligned}\Delta t &= \frac{110\text{ h}}{1\,\cancel{\text{month}}} \times 12\,\cancel{\text{months}} \\ &= 1320\text{ h} \\ &= 1320\,\cancel{\text{h}} \times \frac{3600\text{ s}}{1\,\cancel{\text{h}}} \\ \Delta t &= 4\,752\,000\text{ s}\end{aligned}$$

$$\begin{aligned}\Delta E &= (380\text{ W})(4\,752\,000\text{ s}) \\ &= \left(380\ \frac{\text{J}}{\cancel{\text{s}}}\right)(4\,752\,000\,\cancel{\text{s}}) \\ \Delta E &= 1.806 \times 10^9\text{ J}\ \ \text{(two extra digits carried)}\end{aligned}$$

To find the answer in kilowatt hours, convert from joules:

$$1.806 \times 10^9\,\cancel{\text{J}} \times \frac{1\text{ kWh}}{3.6 \times 10^6\,\cancel{\text{J}}} = 5.0 \times 10^2\text{ kWh}$$

Statement: The plasma television needs 1.8×10^9 J or 5.0×10^2 kWh of energy to operate for one year.

6. Answers may vary. Sample answer:
I was disappointed that wind energy technology is so inefficient since it is in the news as a solution to our energy problems. I thought it would be more efficient if it is being promoted so much.

Section 11.3: Electric Potential Difference

Mini Investigation: Modelling Electric Potential Energy, page 510

A. The amount of energy applied is directly related to the amount of energy emerging from the other side—the higher the beginning balls are raised before release, the higher the end balls fly up.
B. The middle spheres do not move, but merely transfer the energy.
C. When the middle spheres are moved out of the way, the release of the end ball does not result in a transfer of energy to the other end ball. The dropped ball simply swings until it stops and the other end balls remains motionless.
D. A possible limitation of this model is that if the balls are not identical in mass and shape, then the transfer of energy will not be equal from ball to ball. Also the balls must be touching when the motion of the outside ball is set in order for energy transfer to occur.

Tutorial 1 Practice, page 511

1. Given: ΔE = 120 J; Q = 52 C
Required: V
Analysis: $V = \frac{\Delta E}{Q}$
Solution:

$$\begin{aligned} V &= \frac{\Delta E}{Q} \\ &= \frac{120\text{ J}}{52\text{ C}} \\ V &= 2.3\text{ V} \end{aligned}$$

Statement: The electric potential difference of the chip is 2.3 V.

Section 11.3 Questions, page 513

1. Given: ΔE = 1750 J; Q = 3.1 C
Required: V
Analysis: $V = \frac{\Delta E}{Q}$
Solution:

$$\begin{aligned} V &= \frac{\Delta E}{Q} \\ &= \frac{1750\text{ J}}{3.1\text{ C}} \\ V &= 560\text{ V} \end{aligned}$$

Statement: The electric potential difference is 560 V.

2. Given: V = 15 V; Q = 0.075 C
Required: ΔE
Analysis: $V = \frac{\Delta E}{Q}$
Solution:

$$\begin{aligned} V &= \frac{\Delta E}{Q} \\ \Delta E &= VQ \\ &= (15\text{ V})(0.075\text{ C}) \\ &= \left(15\ \frac{\text{J}}{\cancel{\text{C}}}\right)(0.075\ \cancel{\text{C}}) \\ \Delta E &= 1.1\text{ J} \end{aligned}$$

Statement: The energy transformed in the adapter is 1.1 J.

3. Given: V = 3.7 V; ΔE = 6.0 J
Required: Q
Analysis: $V = \frac{\Delta E}{Q}$
Solution:

$$\begin{aligned} V &= \frac{\Delta E}{Q} \\ Q &= \frac{\Delta E}{V} \\ &= \frac{6.0\text{ J}}{3.7\text{ V}} \\ &= \frac{6.0\ \cancel{\text{J}}}{3.7\ \frac{\cancel{\text{J}}}{\text{C}}} \\ Q &= 1.6\text{ C} \end{aligned}$$

Statement: The amount of charge travelling through the cellphone is 1.6 C.

4. (a) Given: P = 7.0 W; Δt = 2.5 h; Q = 525 C
Required: V
Analysis: $V = \frac{\Delta E}{Q}$

$$P = \frac{\Delta E}{\Delta t}$$

Solution: Convert time to seconds to find ΔE in joules using the power equation from Section 11.1.

$$\begin{aligned} \Delta t &= 2.5\text{ h} \\ &= 2.5\ \cancel{\text{h}} \times \frac{3600\text{ s}}{1\ \cancel{\text{h}}} \\ \Delta t &= 9000\text{ s} \end{aligned}$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\begin{aligned}\Delta E &= P\Delta t \\ &= (7.0\ \text{W})(9000\ \text{s}) \\ &= \left(7.0\ \frac{\text{J}}{\cancel{\text{s}}}\right)(9000\ \cancel{\text{s}}) \\ \Delta E &= 63\ 000\ \text{J}\end{aligned}$$

$$\begin{aligned}V &= \frac{\Delta E}{Q} \\ &= \frac{63\ 000\ \text{J}}{525\ \text{C}} \\ V &= 120\ \text{V}\end{aligned}$$

Statement: The electric potential difference of the CFL bulb is 120 V.

(b) Multiply the number of coulombs in part (a) by the number of electrons per coulomb to find the number of electrons that were moved through the CFL bulb:

$$525\ \cancel{\text{C}} \times \frac{6.2\times 10^{18}\ \text{electrons}}{1\ \cancel{\text{C}}} = 3.3\times 10^{21}\ \text{electrons}$$

Statement: In part (a), 3.3×10^{21} electrons were moved through the CFL bulb.

5. Given: $\Delta E = 130$ J; $V = 710$ V

Required: Q

Analysis: $V = \frac{\Delta E}{Q}$

Solution:

$$V = \frac{\Delta E}{Q}$$

$$\begin{aligned}Q &= \frac{\Delta E}{V} \\ &= \frac{130\ \text{J}}{710\ \text{V}} \\ Q &= 0.18\ \text{C}\end{aligned}$$

Statement: The amount of charge delivered to the heart is 0.18 C.

6. (a) I would expect to observe a voltage gain across the battery because it increases the potential difference of the circuit, and to observe a voltage drop across the LED lamp because it is a load.

(b) I would expect no voltage drop or gain across the switch and the connecting wires, since they are conductors designed to have low resistances.

7. (a) A power plant is a source of electrical energy, so it causes a voltage gain.

(b) A digital camera is a load, so it causes a voltage drop.

(c) A game console is a load, so it causes a voltage drop.

(d) A wind turbine is a source of electrical energy, so it causes a voltage gain.

(e) A solar panel is a source of electrical energy, so it causes a voltage gain.

(f) A calculator is a load, so it causes a voltage drop.

8. (a) A voltmeter should not be connected in series. A voltmeter must always be connected in parallel.

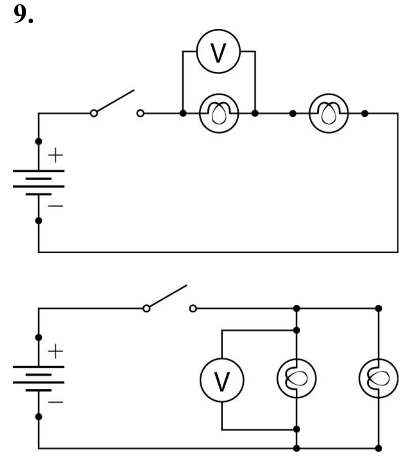
(b) A circuit with more than one complete path is a parallel circuit. A series circuit has exactly one complete path.

(c) Connecting a voltmeter in series will not allow only a small amount of electrical energy to travel through it, since the electrons flowing through the circuit have no alternate path to follow and must pass through the voltmeter. Connecting a voltmeter in parallel will allow only a small amount of electrical energy to travel through it.

(d) A parallel circuit does not need to have only two complete paths. A parallel circuit can have two or more complete paths.

(e) A complete circuit contains a power source and a load but the power source must be switched on.

9.



Section 11.4: Physics Journal
Section 11.4 Questions, page 515

1. The early professions of Benjamin Franklin surprised me because they were not scientific in nature. He had no formal education in science until after 42 years of age.

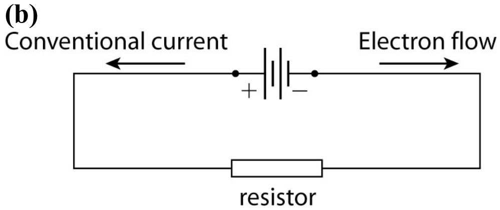
2. Assuming electricity was a fluid was reasonable at that time because it was assumed that electricity flowed from one material to another. Water does this so it was natural for people to use what they know and apply it to new situations.

3. The kite experiment is famous because it was dramatic and dangerous. It proved most evidently (through touch) that lightning was some form of electricity.

4. The development of electricity technologies did not rely on knowing the direction of electricity flow because the direction of electricity flow does not effect how devices function.

5. (a) Conventional current is where the flow of electrons or electricity in an electrical circuit goes from a positive side to a negative side. Electron flow is electric current. There are two types: direct current, DC, and alternating current, AC. In direct current, electron flow is in only one direction. In alternating current, electron flow is in two directions, from positive to negative terminal, and vice versa.

(b)



Section 11.5: Electric Current

Tutorial 1 Practice, page 517

1. Given: Q = 0.20 mC; Δt = 0.75 min
Required: I

Analysis: $I = \dfrac{Q}{\Delta t}$

Solution: Convert time to seconds and charge to coulombs to get the answer in coulombs per second, or amperes:

$$\Delta t = 0.75\,\cancel{\text{min}} \times \frac{60\text{ s}}{1\,\cancel{\text{min}}}$$
$$\Delta t = 45\text{ s}$$

$$Q = 0.20\,\cancel{\text{mC}} \times \frac{1\text{ C}}{1000\,\cancel{\text{mC}}}$$
$$Q = 2.0 \times 10^{-4}\text{ C}$$

$$I = \frac{Q}{\Delta t}$$
$$= \frac{2.0 \times 10^{-4}\text{ C}}{45\text{ s}}$$
$$I = 4.4 \times 10^{-6}\text{ A}$$

Convert the current to microamperes:

$$I = 4.4 \times 10^{-6}\,\cancel{\text{A}} \times \frac{1 \times 10^{6}\,\mu\text{A}}{1\,\cancel{\text{A}}}$$
$$I = 4.4\,\mu\text{A}$$

Statement: The current travelling through the cellphone charger is 4.4×10^{-6} A or 4.4 µA.

2. Given: I = 15 A; Δt = 24 h
Required: Q

Analysis: $I = \dfrac{Q}{\Delta t}$

Solution: Convert time to seconds to get the answer in ampere-seconds, or coulombs:

$$\Delta t = 24\,\cancel{\text{h}} \times \frac{3600\text{ s}}{1\,\cancel{\text{h}}}$$
$$\Delta t = 86\,400\text{ s} \text{ (one extra digit carried)}$$

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (15\text{ A})(86\,400\text{ s})$$
$$Q = 1.3 \times 10^{6}\text{ C}$$

Statement: The number of electrons resulting from the current is 1.3×10^{6} C.

Mini Investigation: How Much Current Can a Lemon Produce?, page 518

A. Answers may vary. Sample answer:
When the lemon was connected, 0.5 V was produced. When the LED load was added, the voltage dropped by 50 mV. The difference is negligible.

B. When more lemon cells are added in series, the brightness of the LED is increased.

Section 11.5 Questions, page 518

1. Direct current is the flow of electrons in one direction only. By convention, the electrons flow from the negative terminal of the source of electrical energy and travel through the conducting wires toward the positive terminal.

2. Given: Q = 2.5 C; Δt = 4.6 s
Required: I

Analysis: $I = \dfrac{Q}{\Delta t}$

Solution: $I = \dfrac{Q}{\Delta t}$
$$= \frac{2.5\text{ C}}{4.6\text{ s}}$$
$$I = 0.54\text{ A}$$

Statement: The current in the circuit is 0.54 A

3. Given: I = 800.0 A; Δt = 1.2 min
Required: Q

Analysis: $I = \dfrac{Q}{\Delta t}$

Solution: Convert time to seconds to get the answer in ampere-seconds, or coulombs:

$$\Delta t = 1.2\,\cancel{\text{min}} \times \frac{60\text{ s}}{1\,\cancel{\text{min}}}$$
$$\Delta t = 72\text{ s}$$

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (800.0\text{ A})(72\text{ s})$$
$$Q = 5.8 \times 10^{4}\text{ C}$$

Statement: The amount of charge travelling through the car battery is 5.8×10^{4} C.

4. Given: I = 250 mA; $Q = 1.7 \times 10^{2}$ C
Required: Δt

Analysis: $I = \dfrac{Q}{\Delta t}$

Solution: Convert current to amperes to get the answer in coulombs per ampere, or seconds:

$$I = 250\,\cancel{\text{mA}} \times \frac{1\text{ A}}{1000\,\cancel{\text{mA}}}$$
$$I = 0.25\text{ A}$$
$$I = \frac{Q}{\Delta t}$$
$$\Delta t = \frac{Q}{I} = \frac{1.7 \times 10^2\text{ C}}{0.25\text{ A}}$$
$$\Delta t = 680\text{ s}$$

Convert the time to minutes:

$$\Delta t = 680\,\cancel{\text{s}} \times \frac{1\text{ min}}{60\,\cancel{\text{s}}}$$
$$\Delta t = 11\text{ min}$$

Statement: The battery can produce the current for 680 s or 11 min.

5. Given: $Q = 150\ \mu\text{C}$; $I = 0.21$ mA

Required: Δt

Analysis: $I = \frac{Q}{\Delta t}$

Solution: Convert charge to coulombs and the current to amperes to get the answer in coulombs per ampere, or seconds:

$$Q = 150\,\cancel{\mu\text{C}} \times \frac{1\text{ C}}{1 \times 10^6\,\cancel{\mu\text{C}}}$$
$$Q = 1.5 \times 10^{-4}\text{ C}$$

$$I = 0.21\,\cancel{\text{mA}} \times \frac{1\text{ A}}{1000\,\cancel{\text{mA}}}$$
$$I = 2.1 \times 10^{-4}\text{ A}$$
$$I = \frac{Q}{\Delta t}$$
$$\Delta t = \frac{Q}{I} = \frac{1.5 \times 10^{-4}\text{ C}}{2.1 \times 10^{-4}\text{ A}}$$
$$\Delta t = 0.71\text{ s}$$

Statement: The time required for the charge to pass through the LED light is 0.71 s.

6. First find the charge of the battery. Convert current to amperes and time to seconds to get the answer in coulombs.

$$I = 2650\,\cancel{\text{mA}} \times \frac{1\text{ A}}{1000\,\cancel{\text{mA}}}$$
$$I = 2.65\text{ A}$$

$$\Delta t = 1\,\cancel{\text{h}} \times \frac{3600\text{ s}}{1\,\cancel{\text{h}}}$$
$$\Delta t = 3600\text{ s}$$

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t = (2.65\text{ A})(3600\text{ s})$$
$$Q = 9540\text{ C}\ \text{(two extra digits carried)}$$

Now find the time it takes for 159 C of charge to deplete with a current of 883 mA. Convert current to amperes to get the answer in seconds.

$$I = 833\,\cancel{\text{mA}} \times \frac{1\text{ A}}{1000\,\cancel{\text{mA}}}$$
$$I = 0.833\text{ A}$$
$$I = \frac{Q}{\Delta t}$$
$$\Delta t = \frac{Q}{I} = \frac{9540\text{ C}}{0.833\text{ A}}$$
$$\Delta t = 1.15 \times 10^4\text{ s}\ \text{(two extra digits carried)}$$

Convert the time to hours:

$$\Delta t = 1.15 \times 10^4\,\cancel{\text{s}} \times \frac{1\text{ h}}{3600\,\cancel{\text{s}}}$$
$$\Delta t = 3\text{ h}$$

So, the battery could produce a current of 883 mA for 3 h.

7. The student connected the ammeter in parallel so there is more than one path for the current to flow along. It is possible that the path passing through the ammeter has a much lower resistance than the path it is connected in parallel with, causing a large amount of current to take this path and resulting in a high reading.

8. Electric current is the conduction of free electrons in a material. If the material does not contain free electrons, then the material is not an electrical conductor. Therefore, no electric current can be produced in an non-conductor.

9. Electricians turn off the power to a circuit before working on it for safety. A current above 0.075 A is extremely dangerous when it flows into the body, and this is below a typical household circuit current rating. An electrician must always turn off the power to avoid accidental contact with an exposed wire or short-circuited electrical component.

Section 11.6: Kirchhoff's Laws

Tutorial 1 Practice, page 522

1. Separate the circuit in Figure 7 into sections that are connected in parallel and sections that are connected in series. Doing this shows how to view the circuit as three complete paths: the path passing through the source, lamp 1, lamp 2, and lamp 3; the path passing through the source, lamp 1, lamp 2, and lamp 4; and the path passing through the source, lamp 1, lamp 2, and lamp 5. Using this approach of three separate paths, you can think of three completely independent series circuits.

Using KVL for a series circuit, you can solve for V_2:

$$V_{\text{source}} = V_1 + V_2 + V_3$$
$$60.0 \text{ V} = 20.0 \text{ V} + V_2 + 15 \text{ V}$$
$$60.0 \text{ V} = 35 \text{ V} + V_2$$
$$V_2 = 25 \text{ V}$$

If you apply the same thinking to the next path, you can solve for V_4:

$$V_{\text{source}} = V_1 + V_2 + V_4$$
$$60.0 \text{ V} = 20.0 \text{ V} + 25 \text{ V} + V_4$$
$$60.0 \text{ V} = 45 \text{ V} + V_4$$
$$V_4 = 15 \text{ V}$$

If you apply the same thinking to the third path, you can solve for V_5:

$$V_{\text{source}} = V_1 + V_2 + V_5$$
$$60.0 \text{ V} = 20.0 \text{ V} + 25 \text{ V} + V_5$$
$$60.0 \text{ V} = 45 \text{ V} + V_5$$
$$V_5 = 15 \text{ V}$$

So, $V_2 = 25$ V, $V_4 = 15$ V, and $V_5 = 15$ V.

2. The current in a series circuit is constant and the same as the source current. The source, lamp 1, and lamp 2 are in series, and $I_1 = 0.70$ A. Using these values and KCL, you can find I_{source} and I_2:

$$I_{\text{source}} = I_1 = I_2$$
$$I_{\text{source}} = 0.70 \text{ A} = I_2$$

Therefore, $I_{\text{source}} = 0.70$ A and $I_2 = 0.70$ A.

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_4:

$$I_{\text{parallel}} = I_3 + I_4 + I_5$$
$$0.70 \text{ A} = 0.10 \text{ A} + I_4 + 0.20 \text{ A}$$
$$0.70 \text{ A} = 0.30 \text{ A} + I_4$$
$$I_4 = 0.40 \text{ A}$$

So, I_4 is equal to 0.40 A.

Section 11.6 Questions, page 522

1. (a) Kirchhoff's current law (KCL) states that the current entering a junction is equal to the current exiting a junction in a circuit, but the current going into the parallel circuit is listed as 0.50 A and the current coming out of the parallel circuit is listed as 0.30 A, which are not equal.

(b) Kirchhoff's voltage law (KVL) states that the voltage gains are equal to the voltage drops in a complete path in a circuit, but the student has measured that the series circuit has one voltage gain of 10 V from the source, and a voltage drop of 10 V from each of the three loads, for a total voltage drop of 30 V.

(c) Kirchhoff's voltage law (KVL) states that the voltage gains are equal to the voltage drops in a complete path in a circuit. The source and the first lamp form one complete path in the circuit, and the source and the second lamp form another complete path in the circuit, so the voltage drop of the first lamp and the voltage drop of the second lamp must both equal the voltage gain of the source. The student has measured that the voltage drop of the first lamp is 20 V and the voltage drop of the second lamp is 10 V, which are not equal, so the student's measurements must be incorrect.

(d) Kirchhoff's current law (KCL) states that the current entering a junction is equal to the current exiting a junction in a circuit. Since there is no junction in a series circuit, only one complete path, the current must be the same for all the loads. Since the lamps have different currents, they cannot be connected in series.

2. (a)

Item	*V* (V)	*I* (A)
source	**3.0**	**3.0**
lamp 1	2.0	3.0
lamp 2	1.0	1.5
lamp 3	**1.0**	**1.5**

Using KVL for a series circuit, you can solve for V_{source}:

$$V_{source} = V_1 + V_2$$
$$= 2.0\text{ V} + 1.0\text{ V}$$
$$V_{source} = 3.0\text{ V}$$

So $V_{source} = 3.0$ V.

If you apply the same thinking to the other path, you can solve for V_3:

$$V_{source} = V_1 + V_3$$
$$3.0\text{ V} = 2.0\text{ V} + V_3$$
$$V_3 = 1.0\text{ V}$$

So $V_3 = 1.0$ V.

The current in a series circuit is constant and the same as the source current. The source and lamp 1 are in series, and $I_1 = 0.70$ A. Using these values and KCL, you can find I_{source}:

$$I_{source} = I_1$$
$$I_{source} = 3.0\text{ A}$$

So $I_{source} = 3.0$ A.

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_3:

$$I_{parallel} = I_2 + I_3$$
$$3.0\text{ A} = 1.5\text{ A} + I_3$$
$$I_3 = 1.5\text{ A}$$

So $I_3 = 1.5$ A.

(b)

Item	*V* (V)	*I* (A)
source	24.0	2.0
lamp 1	10.0	**2.0**
lamp 2	6.0	1.0
lamp 3	**6.0**	**1.0**
lamp 4	**8.0**	**2.0**

Using KVL for a series circuit, you can solve for V_4:

$$V_{source} = V_1 + V_2 + V_4$$
$$24.0\text{ V} = 10.0\text{ V} + 6.0\text{ V} + V_4$$
$$24.0\text{ V} = 16.0\text{ V} + V_4$$
$$V_4 = 8.0\text{ V}$$

So $V_4 = 8.0$ V.

If you apply the same thinking to the other path, you can solve for V_3:

$$V_{source} = V_1 + V_3 + V_4$$
$$24.0\text{ V} = 10.0\text{ V} + V_3 + 8.0\text{ V}$$
$$24.0\text{ V} = 18.0\text{ V} + V_3$$
$$V_3 = 6.0\text{ V}$$

So $V_3 = 6.0$ V.

The current in a series circuit is constant and the same as the source current. Lamp 4, the source, and lamp 1 are in series, and $I_{source} = 2.0$ A. Using these values and KCL, you can find I_1 and I_4:

$$I_{source} = I_1 = I_4$$
$$2.0\text{ A} = I_1 = I_4$$

So $I_1 = 2.0$ A and $I_4 = 2.0$ A.

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_3:

$$I_{parallel} = I_2 + I_3$$
$$2.0\text{ A} = 1.0\text{ A} + I_3$$
$$I_3 = 1.0\text{ A}$$

So $I_3 = 1.0$ A.

(c)

Item	*V* (V)	*I* (A)
source	6.0	4.0
lamp 1	**3.0**	**4.0**
lamp 2	1.0	2.0
lamp 3	2.0	**2.0**
lamp 4	**3.0**	**2.0**

Using KVL for a series circuit, you can solve for V_1:

$$V_{source} = V_1 + V_2 + V_3$$
$$6.0\text{ V} = V_1 + 1.0\text{ V} + 2.0\text{ V}$$
$$6.0\text{ V} = V_1 + 3.0\text{ V}$$
$$V_1 = 3.0\text{ V}$$

So $V_1 = 3.0$ V.

If you apply the same thinking to the other path, you can solve for V_4:

$$V_{\text{source}} = V_1 + V_4$$
$$6.0\text{ V} = 3.0\text{ V} + V_4$$
$$V_4 = 3.0\text{ V}$$

So $V_4 = 3.0$ V.

The current in a series circuit is constant and the same as the source current. The source and lamp 1 are in series, and $I_{\text{source}} = 4.0$ A. Using these values and KCL, you can find I_1:

$$I_{\text{source}} = I_1$$
$$I_1 = 4.0\text{ A}$$

So $I_1 = 4.0$ A.

Lamp 2 and lamp 3 are in series, and $I_2 = 2.0$ A. Using these values and KCL, you can find I_3:

$$I_2 = I_3$$
$$I_3 = 2.0\text{ A}$$

So $I_3 = 2.0$ A.

The amount of current entering a junction is equal to the amount of current exiting the junction. The amount of current entering the junction is equal to I_2 (or I_3). This can be used to find I_4:

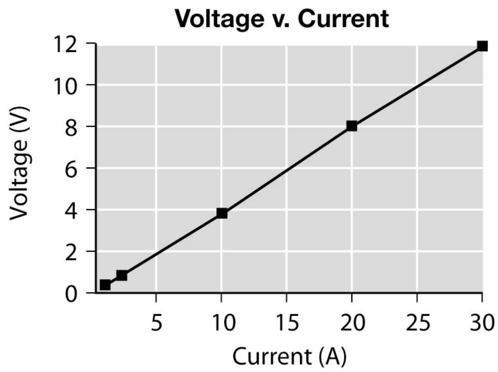
$$I_{\text{parallel}} = I_2 + I_4$$
$$4.0\text{ A} = 2.0\text{ A} + I_4$$
$$I_4 = 2.0\text{ A}$$

So $I_4 = 2.0$ A.

Section 11.7: Electrical Resistance

Mini Investigation: Determining Unknown Resistance, page 523

A. Graphs may vary. Sample graph:



$$\text{slope} = \frac{\Delta V}{\Delta I}$$
$$= \frac{0.72\text{ V} - 0.24\text{ V}}{2.0\text{ A} - 0.8\text{ A}}$$
$$= \frac{0.48\text{ V}}{1.2\text{ A}}$$
$$\text{slope} = 0.4\text{ V/A}$$

The unknown resistance is 0.4 Ω.

B. Answers may vary. Sample answer:
A 100 Ω resistor would give values ranging from 2-15 V and 0.2 A to 0.15 A. Note: the ammeter should be of an appropriate scale. The percent difference is typically around 5 %.

C. Answers may vary. Sample answer:
The other student's graph had the same shape as mine. Both graphs show a linearly proportional relationship, but each had a different slope.

Tutorial 1 Practice, page 525

1. Given: $V = 120$ V; $I = 6.5$ A

Required: R

Analysis: $R = \frac{V}{I}$

Solution: $R = \frac{V}{I}$
$$= \frac{120\text{ V}}{6.5\text{ A}}$$
$$R = 18\ \Omega$$

Statement: The resistance of the toaster element is 18 Ω.

2. Given: $A = 450$ A; $V = 12$ V

Required: R

Analysis: $R = \frac{V}{I}$

Solution: $R = \frac{V}{I}$
$$= \frac{12\text{ V}}{450\text{ A}}$$
$$R = 0.027\ \Omega$$

Statement: The resistance of the car starter is 0.027 Ω.

Section 11.7 Questions, page 526

1. (a) Given: $R = \frac{V}{I}$.

Rearranging: $R = \frac{V}{I}$
$$R \times I = \frac{V}{\cancel{I}} \times \cancel{I}$$
$$IR = V$$
$$\frac{\cancel{R}I}{\cancel{R}} = \frac{V}{R}$$
$$I = \frac{V}{R}$$

The equation solved for current is $I = \frac{V}{R}$.

(b) Given: $R = \frac{V}{I}$.

Rearranging: $R = \frac{V}{I}$
$$R \times I = \frac{V}{\cancel{I}} \times \cancel{I}$$
$$V = IR$$

The equation solved for voltage is $V = IR$.

2. Given: $V = 9.0$ V; $I = 160$ mA

Required: R

Analysis: $R = \frac{V}{I}$

Solution: Convert the current to amperes to get the answer in ohms:
$$I = 160\ \cancel{\text{mA}} \times \frac{1\text{ A}}{1000\ \cancel{\text{mA}}}$$
$$I = 0.16\text{ A}$$

$$R = \frac{V}{I}$$
$$= \frac{9.0\text{ V}}{0.16\text{ A}}$$
$$R = 56\ \Omega$$

Statement: The resistance of the portable fan is 56 Ω.

3. Given: V = 9.0 V; R = 100 000 Ω

Required: I

Analysis: $R = \frac{V}{I}$

$I = \frac{V}{R}$

Solution: $I = \frac{V}{R}$

$= \frac{9.0 \text{ V}}{100\ 000\ \Omega}$

$I = 9 \times 10^{-5}$ A

Statement: The current going through the skin would be 9×10^{-5} A.

4. Given: V = 120 V; R = 1000 Ω.

Required: I

Analysis: $R = \frac{V}{I}$

$I = \frac{V}{R}$

Solution: $I = \frac{V}{R}$

$= \frac{120.0 \text{ V}}{1000\ \Omega}$

$I = 0.1$ A

Statement: The current going through the skin would be 0.1 A.

5. Given: R = 8.0 Ω; V = 5.2 V

Required: I

Analysis: $R = \frac{V}{I}$

$I = \frac{V}{R}$

Solution: $I = \frac{V}{R}$

$= \frac{5.2 \text{ V}}{8.0\ \Omega}$

$I = 0.65$ A

Statement: The current going to the speaker is 0.65 A.

6. Given: I = 2.07 A; R = 8.05 Ω

Required: I

Analysis: $R = \frac{V}{I}$

$V = IR$

Solution: $V = IR$

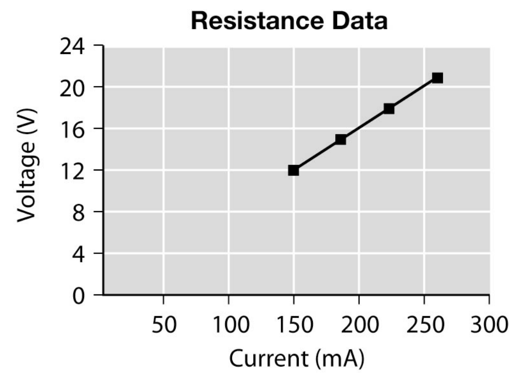
$= (2.07 \text{ A})(8.05\ \Omega)$

$V = 16.7$ V

Statement: The voltage of the charger is 16.7 V.

7. Answers may vary. Sample answer:
Electrical resistance is a term that describes a measure of how able an electric current is to travel through a material. The higher the resistance, the less able an electric current is to travel through a material.

8.



The slope of the line connecting the data points represents the resistance. For example, the line passes through the data points (12 V, 151 mA) and (18 V, 226 mA). First convert the current to amperes to find the resistance in ohms:

$I_1 = 151 \cancel{\text{mA}} \times \frac{1 \text{ A}}{1000 \cancel{\text{mA}}}$

$I_1 = 0.151$ A

$I_2 = 226 \cancel{\text{mA}} \times \frac{1 \text{ A}}{1000 \cancel{\text{mA}}}$

$I_2 = 0.226$ A

The two data points (12 V, 0.151 A) and (18 V, 0.226 A) can be used to find the slope:

$\text{slope} = \frac{\text{rise}}{\text{run}}$

$m = \frac{\Delta V}{\Delta I}$

$= \frac{18 \text{ V} - 12 \text{ V}}{0.226 \text{ A} - 0.151 \text{ A}}$

$m = 80\ \Omega$

So the resistance is 80 Ω.

9. Ohm's law can be stated as an equation as $R = \frac{V}{I}$. For any value for the current, I, on the graph, the load represented by the blue line has a greater voltage than the load represented by the red line. From the equation $R = \frac{V}{I}$, for a constant current, a higher voltage indicates a higher resistance. So the blue line represents the higher value of resistance.

10. The student has incorrectly connected the ohmmeter in series instead of in parallel, and has incorrectly connected the ohmmeter to an operating circuit instead of a circuit that is switched off.

11. Answers may vary. Sample answer:
A situation where electrical resistance is desirable is in an electric circuit that has fine wires and devices sensitive to high currents, since high electrical currents could damage the wires or devices, and a high resistance means that electrical currents do not flow easily.
A situation where electrical resistance is undesirable is in the transmission of electrical energy through wires from a power plant to consumers, since resistance in the wire will cause some of the electrical energy flowing through the wire to be converted into thermal energy, which will be wasted.

12.

Current	Voltage (V)	Resistance (Ω)
25 mA	12	**480**
1.2 A	**610**	510
375 μA	0.25	**670**
3.6 A	120	33
1.0 mA	1.5	1500

Row 1: Convert current to amperes to get the answer in volts per ampere, or ohms:

$$I = 25\,\cancel{\text{mA}} \times \frac{1\text{ A}}{1000\,\cancel{\text{mA}}}$$
$$I = 0.025\text{ A}$$
$$R = \frac{V}{I}$$
$$= \frac{12\text{ V}}{0.025\text{ A}}$$
$$R = 480\ \Omega$$

The resistance is 480 Ω.

Row 2:

$$R = \frac{V}{I}$$
$$V = IR$$
$$= (1.2\text{ A})(510\ \Omega)$$
$$V = 610\text{ V}$$

The voltage is 610 V.

Row 3: Convert current to amperes to get the answer in volts per ampere, or ohms:

$$I = 375\,\cancel{\mu\text{A}} \times \frac{1\text{ A}}{1\times 10^{6}\,\cancel{\mu\text{A}}}$$
$$I = 3.75\times 10^{-4}\text{ A}$$

$$R = \frac{V}{I}$$
$$= \frac{0.25\text{ V}}{3.75\times 10^{-4}\text{ A}}$$
$$R = 670\ \Omega$$

The resistance is 670 Ω.

Row 4:

$$R = \frac{V}{I}$$
$$I = \frac{V}{R}$$
$$= \frac{120\text{ V}}{33\ \Omega}$$
$$I = 3.6\text{ A}$$

The current is 3.6 A.

Row 5:

$$R = \frac{V}{I}$$
$$I = \frac{V}{R}$$
$$= \frac{1.5\text{ V}}{1500\ \Omega}$$
$$I = 1.0\times 10^{-3}\text{ A}$$

Convert current to microamperes:

$$I = 1.0\times 10^{-3}\,\cancel{\text{A}} \times \frac{1000\text{ mA}}{1\,\cancel{\text{A}}}$$
$$I = 1.0\text{ mA}$$

The current is 1.0 mA

Section 11.8: Resistors in Circuits

Tutorial 1 Practice, page 527

1. Given: $R_1 = 25.2\ \Omega$; $R_2 = 28.12\ \Omega$
Required: R_{series}
Analysis: $R_{series} = R_1 + R_2$
Solution:
$$\begin{aligned} R_{series} &= R_1 + R_2 \\ &= 25.2\ \Omega + 28.12\ \Omega \\ R_{series} &= 53.3\ \Omega \end{aligned}$$
Statement: The equivalent resistance is 53.3 Ω.

2. Given: $R_1 = 53.0\ \Omega$; $R_2 = 53.0\ \Omega$; $R_3 = 53.0\ \Omega$
Required: R_{series}
Analysis: $R_{series} = R_1 + R_2 + R_3$
Solution:
$$\begin{aligned} R_{series} &= R_1 + R_2 + R_3 \\ &= 53.0\ \Omega + 53.0\ \Omega + 53.0\ \Omega \\ R_{series} &= 159\ \Omega \end{aligned}$$
Statement: The equivalent resistance is 159 Ω.

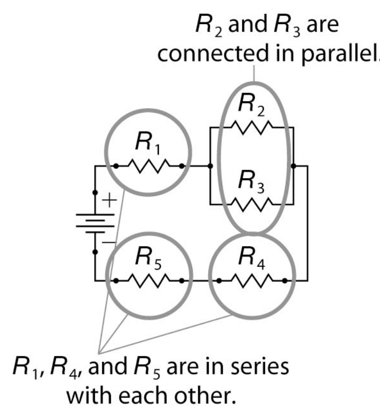
Tutorial 2 Practice, page 529

1. Given: $R_1 = 120\ \Omega$; $R_2 = 60\ \Omega$
Required: $R_{parallel}$
Analysis: $\dfrac{1}{R_{parallel}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$
Solution:
$$\begin{aligned} \frac{1}{R_{parallel}} &= \frac{1}{R_1} + \frac{1}{R_2} \\ &= \frac{1}{120\ \Omega} + \frac{1}{60\ \Omega} \\ &= \frac{1}{120\ \Omega} + \frac{2}{120\ \Omega} \\ \frac{1}{R_{parallel}} &= \frac{3}{120\ \Omega} \\ R_{parallel} &= \frac{120\ \Omega}{3} \\ R_{parallel} &= 40\ \Omega \end{aligned}$$
Statement: The equivalent resistance is 40 Ω.

2. Given: $R_1 = 20\ \Omega$; $R_2 = 20\ \Omega$; $R_3 = 20\ \Omega$; $R_4 = 20\ \Omega$;
Required: $R_{parallel}$
Analysis: $\dfrac{1}{R_{parallel}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}$
Solution:
$$\begin{aligned} \frac{1}{R_{parallel}} &= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \\ &= \frac{1}{20\ \Omega} + \frac{1}{20\ \Omega} + \frac{1}{20\ \Omega} + \frac{1}{20\ \Omega} \\ \frac{1}{R_{parallel}} &= \frac{4}{20\ \Omega} \\ R_{parallel} &= \frac{20\ \Omega}{4} \\ R_{parallel} &= 5\ \Omega \end{aligned}$$
Statement: The equivalent resistance is 5 Ω.

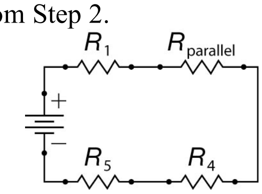
Tutorial 3 Practice, page 530

1. (a)
Step 1. Divide the circuit into series and parallel parts.



Step 2. Find the equivalent resistance of the parallel part of the circuit.
$$\begin{aligned} \frac{1}{R_{parallel}} &= \frac{1}{R_2} + \frac{1}{R_3} \\ &= \frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega} \\ \frac{1}{R_{parallel}} &= \frac{2}{5.0\ \Omega} \\ R_{parallel} &= \frac{5.0\ \Omega}{2} \\ R_{parallel} &= 2.5\ \Omega \end{aligned}$$

Step 3. Redraw the circuit using the equivalent resistance from Step 2.



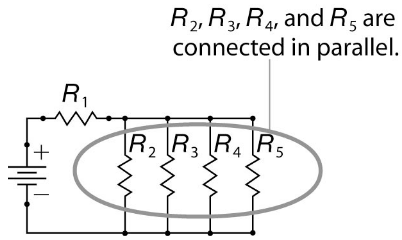
Step 4. Solve to determine the equivalent resistance of the remaining series circuit. Let the equivalent resistance for the complete circuit be R_{total}.

$$R_{total} = R_1 + R_{parallel} + R_4 + R_5$$
$$= 5.0\ \Omega + 2.5\ \Omega + 5.0\ \Omega + 5.0\ \Omega$$
$$R_{total} = 17.5\ \Omega$$

Statement: The total resistance of the mixed circuit is 17.5 Ω.

(b)

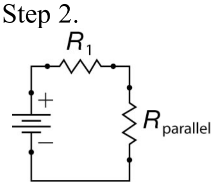
Step 1. Divide the circuit into series and parallel parts.



Step 2. Find the equivalent resistance of the parallel part of the circuit.

$$\frac{1}{R_{parallel}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$
$$= \frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega}$$
$$\frac{1}{R_{parallel}} = \frac{4}{5.0\ \Omega}$$
$$R_{parallel} = \frac{5.0\ \Omega}{4}$$
$$R_{parallel} = 1.3\ \Omega$$

Step 3. Redraw the circuit using the equivalent resistance from Step 2.



Step 4. Solve to determine the equivalent resistance of the remaining series circuit. Let the equivalent resistance for the complete circuit be R_{total}.

$$R_{total} = R_1 + R_{parallel}$$
$$= 5.0\ \Omega + 1.3\ \Omega$$
$$R_{total} = 6.3\ \Omega$$

Statement: The total resistance of the mixed circuit is 6.3 Ω.

Section 11.8 Questions, page 530

1. Start with the equivalent resistance in a series circuit:

$$R_{series} = R_1 + R_2 + R_3 + \cdots$$

Substitute Ohm's Law in the form $R = \frac{V}{I}$:

$$\frac{V_{series}}{I_{series}} = \frac{V_1}{I_1} + \frac{V_2}{I_2} + \frac{V_3}{I_3} + \cdots$$

In a series circuit, the current is constant and the same at all points (KCL). So the currents on the left side will cancel with the currents on the right side:

$$\frac{V_{series}}{I_{series}} = \frac{V_1}{I_1} + \frac{V_2}{I_2} + \frac{V_3}{I_3} + \cdots$$
$$\frac{V_{series}}{\cancel{I_{series}}} = \frac{V_1}{\cancel{I_1}} + \frac{V_2}{\cancel{I_2}} + \frac{V_3}{\cancel{I_3}} + \cdots$$

Therefore, in a series circuit the voltage is given by $V_{series} = V_1 + V_2 + V_3 + \cdot\cdot$

This is Kirchhoff's voltage law for a series circuit.

2. Start with the equivalent resistance in a parallel circuit:

$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

Substitute Ohm's Law in the form $R = \frac{V}{I}$:

$$\frac{1}{\frac{V_{parallel}}{I_{parallel}}} = \frac{1}{\frac{V_1}{I_1}} + \frac{1}{\frac{V_2}{I_3}} + \frac{1}{\frac{V_3}{I_3}} + \cdots$$
$$\frac{I_{parallel}}{V_{parallel}} = \frac{I_1}{V_1} + \frac{I_2}{V_2} + \frac{I_3}{V_3} + \cdots$$

In a parallel circuit, the voltage is constant and the same at all points (KVL). So the voltages on the left side will cancel with the voltages on the right side:

$$\frac{I_{parallel}}{V_{parallel}} = \frac{I_1}{V_1} + \frac{I_2}{V_2} + \frac{I_3}{V_3} + \cdots$$
$$\frac{I_{parallel}}{\cancel{V_{parallel}}} = \frac{I_1}{\cancel{V_1}} + \frac{I_2}{\cancel{V_2}} + \frac{I_3}{\cancel{V_3}} + \cdots$$
$$I_{parallel} = I_1 + I_2 + I_3 + \cdots$$

This is Kirchhoff's current law for a parallel circuit.

3. Suppose the resistance of the two identical resistors is an unknown value r, so that $R_1 = r$ and $R_2 = r$. Since the resistors are in parallel, the equivalent resistance can be found:

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$= \frac{1}{r} + \frac{1}{r}$$
$$\frac{1}{R_{\text{parallel}}} = \frac{2}{r}$$
$$R_{\text{parallel}} = \frac{r}{2}$$

So the equivalent resistance of the two identical resistors in parallel is $\frac{r}{2}$, which is half the resistance of one of the resistors.

4. Answers may vary. Sample answer:
The amount of electric current will increase with each load that is added, since adding a load in parallel causes a decrease in the total resistance of the circuit and an increase in the current. This is a cause for concern because home electrical wiring is designed for low currents, and a high electric current may damage the wires or even begin a fire. In many home electrical systems the dangerous increase in electric current caused by connecting too many loads in parallel is prevented by a device called a circuit breaker.

5. (a) Given: $R_1 = 12.0\ \Omega$; $R_2 = 12.0\ \Omega$; $R_3 = 12.0\ \Omega$; $R_4 = 12.0\ \Omega$
Required: R_{series}
Analysis: $R_{\text{series}} = R_1 + R_2 + R_3 + R_4$
Solution:

$$R_{\text{series}} = R_1 + R_2 + R_3 + R_4$$
$$= 12.0\ \Omega + 12.0\ \Omega + 12.0\ \Omega + 12.0\ \Omega$$
$$R_{\text{series}} = 48.0\ \Omega$$

Statement: The equivalent resistance is 48.0 Ω.

(b) Start by finding the equivalent resistances $R_{1,4}$ and $R_{2,3}$ for the resistors in series in the parallel part of the circuit.
For R_1 and R_4:

$$R_{\text{series}} = R_1 + R_4$$
$$= 12.0\ \Omega + 12.0\ \Omega$$
$$R_{\text{series}} = 24.0\ \Omega$$

$$R_{\text{series}} = R_2 + R_3$$
$$= 12.0\ \Omega + 12.0\ \Omega$$
$$R_{\text{series}} = 24.0\ \Omega$$

Now find the equivalent resistance for the parallel circuit.

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_{1,4}} + \frac{1}{R_{2,3}}$$
$$\frac{1}{R_{\text{parallel}}} = \frac{1}{24.0\ \Omega} + \frac{1}{24.0\ \Omega}$$
$$R_{\text{parallel}} = 12.0\ \Omega$$

Statement: The equivalent resistance is 12.0 Ω.
(c) From part (b), the parallel part of the circuit has an equivalent resistance of 12.0 Ω. Now the total resistance can be found:
R_{parallel} is in series with R_1, so

$$R_{\text{total}} = R_1 + R_{\text{parallel}}$$
$$= 12.0\ \Omega + 12.0\ \Omega$$
$$R_{\text{total}} = 24.0\ \Omega$$

Statement: The equivalent resistance is 24.0 Ω.
(d) From part (b), the parallel part of the circuit has an equivalent resistance of 12.0 Ω. Now the total resistance can be found:
R_{parallel} is in series with R_1 and R_6, so

$$R_{\text{total}} = R_1 + R_{\text{parallel}} + R_6$$
$$= 12.0\ \Omega + 12.0\ \Omega + 12.0\ \Omega$$
$$R_{\text{total}} = 36.0\ \Omega$$

Statement: The equivalent resistance is 36.0 Ω.

Section 11.9: Circuit Analysis

Tutorial 1 Practice, Case 1, page 532

1.

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the parallel part of the circuit.

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{30.0\ \Omega} + \frac{1}{30.0\ \Omega}$$

$$R_{\text{parallel}} = 15.0\ \Omega$$

Now find the total resistance.
R_{parallel} is in series with R_1, so

$$R_{\text{total}} = R_1 + R_{\text{parallel}}$$
$$= 25.0\ \Omega + 15.0\ \Omega$$
$$R_{\text{total}} = 40.0\ \Omega$$

Step 2. Find I_{source} using Ohm's law written as $I = \frac{V}{R}$.

$$I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}}$$
$$= \frac{40.0\ \text{V}}{40.0\ \Omega}$$
$$I_{\text{source}} = 1.00\ \text{A}$$

Step 3. Apply KCL to find I_1. Note that the source is in series with I_1 and the parallel part I_{parallel}.

$$I_{\text{series}} = I_1 = I_2 = I_3 = \cdots$$
$$I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 1.00\ \text{A}$$

Step 4. Find V_1 using Ohm's law written as $V = IR$.

$$V_1 = I_1 R_1$$
$$= (1.00\ \text{A})(25.0\ \Omega)$$
$$V_1 = 25.0\ \text{V}$$

Step 5. Apply KVL to find V_{parallel}.

$$V_{\text{series}} = V_1 + V_2 + V_3 + \cdots$$
$$V_{\text{source}} = V_1 + V_{\text{parallel}}$$
$$V_{\text{parallel}} = V_{\text{source}} - V_1$$
$$V_{\text{parallel}} = 40.0\ \text{V} - 25.0\ \text{V}$$
$$V_{\text{parallel}} = 15.0\ \text{V}$$

Step 6. Apply KVL to find V_2 and V_3.

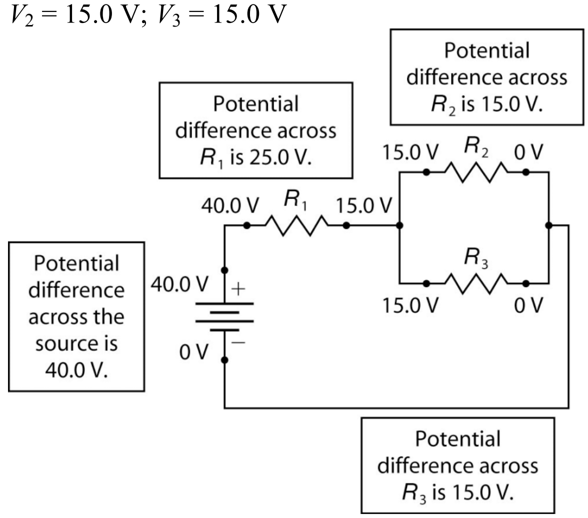
$$V_{\text{parallel}} = V_1 = V_2 = V_3 = \cdots$$
$$V_{\text{parallel}} = V_2 = V_3 = 15.0\ \text{V}$$

Step 7. Find I_2 and I_3 using Ohm's law written as $I = \frac{V}{R}$.

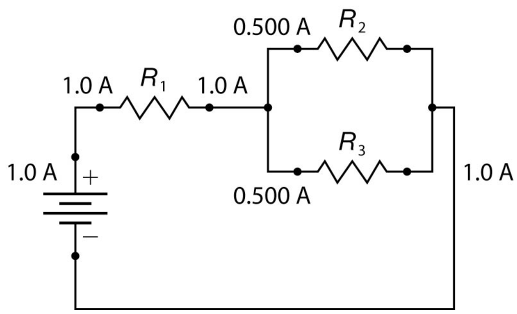
$$I_2 = \frac{V_2}{R_2}$$
$$= \frac{15.0\ \text{V}}{30.0\ \Omega}$$
$$I_2 = 0.500\ \text{A}$$

$$I_3 = \frac{V_3}{R_3}$$
$$= \frac{15.0\ \text{V}}{30.0\ \Omega}$$
$$I_3 = 0.500\ \text{A}$$

Step 8. Record your final answers using the correct number of significant digits. Look back at the circuit and see if the values you have calculated coincide with Kirchoff's laws.
$R_{\text{total}} = 40.0\ \Omega$; $I_{\text{source}} = 1.00$ A; $I_1 = 1.00$ A; $I_2 = 0.500$ A; $I_3 = 0.500$ A; $V_1 = 25.0$ V; $V_2 = 15.0$ V; $V_3 = 15.0$ V



The electric potential energies associated with the electrons are marked on the diagram. We chose a reference point of 0 V. The boxes represent the voltage across each point in the circuit. In each complete path, the sum of the voltage gains (40.0 V) equals the sum of the voltage drops (25.0 V + 15.0 V). Therefore, the problem is solved correctly.



The values on the diagram represent the current at various points in the circuit. The only junction is where the current splits into R_2 and R_3. The current going into the junction is 1.00 A. The current coming out is also 1.00 A. The current in each path of the parallel part of the circuit must add up to 0.500 A. A check of the values (0.500 A + 0.500 A = 1.00 A) shows that the current in the parallel part of the circuit adds up to 1.00 A.

Tutorial 1 Practice, Case 2, page 534

1.

Step 1. Apply KVL to any complete pathway. In this case, one complete pathway involves the source, resistor 1, and resistor 4.

$$V_{\text{source}} = V_1 + V_4$$
$$V_1 = V_{\text{source}} - V_4$$
$$V_1 = 42.0 \text{ V} - 17.5 \text{ V}$$
$$V_1 = 24.5 \text{ V}$$

Step 2. Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 1, resistor 2, and resistor 3.

$$V_{\text{source}} = V_1 + V_2 + V_3$$
$$V_3 = V_{\text{source}} - V_1 - V_2$$
$$= 42.0 \text{ V} - 24.5 \text{ V} - 8.75 \text{ V}$$
$$V_3 = 8.75 \text{ V}$$

Step 3. Find I_2 using Ohm's law written as $I = \frac{V}{R}$.

$$I_2 = \frac{V_2}{R_2}$$
$$= \frac{8.75 \text{ V}}{35.0 \text{ }\Omega}$$
$$I_2 = 0.250 \text{ A}$$

Step 4. Apply KCL to find the missing current values. Note that $I_{2,3}$ represents the current going through the path that contains I_2 and I_3.

Find I_{source}:

$$I_{\text{source}} = I_1$$
$$I_{\text{source}} = 1.75 \text{ A}$$

Find I_3:

$$I_{\text{series}} = I_3$$
$$= I_2$$
$$= 0.250 \text{ A}$$
$$I_3 = 0.250 \text{ A}$$

Find I_4:

$$I_{\text{source}} = I_{2,3} + I_4$$
$$I_4 = I_{\text{source}} - I_{2,3}$$
$$I_4 = 1.75 \text{ A} - 0.250 \text{ A}$$
$$I_4 = 1.50 \text{ A}$$

Step 5. Find all other missing values using Ohm's law.

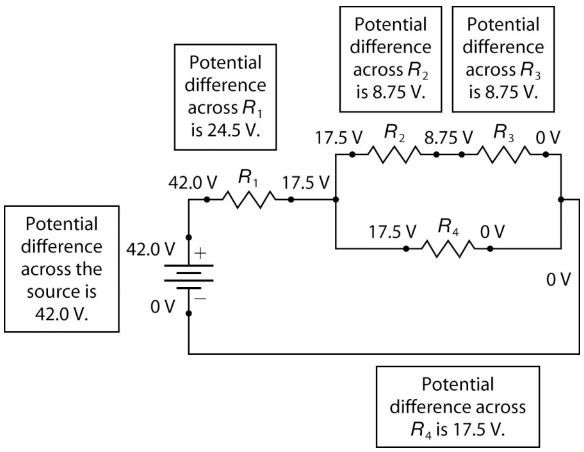
$$R_1 = \frac{V_1}{I_1}$$
$$= \frac{24.5 \text{ V}}{1.75 \text{ A}}$$
$$R_1 = 14.0 \text{ }\Omega$$

$$R_3 = \frac{V_3}{I_3}$$
$$= \frac{8.75 \text{ V}}{0.250 \text{ A}}$$
$$R_3 = 35.0 \text{ }\Omega$$

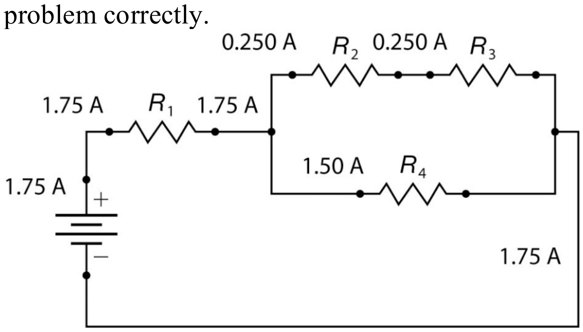
$$R_4 = \frac{V_4}{I_4}$$
$$= \frac{17.5 \text{ V}}{1.50 \text{ A}}$$
$$R_4 = 11.7 \text{ }\Omega$$

$$R_{\text{total}} = \frac{V_{\text{source}}}{I_{\text{source}}}$$
$$= \frac{42.0 \text{ V}}{1.7 \text{ 5A}}$$
$$R_{\text{total}} = 24.0 \text{ }\Omega$$

Step 6. Record your final answers with the correct number of significant digits. Now that you have finished the problem, you can look back at the circuit and see if the values you have calculated coincide with Kirchhoff's laws.
I_{source} = 1.75 A; I_2 = 0.250 A; I_3 = 0.250 A; I_4 = 1.50 A; V_1 = 24.5 V; V_3 = 8.75 V; R_1 = 14.0 Ω; R_3 = 35.0 Ω; R_4 = 11.7 Ω; R_{total} = 24.0 Ω



The electric potential energies associated with the electrons are marked on the diagram. We chose a reference point of 0 V. The red boxes represent the electric potential difference (or voltage) across the electric circuit parts. In one complete path, the sum of the voltage gains (42.0 V) equals the sum of the voltage drops (17.5 V + 15.75 V + 8.75 V). In the other complete path, the sum of the voltage gains (42.0 V) equals the sum of the voltage drops (24.5 V + 17.5 V). Therefore, you have solved the problem correctly.



The values on the diagram represent the current at various points in the circuit. The only junction is at the parallel part where the current splits into $R_{2,3}$ (R_2 and R_3 together) and R_4. The current going into the junction is 1.75 A. The current coming out is also 1.75 A. The currents in both paths of the parallel part of the circuit must add up to 1.75 A.

A check of the values (1.50 A + 0.250 = 1.75 A) shows that they do. Note that the current in the two resistors connected in series (R_2 and R_3) stays constant.

Section 11.9 Questions, page 535

1. (a)

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the parallel part of the circuit.

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{12.0\ \Omega} + \frac{1}{12.0\ \Omega}$$

$$R_{\text{parallel}} = 6.00\ \Omega$$

Now find the total resistance.
$R_{parallel}$ is in series with R_1, so

$$\begin{aligned} R_{\text{total}} &= R_1 + R_{\text{parallel}} \\ &= 12.0\ \Omega + 6.00\ \Omega \\ R_{\text{total}} &= 18.0\ \Omega \end{aligned}$$

Step 2. Find I_{source} using Ohm's law written as $I = \frac{V}{R}$.

$$\begin{aligned} I_{\text{source}} &= \frac{V_{\text{source}}}{R_{\text{source}}} \\ &= \frac{6.0\ \text{V}}{18.0\ \Omega} \\ I_{\text{source}} &= 0.33\ \text{A} \end{aligned}$$

Step 3. Apply KCL to find I_1. Note that the source is in series with I_1 and the parallel part $I_{parallel}$.

$$I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 0.33\ \text{A}$$

Step 4. Find V_1 using Ohm's law written as $V = IR$.

$$\begin{aligned} V_1 &= I_1 R_1 \\ &= (0.33\ \text{A})(12.0\ \Omega) \\ V_1 &= 4.0\ \text{V} \end{aligned}$$

Step 5. Apply KVL to find $V_{parallel}$.

$$\begin{aligned} V_{\text{source}} &= V_1 + V_{\text{parallel}} \\ V_{\text{parallel}} &= V_{\text{source}} - V_1 \\ &= 6.0\ \text{V} - 4.0\ \text{V} \\ V_{\text{parallel}} &= 2.0\ \text{V} \end{aligned}$$

Step 6. Apply KVL to find V_2 and V_3.

$$V_{\text{parallel}} = V_2 = V_3 = 2.0\text{ V}$$

Step 7. Find I_2 and I_3 using Ohm's law written as $I = \dfrac{V}{R}$.

$$\begin{aligned} I_2 &= \frac{V_2}{R_2} \\ &= \frac{2.0\text{ V}}{12.0\ \Omega} \\ I_2 &= 0.17\text{ A} \end{aligned}$$

$$\begin{aligned} I_3 &= \frac{V_3}{R_3} \\ &= \frac{2.0\text{ V}}{12.\ \Omega} \\ I_3 &= 0.17\text{ A} \end{aligned}$$

Step 8. Final answers:
$R_{\text{source}} = 18.0\ \Omega$; $I_{\text{source}} = 0.33$ A; $I_1 = 0.33$ A; $I_2 = 0.17$ A; $I_3 = 0.17$ A; $V_1 = 4.0$ V; $V_2 = 2.0$ V; $V_3 = 2.0$ V

(b)

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the resistors in series in the parallel part of the circuit. Find R_{series1}, the equivalent of R_2 and R_3:

$$\begin{aligned} R_{series1} &= R_2 + R_3 \\ &= 12.0\ \Omega + 12.0\ \Omega \\ R_{series1} &= 24.0\ \Omega \end{aligned}$$

Find R_{series2}, the equivalent of R_4 and R_5:

$$\begin{aligned} R_{series2} &= R_4 + R_5 \\ &= 12.0\ \Omega + 12.0\ \Omega \\ R_{series2} &= 24.0\ \Omega \end{aligned}$$

Now find the equivalent resistance for the parallel part of the circuit.

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_{series1}} + \frac{1}{R_{series2}}$$

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{24.0\ \Omega} + \frac{1}{24.0\ \Omega}$$

$$R_{\text{parallel}} = 12.0\ \Omega$$

Now find the total resistance.
R_{parallel} is in series with R_1 and R_6, so

$$\begin{aligned} R_{\text{total}} &= R_1 + R_{\text{parallel}} + R_6 \\ &= 12.0\ \Omega + 12.0\ \Omega + 12.0\ \Omega \\ R_{\text{total}} &= 36.0\ \Omega \end{aligned}$$

Step 2. Find I_{source} using Ohm's law written as $I = \dfrac{V}{R}$.

$$\begin{aligned} I_{\text{source}} &= \frac{V_{\text{source}}}{R_{\text{source}}} \\ &= \frac{6.0\text{ V}}{36.0\ \Omega} \\ I_{\text{source}} &= 0.17\text{ A} \end{aligned}$$

Step 3. Apply KCL to find I_1. Note that the source is in series with I_1, the parallel part I_{parallel}, and I_6.

$$I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = I_6 = 0.17\text{ A}$$

Step 4. Find V_1 and V_6 using Ohm's law written as $V = IR$.

$$\begin{aligned} V_1 &= I_1 R_1 \\ &= (0.17\text{ A})(12.0\ \Omega) \\ V_1 &= 2.0\text{ V} \end{aligned}$$

$$\begin{aligned} V_6 &= I_6 R_6 \\ &= (0.17\text{ A})(12.0\ \Omega) \\ V_6 &= 2.0\text{ V} \end{aligned}$$

Step 5. Apply KVL to find V_{parallel}.

$$\begin{aligned} V_{\text{source}} &= V_1 + V_{\text{parallel}} + V_6 \\ V_{\text{parallel}} &= V_{\text{source}} - V_1 - V_6 \\ &= 6.0\text{ V} - 2.0\text{ V} - 2.0\text{ V} \\ V_{\text{parallel}} &= 2.0\text{ V} \end{aligned}$$

Step 6. Apply KVL to find $V_{2,3}$ and $V_{4,5}$.

$$V_{\text{parallel}} = V_{2,3} = V_{4,5} = 2.0\text{ V}$$

Step 7. Find $I_{2,3}$ and $I_{4,5}$ using Ohm's law written as $I = \dfrac{V}{R}$. Note that $I_{2,3}$ represents the current going through the path that contains I_2 and I_3, and $I_{4,5}$ represents the current going through the path that contains I_4 and I_5.

$$\begin{aligned} I_{2,3} &= \frac{V_{2,3}}{R_{series1}} \\ &= \frac{2.0\text{ V}}{24.0\ \Omega} \\ I_{2,3} &= 0.083\text{ A} \end{aligned}$$

The same amount of current goes through both I_2 and I_3, so:
$I_{2,3} = I_2 = I_3 = 0.083$ A

$$I_{4,5} = \frac{V_{4,5}}{R_{series2}}$$
$$= \frac{2.0 \text{ V}}{24.0 \ \Omega}$$
$$I_{4,5} = 0.083 \text{ A}$$

The same amount of current goes through both I_4 and I_5, so:
$I_{4,5} = I_4 = I_5 = 0.083$ A

Step 8. Find all other missing values using Ohm's law.

$$V_2 = I_2R_2$$
$$= (0.083 \text{ A})(12.0 \ \Omega)$$
$$V_2 = 1.0 \text{ V}$$

$$V_3 = I_3R_3$$
$$= (0.083 \text{ A})(12.0 \ \Omega)$$
$$V_3 = 1.0 \text{ V}$$

$$V_4 = I_4R_4$$
$$= (0.083 \text{ A})(12.0 \ \Omega)$$
$$V_4 = 1.0 \text{ V}$$

$$V_5 = I_5R_5$$
$$= (0.083 \text{ A})(12.0 \ \Omega)$$
$$V_5 = 1.0 \text{ V}$$

Step 9. Final answers:
$R_{source} = 36.0\ \Omega$; $I_{source} = 0.17$ A; $I_1 = 0.17$ A; $I_2 = 0.083$ A; $I_3 = 0.083$ A; $I_4 = 0.083$ A; $I_5 = 0.083$ A; $I_6 = 0.17$ A; $V_1 = 2.0$ V; $V_2 = 1.0$ V; $V_3 = 1.0$ V; $V_4 = 1.0$ V; $V_5 = 1.0$ V; $V_6 = 2.0$ V

(c)

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the resistors in series in the parallel part of the circuit. Find $R_{series1}$, the equivalent of R_2 and R_3:

$$R_{series1} = R_2 + R_3$$
$$= 12.0 \ \Omega + 12.0 \ \Omega$$
$$R_{series1} = 24.0 \ \Omega$$

Now find the equivalent resistance for the parallel part of the circuit.

$$\frac{1}{R_{parallel}} = \frac{1}{R_{series1}} + \frac{1}{R_4}$$
$$\frac{1}{R_{parallel}} = \frac{1}{24.0 \ \Omega} + \frac{1}{12.0 \ \Omega}$$
$$R_{parallel} = 8.00 \ \Omega$$

Now find the total resistance.
$R_{parallel}$ is in series with R_1, so

$$R_{total} = R_1 + R_{parallel}$$
$$= 12.0 \ \Omega + 8.0 \ \Omega$$
$$R_{total} = 20.0 \ \Omega$$

Step 2. Find I_{source} using Ohm's law written as $I = \frac{V}{R}$.

$$I_{source} = \frac{V_{source}}{R_{source}}$$
$$= \frac{6.0 \text{ V}}{20.0 \ \Omega}$$
$$I_{source} = 0.30 \text{ A}$$

Step 3. Apply KCL to find I_1. Note that the source is in series with I_1 and the parallel part $I_{parallel}$.

$$I_{series} = I_{source} = I_1 = I_{parallel} = 0.30 \text{ A}$$

Step 4. Find V_1 using Ohm's law written as $V = IR$.

$$V_1 = I_1R_1$$
$$= (0.3 \text{ A})(12.0 \ \Omega)$$
$$V_1 = 3.6 \text{ V}$$

Step 5. Apply KVL to find $V_{parallel}$.

$$V_{source} = V_1 + V_{parallel}$$
$$V_{parallel} = V_{source} - V_1$$
$$= 6.0 \text{ V} - 3.6 \text{ V}$$
$$V_{parallel} = 2.4 \text{ V}$$

Step 6. Apply KVL to find $V_{2,3}$ and V_4.

$$V_{parallel} = V_{2,3} = V_4 = 2.4 \text{ V}$$

Step 7. Find $I_{2,3}$ and I_4 using Ohm's law written as $I = \frac{V}{R}$. Note that $I_{2,3}$ represents the current going through the path that contains I_2 and I_3.

$$\begin{aligned} I_{2,3} &= \frac{V_{2,3}}{R_{series1}} \\ &= \frac{2.4\ \text{V}}{24.0\ \Omega} \\ I_{2,3} &= 0.10\ \text{A} \end{aligned}$$

The same amount of current goes through both I_2 and I_3, so:
$I_{2,3} = I_2 = I_3 = 0.10$ A

$$\begin{aligned} I_4 &= \frac{V_4}{R_4} \\ &= \frac{2.4\ \text{V}}{12.0\ \Omega} \\ I_{4,5} &= 0.20\ \text{A} \end{aligned}$$

Step 8. Find all other missing values using Ohm's law.

$$\begin{aligned} V_2 &= I_2R_2 \\ &= (0.10\ \text{A})(12.0\ \Omega) \\ V_2 &= 1.2\ \text{V} \end{aligned}$$

$$\begin{aligned} V_3 &= I_3R_3 \\ &= (0.10\ \text{A})(12.0\ \Omega) \\ V_3 &= 1.2\ \text{V} \end{aligned}$$

$$\begin{aligned} V_4 &= I_4R_4 \\ &= (0.20\ \text{A})(12.0\ \Omega) \\ V_4 &= 2.4\ \text{V} \end{aligned}$$

Step 9. Final answers:
$R_{source} = 20.0\ \Omega$; $I_{source} = 0.30$ A; $I_1 = 0.30$ A; $I_2 = 0.10$ A; $I_3 = 0.10$ A; $I_4 = 0.20$ A; $V_1 = 3.6$ V; $V_2 = 1.2$ V; $V_3 = 1.2$ V; $V_4 = 2.4$ V

(d)

Step 1. Find the total resistance of the circuit. Start by finding the equivalent resistance for the resistors in series in the parallel part of the circuit.
Find $R_{series1}$, the equivalent of R_2 and R_3:

$$\begin{aligned} R_{series1} &= R_2 + R_3 \\ &= 12.0\ \Omega + 12.0\ \Omega \\ R_{series1} &= 24.0\ \Omega \end{aligned}$$

Find $R_{series2}$, the equivalent of R_4 and R_5:

$$\begin{aligned} R_{series2} &= R_4 + R_5 \\ &= 12.0\ \Omega + 12.0\ \Omega \\ R_{series2} &= 24.0\ \Omega \end{aligned}$$

Now find the equivalent resistance for the parallel part of the circuit.

$$\begin{aligned} \frac{1}{R_{\text{parallel}}} &= \frac{1}{R_{series1}} + \frac{1}{R_{series2}} \\ \frac{1}{R_{\text{parallel}}} &= \frac{1}{24.0\ \Omega} + \frac{1}{24.0\ \Omega} \\ R_{\text{parallel}} &= 12.0\ \Omega \end{aligned}$$

Now find the total resistance.
R_{parallel} is in series with R_1, so

$$\begin{aligned} R_{\text{total}} &= R_1 + R_{\text{parallel}} \\ &= 12.0\ \Omega + 12.0\ \Omega \\ R_{\text{total}} &= 24.0\ \Omega \end{aligned}$$

Step 2. Find I_{source} using Ohm's law written as $I = \frac{V}{R}$.

$$\begin{aligned} I_{\text{source}} &= \frac{V_{\text{source}}}{R_{\text{source}}} \\ &= \frac{6.0\ \text{V}}{24.0\ \Omega} \\ I_{\text{source}} &= 0.25\ \text{A} \end{aligned}$$

Step 3. Apply KCL to find I_1. Note that the source is in series with I_1 and the parallel part I_{parallel}.

$$I_{\text{series}} = I_{\text{source}} = I_1 = I_{\text{parallel}} = 0.25\ \text{A}$$

Step 4. Find V_1 using Ohm's law written as $V = IR$.

$$\begin{aligned} V_1 &= I_1R_1 \\ &= (0.25\ \text{A})(12.0\ \Omega) \\ V_1 &= 3.0\ \text{V} \end{aligned}$$

Step 5. Apply KVL to find V_{parallel}.

$$\begin{aligned} V_{\text{source}} &= V_1 + V_{\text{parallel}} \\ V_{\text{parallel}} &= V_{\text{source}} - V_1 \\ &= 6.0\ \text{V} - 3.0\ \text{V} \\ V_{\text{parallel}} &= 3.0\ \text{V} \end{aligned}$$

Step 6. Apply KVL to find $V_{2,3}$ and $V_{4,5}$.

$$V_{\text{parallel}} = V_{2,3} = V_{4,5} = 3.0\ \text{V}$$

Step 7. Find $I_{2,3}$ and $I_{4,5}$ using Ohm's law written as $I = \frac{V}{R}$. Note that $I_{2,3}$ represents the current going through the path that contains I_2 and I_3, and $I_{4,5}$ represents the current going through the path that contains I_4 and I_5.

$$I_{2,3} = \frac{V_{2,3}}{R_{series1}}$$
$$= \frac{3.0\text{ V}}{24.0\ \Omega}$$
$$I_{2,3} = 0.125\text{ A (one extra digit carried)}$$

The same amount of current goes through both I_2 and I_3, so:

$I_{2,3} = I_2 = I_3 = 0.125$ A (one extra digit carried)

$$I_{4,5} = \frac{V_{4,5}}{R_{series2}}$$
$$= \frac{3.0\text{ V}}{24.0\ \Omega}$$
$$I_{4,5} = 0.125\text{ A (one extra digit carried)}$$

The same amount of current goes through both I_4 and I_5, so:

$I_{4,5} = I_4 = I_5 = 0.125$ A (one extra digit carried)

Step 8. Find all other missing values using Ohm's law.

$$V_2 = I_2R_2$$
$$= (0.125\text{ A})(12.0\ \Omega)$$
$$V_2 = 1.5\text{ V}$$

$$V_3 = I_3R_3$$
$$= (0.125\text{ A})(12.0\Omega)$$
$$V_3 = 1.5\text{ V}$$

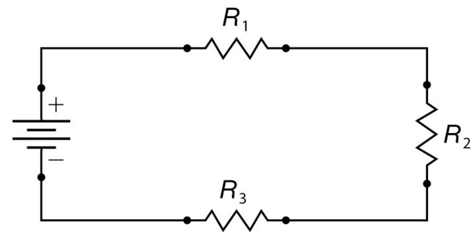
$$V_4 = I_4R_4$$
$$= (0.125\text{ A})(12.0\ \Omega)$$
$$V_4 = 1.5\text{ V}$$

$$V_5 = I_5R_5$$
$$= (0.125\text{ A})(12.0\ \Omega)$$
$$V_5 = 1.5\text{ V}$$

Step 9. Final answers:

$R_{source} = 24.0\ \Omega$; $I_{source} = 0.25$ A; $I_1 = 0.25$ A; $I_2 = 0.13$ A; $I_3 = 0.13$ A; $I_4 = 0.13$ A; $I_5 = 0.13$ A; $V_1 = 3.0$ V; $V_2 = 1.5$ V; $V_3 = 1.5$ V; $V_4 = 1.5$ V; $V_5 = 1.5$ V

2.



Step 1. Apply KCL to find the missing current values.

$$I_{series} = I_{source} = I_1 = I_3 = 0.20\text{ A}$$

Step 2. Find V_1 using Ohm's law written as $V = IR$.

$$V_1 = I_1R_1$$
$$= (0.20\text{ A})(30.0\ \Omega)$$
$$V_1 = 6.0\text{ V}$$

Step 3. Apply KVL to any complete pathway. In this case, one complete pathway involves the source, resistor 1, resistor 2, and resistor 3.

$$V_{source} = V_1 + V_2 + V_3$$
$$V_3 = V_{source} - V_1 - V_2$$
$$V_3 = 15.0\text{ V} - 6.0\text{ V} - 4.0\text{ V}$$
$$V_3 = 5.0\text{ V}$$

Step 4. Find all other missing values using Ohm's law.

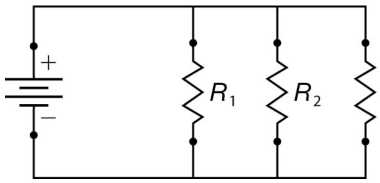
$$R_2 = \frac{V_2}{I_2}$$
$$= \frac{4.0\text{ V}}{0.20\text{ A}}$$
$$R_2 = 2.0 \times 10^1\ \Omega$$

$$R_3 = \frac{V_3}{I_3}$$
$$= \frac{5.0\text{ V}}{0.20\text{ A}}$$
$$R_3 = 25\ \Omega$$

$$R_{total} = \frac{V_{source}}{I_{source}}$$
$$= \frac{15.0\text{ V}}{0.20\text{ A}}$$
$$R_{total} = 75\ \Omega$$

Step 5. Final answers:
V_1 = 6.0 V; V_3 = 5.0 V; I_1 = 0.20 A; I_3 = 0.20 A; I_{source} = 0.20 A; $R_2 = 2.0 \times 10^1$ Ω; R_3 = 25 Ω; R_{total} = 75 Ω

3.



Step 1. Apply KVL to any complete pathway. In this case, one complete pathway involves the source and resistor 1.

$$V_{source} = V_1$$
$$V_1 = 1.5\ \text{V}$$

Step 2. Apply KVL to any complete pathway. In this case, another complete pathway involves the source and resistor 2.

$$V_{source} = V_2$$
$$V_2 = 1.5\ \text{V}$$

Step 3. Apply KVL to any complete pathway. In this case, another complete pathway involves the source and resistor 3.

$$V_{source} = V_3$$
$$V_3 = 1.5\ \text{V}$$

Step 4. Find I_2 and I_3 using Ohm's law written as $I = \frac{V}{R}$.

$$I_2 = \frac{V_2}{R_2} = \frac{1.5\ \text{V}}{7.5\ \Omega}$$
$$I_2 = 0.20\ \text{A}$$

$$I_3 = \frac{V_3}{R_3} = \frac{1.5\ \text{V}}{5.0\ \Omega}$$
$$I_3 = 0.30\ \text{A}$$

Step 5. Apply KCL to find the missing current values.
Find I_{source}:

$$I_{source} = I_1 + I_2 + I_3 = 0.10\ \text{A} + 0.20\ \text{A} + 0.30\ \text{A}$$
$$I_{source} = 0.60\ \text{A}$$

Step 6. Find all other missing values using Ohm's law.

$$R_1 = \frac{V_1}{I_1} = \frac{1.5\ \text{V}}{0.10\ \text{A}}$$
$$R_1 = 15\ \Omega$$

$$R_{total} = \frac{V_{source}}{I_{source}} = \frac{1.5\ \text{V}}{0.60\ \text{A}}$$
$$R_{total} = 2.5\ \Omega$$

Step 7. Final answers:
V_1 = 1.5 V; V_2 = 1.5 V; V_3 = 1.5 V; I_2 = 0.20 A; I_3 = 0.30 A; I_{source} = 0.60 A; R_1 = 15 Ω; R_{total} = 2.5 Ω

4.

Step 1. Find V_4 using Ohm's law written as $V = IR$.

$$V_4 = I_4R_4 = (0.10\ \text{A})(70.0\ \Omega)$$
$$V_4 = 7.0\ \text{V}$$

Step 2. Apply KVL to any complete pathway. In this case, one complete pathway involves the source, resistor 1, resistor 3, and resistor 4.

$$V_{source} = V_1 + V_3 + V_4 = 2.5\ \text{V} + 5.0\ \text{V} + 7.0\ \text{V}$$
$$V_{source} = 14.5\ \text{V}$$

Step 3. Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 1, resistor 3, and resistor 5.

$$V_{source} = V_1 + V_3 + V_5$$
$$V_5 = V_{source} - V_1 - V_3 = 14.5\ \text{V} - 2.5\ \text{V} - 5.0\ \text{V}$$
$$V_5 = 7.0\ \text{V}$$

Step 4. Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 2, resistor 3, and resistor 4.

$$V_{\text{source}} = V_2 + V_3 + V_4$$
$$V_2 = V_{\text{source}} - V_3 - V_4$$
$$V_2 = 14.5\text{ V} - 5.0\text{ V} - 7.0\text{ V}$$
$$V_2 = 2.5\text{ V}$$

Step 5. Apply KCL to find the missing current values.

Find I_{source}:

$$I_{\text{source}} = I_3$$
$$I_{\text{source}} = 0.50\text{ A}$$

Find I_1:

$$I_{\text{source}} = I_1 + I_2$$
$$I_1 = I_{\text{source}} - I_2$$
$$I_1 = 0.50\text{ A} - 0.30\text{ A}$$
$$I_1 = 0.20\text{ A}$$

Find I_5:

$$I_{\text{source}} = I_4 + I_5$$
$$I_5 = I_{\text{source}} - I_4$$
$$I_5 = 0.50\text{ A} - 0.10\text{ A}$$
$$I_5 = 0.40\text{ A}$$

Step 6. Find all other missing values using Ohm's law.

$$R_1 = \frac{V_1}{I_1} = \frac{2.5\text{ V}}{0.20\text{ A}}$$
$$R_1 = 13\ \Omega$$

$$R_2 = \frac{V_2}{I_2} = \frac{2.5\text{ V}}{0.30\text{ A}}$$
$$R_2 = 8.3\ \Omega$$

$$R_3 = \frac{V_3}{I_3} = \frac{5.0\text{ V}}{0.50\text{ A}}$$
$$R_3 = 1.0 \times 10^1\ \Omega$$

$$R_5 = \frac{V_5}{I_5} = \frac{7.0\text{ V}}{0.40\text{ A}}$$
$$R_5 = 18\ \Omega$$

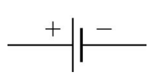
$$R_{\text{total}} = \frac{V_{\text{source}}}{I_{\text{source}}} = \frac{14.5\text{ V}}{0.50\text{ A}}$$
$$R_{\text{total}} = 29\ \Omega$$

Step 6. Final answers:
$V_{\text{source}} = 14.5$ V; $V_2 = 2.5$ V; $V_4 = 7.0$ V; $V_5 = 7.0$ V; $I_{\text{source}} = 0.50$ A; $I_1 = 0.20$ A; $I_5 = 0.40$ A; $R_1 = 13\ \Omega$; $R_2 = 8.3\ \Omega$; $R_3 = 1.0 \times 10^1\ \Omega$; $R_5 = 18\ \Omega$; $R_{\text{total}} = 29\ \Omega$

Chapter 11 Review, pages 540–545

Knowledge

1. (b)
2. (b)
3. (c)
4. (d)
5. (b)
6. (c)
7. (a)
8. (d)
9. (c)
10. True
11. False. *Carbon capture and storage* is a technology that captures carbon dioxide leaving the smokestack, compresses it, and transports it by pipeline to a storage location deep underground.
12. True
13. False. Conventional current is the movement of charge from *positive to negative*.
14. False. Direct current is the flow of electrons *in one direction only.*
15. True
16. True
17. False. Superconductors are materials with *no* electrical resistance.
18. False. For resistors in series, the total resistance is given by $R_{series} = R_1 + R_2 + R_3 + \cdots$.
19. Using Kirchhoff's voltage law (KVL) for a series circuit, the potential difference across the voltage source is: $V_{source} = V_1 + V_2 + V_3$.
20. In a parallel circuit the equivalent resistance is given by $\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$, so the total resistance, R, for three resistors placed in parallel is given by $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.
21.



Understanding

22. The nuclear power plant has an efficiency of 35 %, so 35 % of the total power is transformed into electrical energy. 35 % of 12 000 MW is: 0.35 × 12 000 MW = 4200 MW. So, the power plant produces 4200 MW of electrical power.

23. Given: P = 60.0 W; Δt = 3.0 h
Required: ΔE
Analysis: $P = \frac{\Delta E}{\Delta t}$

$\Delta E = P\Delta t$

Solution: Convert time to seconds to get the answer in joules:

$$\Delta t = 3.0\cancel{h} \times \frac{3600\ s}{1\cancel{h}}$$
$$\Delta t = 10\ 800\ s$$

$$\Delta E = (60.0\ W)(10\ 800\ s)$$
$$= 6.48 \times 10^5\ W \bullet s$$
$$\Delta E = 6.48 \times 10^5\ J\ \text{(one extra digit carried)}$$

To find the answer in kilowatt hours, convert from joules:

$$6.48 \times 10^5\ \cancel{J} \times \frac{1\ kWh}{3.6 \times 10^6\ \cancel{J}} = 0.18\ kWh$$

Statement: The light bulb requires 0.18 kWh of energy to operate for 3.0 h.

24. Given: P = 450 W; Δt = 48 h
Required: ΔE
Analysis: $P = \frac{\Delta E}{\Delta t}$

$\Delta E = P\Delta t$

Solution: Convert time to seconds to get the answer in joules:

$$\Delta t = 48\cancel{h} \times \frac{3600\ s}{1\cancel{h}}$$
$$\Delta t = 172\ 800\ s$$

$$\Delta E = (450\ W)(172\ 800\ s)$$
$$= 7.776 \times 10^7\ W \bullet s$$
$$\Delta E = 7.776 \times 10^7\ J\ \text{(two extra digits carried)}$$

To find the answer in kilowatt hours, convert from joules:

$$7.776 \times 10^7\ \cancel{J} \times \frac{1\ kWh}{3.6 \times 10^6\ \cancel{J}} = 22\ kWh$$

Statement: The window air conditioner needs 78 MJ or 22 kWh of energy to operate for 48 h.

25. Given: ΔE = 1200 J; Δt = 5 min
Required: P

Analysis: $P = \dfrac{\Delta E}{\Delta t}$

Solution: First convert time to seconds to get the answer in joules per second or watts:

$$\Delta t = 5\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}}$$
$$\Delta t = 300\ \text{s}$$

$$P = \frac{\Delta E}{\Delta t}$$
$$= \frac{1200\ \text{J}}{300\ \text{s}}$$
$$P = 4\ \text{W}$$

Statement: The amount of power required to charge the battery is 4 W.

26. (a) The solar power plant has an efficiency of 16% and produces 30.0 MW of electrical power, so 16% of the input power, P_{in}, is 30.0 MW. This is 0.16 × P_{in} = 30.0 MW, which can be used to solve for P_{in}:

$$0.16 \times P_{in} = 30.0\ \text{MW}$$
$$P_{in} = \frac{30.0\ \text{MW}}{0.16}$$
$$P_{in} = 190\ \text{MW}$$

The power plant requires 190 MW of input power to produce an output of 30.0 MW.

(b) The solar power plant has 190 MW of power as an input and 30.0 MW of power as an output, so 190 MW - 30.0 MW = 160 MW of power is lost. 160 MW is 160 MJ/s, so 160 MJ is lost by being converted to thermal energy each second.

27. Given: ΔE = 1080 J; Q = 120 C
Required: V

Analysis: $V = \dfrac{\Delta E}{Q}$

Solution: $V = \dfrac{\Delta E}{Q}$

$$= \frac{1080\ \text{J}}{120\ \text{C}}$$
$$V = 9.0\ \text{V}$$

Statement: The electric potential difference between the terminals of the battery is 9.0 V.

28. Given: V = 120 V; ΔE = 480 J
Required: Q

Analysis: $V = \dfrac{\Delta E}{Q}$

$$Q = \frac{\Delta E}{V}$$

Solution: $Q = \dfrac{\Delta E}{V}$

$$= \frac{480\ \text{J}}{120\ \text{V}}$$
$$Q = 4.0\ \text{C}$$

Statement: The total amount of charge moved across the terminals is 4.0 C.

29. Given: P = 35 W; Δt = 2.5 h; V = 120 V
Required: Q

Analysis: $V = \dfrac{\Delta E}{Q}$

$$Q = \frac{\Delta E}{V}$$
$$P = \frac{\Delta E}{\Delta t}$$

Solution: Convert time to seconds to find ΔE in joules using the power equation from Section 11.1:

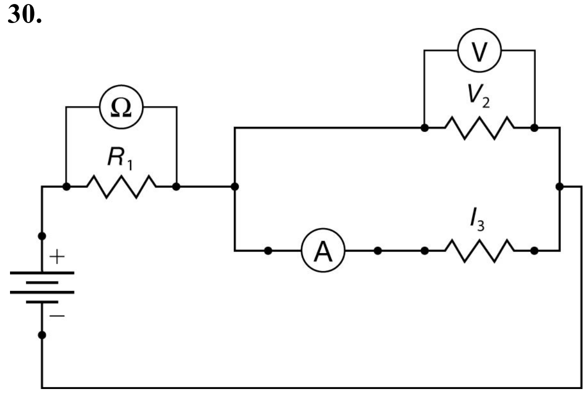
$$\Delta t = 2.5\ \text{h}$$
$$= 2.5\cancel{\text{h}} \times \frac{3600\ \text{s}}{1\cancel{\text{h}}}$$
$$\Delta t = 9000\ \text{s}$$

$$P = \frac{\Delta E}{\Delta t}$$
$$\Delta E = P\Delta t$$
$$= (35\ \text{W})(9000\ \text{s})$$
$$= \left(35\ \frac{\text{J}}{\cancel{\text{s}}}\right)(9000\ \cancel{\text{s}})$$
$$\Delta E = 315\ 000\ \text{J}$$

$$Q = \frac{\Delta E}{V}$$
$$= \frac{315\ 000\ \text{J}}{120\ \text{V}}$$
$$\text{Q} = 2600\ \text{C}$$

Statement: The total amount of charge that moves through the bulb while it is on is 2600 C.

30.



31. (a) Given: $V = 240$ V; $\Delta E = 2.0$ kWh
Required: Q

Analysis: $V = \frac{\Delta E}{Q}$

$$Q = \frac{\Delta E}{V}$$

Solution: First convert energy to joules to get the answer in coulombs:

$$\Delta E = 2.0\ \cancel{\text{kWh}} \times \frac{3.6\times10^6\ \text{J}}{1\ \cancel{\text{kWh}}}$$

$$\Delta E = 7.2\times10^6\ \text{J}$$

$$V = \frac{\Delta E}{Q} = \frac{7.2\times10^6\ \text{J}}{240\ \text{V}}$$

$$Q = 3.0\times10^4\ \text{C}$$

Statement: The total amount of charge moved through the machine for each load is 3.0×10^4 C.

(b) Given: $\Delta t = 35$ min; $\Delta E = 2.0$ kWh
Required: P

Analysis: $P = \frac{\Delta E}{\Delta t}$

Solution: Convert time to seconds and energy to joules to find P in watts using the power equation from Section 11.1:

$$\Delta t = 35\ \text{min} = 35\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}}$$

$$\Delta t = 2100\ \text{s}$$

$$P = \frac{\Delta E}{\Delta t} = \frac{7.2\times10^6\ \text{J}}{2100\ \text{s}} = 3400\ \text{W} = 3400\ \cancel{\text{W}} \times \frac{1\ \text{kW}}{1000\ \cancel{\text{W}}} = 3400\ \text{W}$$

$$P = 3.4\ \text{kW}$$

Statement: The washing machine uses 3400 W or 3.4 kW of power for a 35 min load.

(c) Given: $\Delta t = 35$ min; $Q = 3.0 \times 10^4$ C
Required: I

Analysis: $I = \frac{Q}{\Delta t}$

Solution: Convert time to seconds and use the value for Q found in part (a) to get the answer in coulombs per second, or amperes:

$$\Delta t = 35\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}}$$

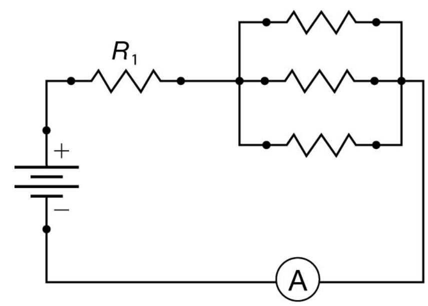
$$\Delta t = 2100\ \text{s}$$

$$I = \frac{Q}{\Delta t} = \frac{3.0\times10^4\ \text{C}}{2100\ \text{s}}$$

$$I = 14\ \text{A}$$

Statement: The washing machine draws 14 A of current for a 35 min load.

32.



33. Given: $Q = 0.75$ C; $\Delta t = 1.7$ min
Required: I

Analysis: $I = \frac{Q}{\Delta t}$

Solution: Convert time to seconds to get the answer in coulombs per second, or amperes:

$$\Delta t = 1.7\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}}$$

$$\Delta t = 102\ \text{s}$$

$$I = \frac{Q}{\Delta t} = \frac{0.75\ \text{C}}{102\ \text{s}}$$

$$I = 7.4\times10^{-3}\ \text{A}$$

Convert the current to milliamperes:

$$I = 7.4\times10^{-3}\ \cancel{\text{A}} \times \frac{1000\ \text{mA}}{1\ \cancel{\text{A}}}$$

$$I = 7.4\ \text{mA}$$

Statement: The amount of current in the wire is 7.4 mA.

34. Given: $I = 3.2$ A; $\Delta t = 5.0$ h
Required: Q

Analysis: $I = \frac{Q}{\Delta t}$

$Q = I\Delta t$

Solution: Convert time to seconds to get the answer in ampere-seconds, or coulombs:

$$\Delta t = 5.0\cancel{\text{h}} \times \frac{3600 \text{ s}}{1\cancel{\text{h}}}$$
$$\Delta t = 18\ 000 \text{ s}$$

$$Q = I\Delta t$$
$$= (3.2 \text{ A})(18\ 000 \text{ s})$$
$$Q = 58\ 000 \text{ C}$$

Statement: In 5.0 h, 58 000 C pass through the wire.

35. Given: $Q = 3$ C; $I = 750$ mA
Required: Δt

Analysis: $I = \frac{Q}{\Delta t}$

$\Delta t = \frac{Q}{I}$

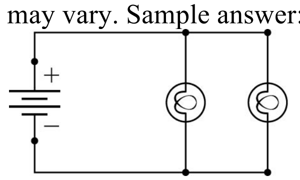
Solution: Convert current to amperes to get the answer in coulombs per ampere, or seconds:

$$I = 750\cancel{\text{mA}} \times \frac{1 \text{ A}}{1000\cancel{\text{mA}}}$$
$$I = 0.75 \text{ A}$$

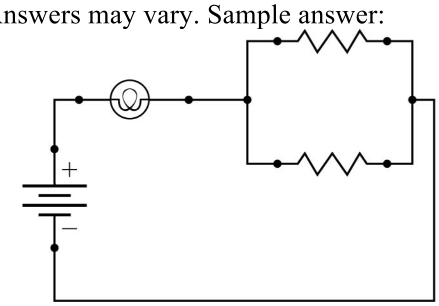
$$\Delta t = \frac{Q}{I}$$
$$= \frac{3 \text{ C}}{0.75 \text{ A}}$$
$$\Delta t = 4 \text{ s}$$

Statement: It takes 4 s for the charge to pass through the resistor.

36. Answers may vary. Sample answer:



37. Answers may vary. Sample answer:



38. (a) Using KVL for a series circuit, you can solve for V_2:

$$V_{\text{source}} = V_1 + V_2$$
$$9.0 \text{ V} = 3.0 \text{ V} + V_2$$
$$V_2 = 6.0 \text{ V}$$

So V_2 is 6.0 V.

(b) Using KVL for a series circuit and letting $V_1 = V_2$, you can solve for V_2:

$$V_{\text{source}} = V_1 + V_2$$
$$V_{\text{source}} = V_2 + V_2$$
$$V_{\text{source}} = 2V_2$$
$$V_2 = \frac{V_{\text{source}}}{2}$$
$$= \frac{9.0 \text{ V}}{2}$$
$$V_2 = 4.5 \text{ V}$$

So V_2 is 4.5 V.

39. (a) The current in a series circuit is constant and the same as the source current. The source and lamp 1 are in series, and $I_1 = 7.5$ mA. Using these values and KCL, you can find I_{source}:

$$I_{\text{source}} = I_1$$
$$I_{\text{source}} = 7.5 \text{ mA}$$

The amount of current entering a junction is equal to the amount of current exiting the junction. This can be used to find I_3:

$$I_{\text{parallel}} = I_2 + I_3$$
$$7.5 \text{ mA} = 4.3 \text{ mA} + I_3$$
$$I_3 = 3.2 \text{ mA}$$

So I_3 is 3.2 mA.

(b) The current in a series circuit is constant and the same as the source current. From part (a), $I_{\text{source}} = 7.5$ mA. The amount of current entering a junction is equal to the amount of current exiting the junction. Letting $I_2 = I_3$, this can be used to find I_3:

$$I_{\text{parallel}} = I_2 + I_3$$
$$I_{\text{parallel}} = I_3 + I_3$$
$$I_{\text{parallel}} = 2I_3$$
$$I_3 = \frac{I_{\text{parallel}}}{2}$$
$$= \frac{7.5 \text{ mA}}{2}$$
$$I_3 = 3.8 \text{ mA}$$

So I_3 is 3.8 mA.

40. Given: V = 60 V; A = 750 mA.
Required: R
Analysis: $R = \frac{V}{I}$
Solution: Convert the current to amperes to get the answer in ohms:

$$I = 750\,\cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\,\cancel{\text{mA}}}$$
$$I = 0.75\ \text{A}$$

$$R = \frac{V}{I} = \frac{60\ \text{V}}{0.75\ \text{A}}$$
$$R = 80\ \Omega$$

Statement: The resistance of the load is 80 Ω.

41. Given: R = 80.0 Ω; A = 0.85 mA.
Required: R
Analysis: $R = \frac{V}{I}$
Solution: Convert the current to amperes to get the answer in volts:

$$I = 0.85\,\cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\,\cancel{\text{mA}}}$$
$$I = 8.5 \times 10^{-4}\ \text{A}$$

$$R = \frac{V}{I}$$
$$V = IR$$
$$= (8.5 \times 10^{-4}\ \text{A})(80.0\ \Omega)$$
$$= 6.8 \times 10^{-2}\ \text{V}$$
$$= 6.8 \times 10^{-2}\,\cancel{\text{V}} \times \frac{1000\ \text{mV}}{1\,\cancel{\text{V}}}$$
$$V = 68\ \text{mV}$$

Statement: The potential difference across the resistor is 68 mV.

42. The current in a series circuit is constant and the same as the source current. The source, load 1, and load 2 are in series, and I_{source} = 0.50 mA. Using these values and KCL, you can find I_1 and I_2:

$$I_{\text{source}} = I_1 = I_2$$
$$0.50\ \text{mA} = I_1 = I_2$$

Using KVL for a series circuit, you can solve for V_2:

$$V_{\text{source}} = V_1 + V_2$$
$$12\ \text{V} = 4.55\ \text{V} + V_2$$
$$V_2 = 7.45\ \text{V}$$

Using the given value for V_1 and the values found for I_1, I_2, and V_2, the resistances R_1 and R_2 can be found:

Required: R_1
Analysis: $R_1 = \frac{V_1}{I_1}$
Solution: Convert the current to amperes to get the answer in ohms:

$$I_1 = 0.50\,\cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\,\cancel{\text{mA}}}$$
$$I_1 = 5.0 \times 10^{-4}\ \text{A}$$

$$R_1 = \frac{V_1}{I_1}$$
$$= \frac{4.55\ \text{V}}{5.0 \times 10^{-4}\ \text{A}}$$
$$= 9100\ \Omega$$
$$= 9100\,\cancel{\Omega} \times \frac{1\ \text{k}\Omega}{1000\,\cancel{\Omega}}$$
$$R_1 = 9.1\ \text{k}\Omega$$

Statement: The resistance of load 1 is 9.1 kΩ.

Required: R_2
Analysis: $R_2 = \frac{V_2}{I_2}$
Solution: Convert the current to amperes to get the answer in ohms:

$$I_2 = 0.50\,\cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\,\cancel{\text{mA}}}$$
$$I_2 = 5.0 \times 10^{-4}\ \text{A}$$

$$R_2 = \frac{V_2}{I_2}$$
$$= \frac{7.45\ \text{V}}{5.0 \times 10^{-4}\ \text{A}}$$
$$= 15\ 000\ \Omega$$
$$= 15\ 000\,\cancel{\Omega} \times \frac{1\ \text{k}\Omega}{1000\,\cancel{\Omega}}$$
$$R_2 = 15\ \text{k}\Omega$$

Statement: The resistance of load 2 is 15 kΩ.

43. Given: R_1 = 2.3 Ω; R_2 = 4.3 Ω; R_3 = 0.85 Ω; R_4 = 1.2 Ω
Required: R_{series}
Analysis: $R_{series} = R_1 + R_2 + R_3 + R_4$
Solution:

$$\begin{aligned} R_{series} &= R_1 + R_2 + R_3 + R_4 \\ &= 2.3\ \Omega + 4.3\ \Omega + 0.85\ \Omega + 1.2\ \Omega \\ R_{series} &= 8.7\ \Omega \end{aligned}$$

Statement: The total resistance of the circuit is 8.7 Ω.

44. Given: R_1 = 2.1 Ω; R_2 = 7.2 Ω; R_3 = 4.5 Ω
Required: $R_{parallel}$
Analysis: $\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
Solution:

$$\begin{aligned} \frac{1}{R_{parallel}} &= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \\ \frac{1}{R_{parallel}} &= \frac{1}{2.1\ \Omega} + \frac{1}{7.2\ \Omega} + \frac{1}{4.5\ \Omega} \\ R_{parallel} &= 1.2\ \Omega \end{aligned}$$

Statement: The equivalent resistance of the circuit is 1.2 Ω.

45. The resistors R_2 and R_3 are in parallel and can be replaced with an equivalent resistance:

$$\begin{aligned} \frac{1}{R_{parallel}} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \frac{1}{R_{parallel}} &= \frac{1}{13\ \Omega} + \frac{1}{27.2\ \Omega} \\ R_{parallel} &= 8.8\ \Omega \end{aligned}$$

The resistor R_1 and the equivalent resistance $R_{parallel}$ are in series and can be replaced with an equivalent resistance:

$$\begin{aligned} R_{total} &= R_1 + R_{parallel} \\ &= 6.1\ \Omega + 8.8\ \Omega \\ R_{total} &= 15\ \Omega \end{aligned}$$

Statement: The total resistance of the circuit is 15 Ω..

46. Using KVL for a series circuit, you can solve for V_2:

$$\begin{aligned} V_{source} &= V_1 + V_2 \\ 18\ \text{V} &= 7.0\ \text{V} + V_2 \\ V_2 &= 11\ \text{V} \end{aligned}$$

You can now solve for I_2:

$$\begin{aligned} R_2 &= \frac{V_2}{I_2} \\ I_2 &= \frac{V_2}{R_2} \\ &= \frac{11\ \text{V}}{30.0\ \Omega} \\ I_2 &= 0.37\ \text{A} \end{aligned}$$

The current in a series circuit is constant and the same as the source current. The source, load 1, and load 2 are in series, and I_2 = 0.37 A. Using these values and KCL, you can find I_{source} and I_1:

$$\begin{aligned} I_{source} &= I_1 = I_2 \\ I_{source} &= I_1 = 0.37\ \text{A} \end{aligned}$$

You can now solve for R_1:

$$\begin{aligned} R_1 &= \frac{V_1}{I_1} \\ &= \frac{7.0\ \text{V}}{0.37\ \text{A}} \\ R_1 &= 19\ \Omega \end{aligned}$$

Statement: The value of R_1 is 19 Ω, the value of V_2 is 11 V, and the current through the circuit is 0.37 A.

47.
Step 1. Apply KVL to any complete pathway. In this case, one complete pathway involves the source, resistor 1, and resistor 2.

$$\begin{aligned} V_{source} &= V_1 + V_2 \\ V_2 &= V_{source} - V_1 \\ &= 22\ \text{V} - 12\ \text{V} \\ V_2 &= 10\ \text{V} \end{aligned}$$

Step 2. Apply KVL to any complete pathway. In this case, another complete pathway involves the source, resistor 1, and resistor 3.

$$\begin{aligned} V_{source} &= V_1 + V_3 \\ V_3 &= V_{source} - V_1 \\ &= 22\ \text{V} - 12\ \text{V} \\ V_3 &= 10\ \text{V} \end{aligned}$$

Step 3. Find I_1 and I_2 using Ohm's law written as $I = \frac{V}{R}$.

$$I_1 = \frac{V_1}{R_1}$$
$$= \frac{12\text{ V}}{3.0\ \Omega}$$
$$I_1 = 4.0\text{ A}$$

$$I_2 = \frac{V_2}{R_2}$$
$$= \frac{10\text{ V}}{60.0\ \Omega}$$
$$= 0.1667\text{ A}$$
$$= 0.1667\not{\text{A}} \times \frac{1000\text{ mA}}{1\not{\text{A}}}$$
$$I_2 = 166.7\text{ mA (two extra digits carried)}$$

Step 4. Apply KCL to find the missing current values.

Find I_{source}:

$$I_{\text{source}} = I_1$$
$$I_{\text{source}} = 4.0\text{ A}$$

Find I_3:

$$I_{\text{source}} = I_2 + I_3$$
$$I_3 = I_{\text{source}} - I_2$$
$$I_3 = 4.0\text{ A} - 0.1667\text{ A}$$
$$I_3 = 3.833\text{ A (two extra digits carried)}$$

Step 5. Find R_3 using Ohm's law in the form $R = \frac{V}{I}$.

$$R_3 = \frac{V_3}{I_3}$$
$$= \frac{10\text{ V}}{3.833\text{ A}}$$
$$R_3 = 2.6\ \Omega$$

Step 6. Final answers:
$I_1 = 4.0$ A; $I_2 = 170$ mA; $I_3 = 3.8$ A; $R_3 = 2.6\ \Omega$

Analysis and Application

48. (a) The hydroelectric power plant has an efficiency of 85 % and produces 1200 MW of electrical power, so 85 % of the input power, P_{in}, is 1200 MW. This is $0.85 \times P_{\text{in}} = 1200$ MW, which can be used to solve for P_{in}:

$$0.85 \times P_{\text{in}} = 1200\text{ MW}$$
$$P_{\text{in}} = \frac{1200\text{ MW}}{0.85}$$
$$P_{\text{in}} = 1400\text{ MW}$$

The power wasted is P_{in} - P_{out}, and P_{out} is 1200 MW, so the power wasted is
1400 MW – 1200 MW = 200 MW

The nuclear power plant has an efficiency of 40 % and produces 1200 MW of electrical power, so 40 % of the input power, P_{in}, is 1200 MW. This is $0.40 \times P_{\text{in}} = 1200$ MW, which can be used to solve for P_{in}:

$$0.40 \times P_{\text{in}} = 1200\text{ MW}$$
$$P_{\text{in}} = \frac{1200\text{ MW}}{0.40}$$
$$P_{\text{in}} = 3000\text{ MW}$$

The power wasted is $P_{\text{in}} - P_{\text{out}}$, and P_{out} is 1200 MW, so the power wasted is
3000 MW – 1200 MW = 1800 MW

The difference in the amounts of power wasted is 1800 MW – 200 MW = 1600 MW.
So, the nuclear power plant wastes 1600 MW more power than the hydroelectric power plant.

(b) Answers may vary. Sample answer:
Two power plant technologies that can be compared more directly are wind power and solar power.

49. The coal-fired power plant has an efficiency of 46 % and produces 2500 MW of electrical power, so 46 % of the input power, P_{in}, is 2500 MW. This is $0.46 \times P_{\text{in}} = 2500$ MW, which can be used to solve for P_{in}:

$$0.46 \times P_{\text{in}} = 2500\text{ MW}$$
$$P_{\text{in}} = \frac{2500\text{ MW}}{0.46}$$
$$P_{\text{in}} = 5435\text{ MW (two extra digits carried)}$$

The coal-fire power plant with carbon capture technology installed has an efficiency of 42 % and still has an input of 5435 MW of electrical power, so 42 % of 5435 MW, is P_{out}. This is $0.42 \times 5435\text{ MW} = P_{\text{out}}$, which can be used to solve for P_{out}:

$$0.42 \times 5435\text{ MW} = P_{\text{out}}$$
$$P_{\text{out}} = 2283\text{ MW (two extra digits carried)}$$

The difference in the amount of output power is 2500 MW – 2283 MW = 220 MW.
So the amount of extra power lost to the carbon capture technology is 220 MW.

50. Given: P = 90 % of 40.0 W; ΔE = 2.0 MJ

Required: Δt

Analysis: $P = \dfrac{\Delta E}{\Delta t}$

Solution: Convert ΔE to joules to get the answer in joules per second, or watts:

$$\begin{aligned}\Delta E &= 2.0 \text{ MJ} \\ &= 2.0 \cancel{\text{MJ}} \times \frac{10^6 \text{ J}}{1 \cancel{\text{MJ}}} \\ \Delta E &= 2.0 \times 10^6 \text{ J}\end{aligned}$$

$$\begin{aligned}P &= 90 \text{ \% of } 40.0 \text{ W} \\ &= 0.90 \times 40.0 \text{ W} \\ P &= 36.0 \text{ W}\end{aligned}$$

$$\begin{aligned}P &= \frac{\Delta E}{\Delta t} \\ \Delta t &= \frac{\Delta E}{P} \\ &= \frac{2.0 \times 10^6 \cancel{\text{J}}}{36.0 \dfrac{\cancel{\text{J}}}{\text{s}}} \\ &= 5.56 \times 10^4 \text{ s (one extra digit carried)} \\ &= 5.56 \times 10^4 \cancel{\text{s}} \times \frac{1 \text{ h}}{3600 \text{ s}} \\ \Delta t &= 15 \text{ h}\end{aligned}$$

Statement: It takes 15 h to charge the battery.

51. Given: P = 11 % of 60.0 W; Δt = 2.0 h

Required: ΔE_{input}; ΔE_{output}

Analysis: $P = \dfrac{\Delta E}{\Delta t}$

Solution: Convert time to seconds to get the answer in joules:

$$\begin{aligned}\Delta t &= 2.0 \cancel{\text{h}} \times \frac{60 \cancel{\text{min}}}{1 \cancel{\text{h}}} \times \frac{60 \text{ s}}{1 \cancel{\text{min}}} \\ \Delta t &= 7200 \text{ s}\end{aligned}$$

For input energy, ΔE_{input}:

$$\begin{aligned}P &= \frac{\Delta E_{\text{input}}}{\Delta t} \\ \Delta E_{\text{intput}} &= P \times \Delta t \\ &= 60.0 \text{ W} \times 7200 \text{ s} \\ \Delta E_{\text{input}} &= 4.3 \times 10^5 \text{ J}\end{aligned}$$

For output energy, ΔE_{output}:

$$\begin{aligned}P &= 11 \text{ \% of } 60.0 \text{ W} \\ &= 0.11 \times 60.0 \text{ W} \\ P &= 6.6 \text{ W}\end{aligned}$$

$$\begin{aligned}P &= \frac{\Delta E_{\text{output}}}{\Delta t} \\ \Delta E_{\text{output}} &= P \times \Delta t \\ &= 6.6 \text{ W} \times 7200 \text{ s} \\ \Delta E_{\text{output}} &= 4.8 \times 10^4 \text{ J}\end{aligned}$$

Statement: The input energy is 4.3×10^5 J. The output energy is 4.8×10^4 J.

52. Given: P = 75 % of 14 W; ΔE_{input} = 5.1 kWh

Required: ΔE_{output}; Δt

Analysis: $P = \dfrac{\Delta E}{\Delta t}$

Solution:

$$\begin{aligned}\Delta E_{\text{output}} &= 75\% \text{ of } 5.1 \text{ kWh} \\ &= 0.75 \times 5.1 \text{ kWh} \\ \Delta E_{\text{output}} &= 3.8 \text{ kWh}\end{aligned}$$

$$\begin{aligned}P &= 75\% \text{ of } 14 \text{ W} \\ &= 0.75 \times \text{ W} \\ &= 10.5 \text{ W} \\ P &= 0.0105 \text{ kW (two digits extra carried)}\end{aligned}$$

$$\begin{aligned}P &= \frac{\Delta E_{\text{output}}}{\Delta t} \\ \Delta t &= \frac{\Delta E_{\text{output}}}{P} \\ &= \frac{3.8 \cancel{\text{kW}}\text{h}}{0.0105 \cancel{\text{kW}}} \\ \Delta t &= 360 \text{ h}\end{aligned}$$

Statement: The energy of output is 3.8 kWh. The time of use is 360 h.

53. Start by finding R_{total}.

$$R_{total} = R_1 + R_2$$
$$= 30.0\ \Omega + 12.0\ \Omega$$
$$R_{total} = 42.0\ \Omega$$

Now find I_{source} using Ohm's law written as $I = \frac{V}{R}$.

$$I_{source} = \frac{V_{source}}{R_{source}}$$
$$= \frac{20.0\text{ V}}{42.0\ \Omega}$$
$$I_{source} = 0.476\text{ A}$$

The amount of charge in coulombs passing through the circuit in 10 s can now be found using $I = \frac{Q}{\Delta t}$.

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (0.476\text{ A})(10.0\text{ s})$$
$$Q = 4.76\text{ C}$$

So, in 10.0 s, 4.76 C of charge that passes through the circuit.

54. (a) Start by finding V_1.

$$V_{source} = V_1 + V_2$$
$$V_1 = V_{source} - V_2$$
$$V_1 = 5.0\text{ V} - 3.55\text{ V}$$
$$V_1 = 1.45\text{ V (one extra digit carried)}$$

Now find I_1 using Ohm's law written as $I = \frac{V}{R}$.

$$I_1 = \frac{V_1}{R_1}$$
$$= \frac{1.45\text{ V}}{7.0\ \Omega}$$
$$I_1 = 0.2071\text{ A (two extra digits carried)}$$

Resistor 1 and resistor 2 are in series. Using KCL for a series circuit, you can find I_2:

$$I_1 = I_2$$
$$I_2 = 0.2071\text{ A (two extra digits carried)}$$

You can now find R_2 using Ohm's law written as $R = \frac{V}{I}$.

$$R_2 = \frac{V_2}{I_2}$$
$$= \frac{3.55\text{ V}}{0.2071\text{ A}}$$
$$R_2 = 17\ \Omega$$

So the value of R_2 is 17 Ω.

(b) The source and resistor 1 are in series. From part (a), I_1 = 0.2071 A (two extra digits carried). Using KCL for a series circuit, you can find I_{source}.

$$I_{source} = I_1$$
$$I_{source} = 0.2071\text{ A (two extra digits carried)}$$

The time it will take for 12 C of charge to pass through the circuit can now be found using $I = \frac{Q}{\Delta t}$.

$$I = \frac{Q}{\Delta t}$$
$$\Delta t = \frac{Q}{I}$$
$$= \frac{12\text{ C}}{0.2071\text{ A}}$$
$$\Delta t = 58\text{ s}$$

So it takes 58 s for 12 C of charge to pass through the circuit.

55. (a) First find the total resistance of the circuit. Start by finding the equivalent resistance for the parallel part of the circuit.

$$\frac{1}{R_{parallel}} = \frac{1}{R_2} + \frac{1}{R_3}$$
$$\frac{1}{R_{parallel}} = \frac{1}{16\ \Omega} + \frac{1}{30.0\ \Omega}$$
$$R_{parallel} = 10.43\ \Omega\text{ (two extra digits carried)}$$

Now find the total resistance. $R_{parallel}$ is in series with R_1, so

$$R_{total} = R_1 + R_{parallel}$$
$$= 5.0\ \Omega + 10.43\ \Omega$$
$$R_{total} = 15.43\ \Omega\text{ (two extra digits carried)}$$

Now find I_{source} using Ohm's law written as $I = \frac{V}{R}$.

$$I_{source} = \frac{V_{source}}{R_{source}}$$
$$= \frac{12\text{ V}}{15.43\ \Omega}$$
$$I_{source} = 0.7777\text{ A (two extra digits carried)}$$

The amount of charge in coulombs passing through the circuit can now be found using $I = \frac{Q}{\Delta t}$.

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (0.7777 \text{ A})(7.0 \text{ s})$$
$$Q = 5.4 \text{ C}$$

So after 7.0 s, 5.4 C of charge passes through the circuit.

(b) The source and resistor 1 are in series. Using the value found for I_{source} in part (a) and KCL for a series circuit, you can find I_1:

$$I_{source} = I_1$$
$$I_1 = 0.7777 \text{ A} \text{ (two extra digits carried)}$$

You can now find V_1 using Ohm's law written as $V = IR$.

$$V_1 = I_1R_1$$
$$= (0.7777 \text{ A})(5.0 \ \Omega)$$
$$V_1 = 3.889 \text{ V} \text{ (two extra digits carried)}$$

Apply KVL to the complete pathway involving the source, resistor 1, and resistor 2 to find V_2.

$$V_{source} = V_1 + V_2$$
$$V_2 = V_{source} - V_1$$
$$= 12 \text{ V} - 3.889 \text{ V}$$
$$V_2 = 8.111 \text{ V} \text{ (two extra digits carried)}$$

You can now find I_2 using Ohm's law written as $I = \frac{V}{R}$.

$$I_2 = \frac{V_2}{R_2}$$
$$= \frac{8.111 \text{ V}}{16 \ \Omega}$$
$$I_2 = 0.5069 \text{ A}$$

The amount of charge in coulombs passing through R_2 can now be found using $I = \frac{Q}{\Delta t}$.

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (0.5069 \text{ A})(12 \text{ s})$$
$$Q = 6.1 \text{ C}$$

So after 12 s, 6.1 C of charge passes through R_2.

56. (a) Apply KVL to the complete pathway involving the source, resistor 1, and resistor 2 to find V_2.

$$V_{source} = V_1 + V_2$$
$$V_2 = V_{source} - V_1$$
$$= 15 \text{ V} - 9.0 \text{ V}$$
$$V_2 = 6.0 \text{ V}$$

Apply KVL to the complete pathway involving the source, resistor 1, and resistor 2 to find V_3.

$$V_{source} = V_1 + V_3$$
$$V_3 = V_{source} - V_1$$
$$V_3 = 15 \text{ V} - 9.0 \text{ V}$$
$$V_3 = 6.0 \text{ V}$$

You can now find R_3 using Ohm's law written as $R = \frac{V}{I}$. First convert I_3 to amperes to get the answer in ohms:

$$I_3 = 500.0 \ \cancel{\text{mA}} \times \frac{1 \text{ A}}{1000 \ \cancel{\text{mA}}}$$
$$I_3 = 0.5000 \text{ A}$$
$$R_3 = \frac{V_3}{I_3}$$
$$= \frac{6.0 \text{ V}}{0.5000 \text{ A}}$$
$$R_3 = 12 \ \Omega$$

You can now find I_2 using Ohm's law written as $I = \frac{V}{R}$.

$$I_2 = \frac{V_2}{R_2}$$
$$= \frac{6.0 \text{ V}}{30.0 \ \Omega}$$
$$I_2 = 0.20 \text{ A}$$

So the value of R_3 is 12 Ω and the value of I_2 is 0.20 A.

(b) First use KCL for a parallel circuit to find $I_{parallel}$. Note that in part (a), I_2 was found to be 0.5000 A.

$$I_{parallel} = I_2 + I_3$$
$$= 0.5000 \text{ A} + 0.20 \text{ A}$$
$$I_{parallel} = 0.70 \text{ A}$$

The source and $I_{parallel}$ are in series. Using KCL for a series circuit, you can find I_{source}.

$$I_{source} = I_{parallel}$$

$$I_{source} = 0.70 \text{ A}$$

The time it will take for 20.0 C of charge to pass through the circuit can now be found using $I = \frac{Q}{\Delta t}$.

$$I = \frac{Q}{\Delta t}$$

$$\Delta t = \frac{Q}{I}$$

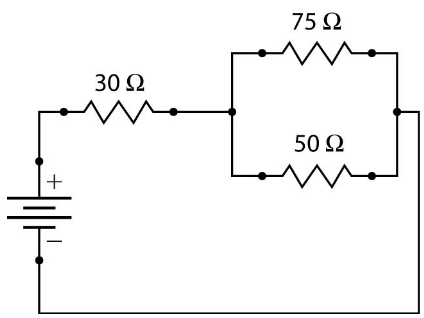
$$= \frac{20.0 \text{ C}}{0.70 \text{ A}}$$

$$\Delta t = 29 \text{ s}$$

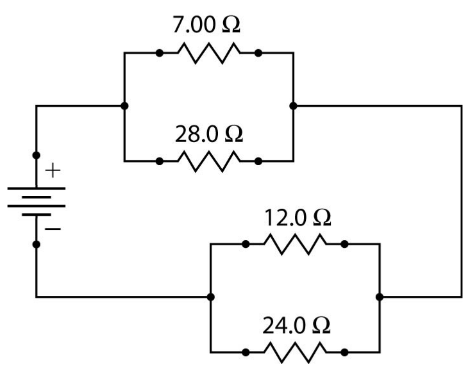
So it takes 29 s for 20.0 C of charge to pass through the circuit.

57. The resistance values would not be the same in both measurements, because an ohmmeter will not give an accurate measurement if the circuit is live. The correct scenario for measuring the resistance values is the one in which the power supply is turned off.

58.



59.



60. $V = \frac{\Delta E}{Q}$

$$I = \frac{Q}{\Delta t}$$

$$P = \frac{\Delta E}{\Delta t}$$

Solve for ΔE in the electric potential difference equation and Δt in the current equation, and then substitute these expressions into the power equation:

$$V = \frac{\Delta E}{Q}$$

$$\Delta E = VQ$$

$$I = \frac{Q}{\Delta t}$$

$$\Delta t = \frac{Q}{I}$$

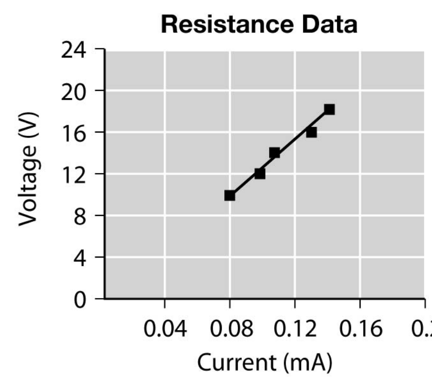
$$P = \frac{\Delta E}{\Delta t}$$

$$= \frac{V\cancel{Q}}{\frac{\cancel{Q}}{I}}$$

$$P = VI$$

So an expression for power in terms of current and potential is $P = VI$.

61. (a)



(b) The slope of the line connecting the data points represents the resistance. For example, the line passes through the data points (12 V, 0.097 mA) and (16 V, 0.129 mA). First convert the current to amperes to find the resistance in ohms:

$$I_2 = 0.097 \cancel{\text{mA}} \times \frac{1 \text{ A}}{1000 \cancel{\text{mA}}}$$

$$I_2 = 9.7 \times 10^{-5} \text{ A}$$

$$I_4 = 0.129 \cancel{\text{mA}} \times \frac{1 \text{ A}}{1000 \cancel{\text{mA}}}$$

$$I_4 = 1.29 \times 10^{-4} \text{ A}$$

The two data points (12 V, 9.7 × 10^{-5} A) and (16 V, 1.29 × 10^{-4} A) can be used to find the slope:

$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$m = \frac{\Delta V}{\Delta I}$$
$$= \frac{16\text{ V} - 12\text{ V}}{1.29\times10^{-4}\text{ A} - 9.7\times10^{-5}\text{ A}}$$
$$m = 1.3\times10^{5}\ \Omega$$

So the resistance of the circuit is 1.3 × 10^5 Ω.

62. (a) First find I_1 using Ohm's law in the form $I = \frac{V}{R}$.

$$I_1 = \frac{V_1}{R_1}$$
$$= \frac{12\text{ V}}{30.0\ \Omega}$$
$$I_1 = 0.40\ \Omega$$

Resistor 1 and resistor 2 are in series. Using KCL for a series circuit, you can find I_2.

$$I_2 = I_1$$
$$I_2 = 0.40\ \Omega$$

Now find V_2 using Ohm's law in the form $V = IR$.

$$V_2 = I_2R_2$$
$$= (0.40\text{ A})(50.0\ \Omega)$$
$$V_2 = 20\text{ V}$$

Apply KVL to the complete pathway involving the source, resistor 1, and resistor 2 to find V_{source}.

$$V_{\text{source}} = V_1 + V_2$$
$$= 12\text{ V} + 20\text{ V}$$
$$V_{\text{source}} = 32\text{ V}$$

Now find the total resistance of the circuit. Start by finding the equivalent resistances $R_{1,2}$ and $R_{2,3}$ for the resistors in series in the parallel part of the circuit.

$$R_{1,2} = R_1 + R_2$$
$$= 30.0\ \Omega + 50.0\ \Omega$$
$$R_{1,2} = 80.0\ \Omega$$

$$R_{3,4} = R_3 + R_4$$
$$= 60.0\ \Omega + 60.0\ \Omega$$
$$R_{3,4} = 120\ \Omega$$

Now find the equivalent resistance for the parallel part of the circuit.

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_{1,2}} + \frac{1}{R_{3,4}}$$
$$\frac{1}{R_{\text{parallel}}} = \frac{1}{80.0\ \Omega} + \frac{1}{120\ \Omega}$$
$$R_{\text{parallel}} = 48.0\ \Omega$$

So R_{total} = 48.0 Ω.

Now find I_{source} using Ohm's law in the form $I = \frac{V}{R}$.

$$I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}}$$
$$= \frac{32\text{ V}}{48.0\ \Omega}$$
$$I_{\text{source}} = 0.67\text{ A}$$

So the total current through the circuit is 0.67 A.

(b) As found in part (a), V_{source} is 32 V.

63. Note: After the first printing, V_1 was changed to I_1 in both the question and Figure 15.

(a) First apply KVL to the complete pathway involving the source, resistor 1, and resistor 3 to find V_3.

$$V_{\text{source}} = V_1 + V_3$$
$$V_3 = V_{\text{source}} - V_1$$
$$= 15\text{ V} - 4.0\text{ V}$$
$$V_3 = 11\text{ V}$$

Now find I_3 using Ohm's law in the form $I = \frac{V}{R}$.

$$I_3 = \frac{V_3}{R_3}$$
$$= \frac{11\text{ V}}{150\ \Omega}$$
$$I_3 = 0.073\text{ A}$$

Resistor 1 and resistor 3 are in series. Using KCL for a series circuit, you can find I_1.

$$I_1 = I_3$$
$$I_1 = 0.073\ \Omega$$

Now find R_1 using Ohm's law in the form $R = \frac{V}{I}$.

$$R_1 = \frac{V_1}{I_1} = \frac{4.0\ \text{V}}{0.073\ \text{A}}$$
$$R_1 = 55\ \Omega$$

Use the relationship between R_1 and R_2 to find R_2.

$$R_2 = R_1$$
$$R_2 = 55\ \Omega$$

So the resistance of R_1 and R_2 are both 55 Ω.

(b) As found in part (a), I_3 is 0.073 A.

64. (a) First let $V_4 = V_1$ and apply KVL to the complete pathway involving the source, resistor 1, and resistor 4 to find V_1.

$$V_{\text{source}} = V_1 + V_4$$
$$V_{\text{source}} = 2V_1$$
$$V_1 = \frac{V_{\text{source}}}{2} = \frac{50.0\ \text{V}}{2}$$
$$V_1 = 25.0\ \text{V}$$

So $V_1 = 25.0$ V and $V_4 = 25.0$ V.

The source, resistor 1, and the parallel part of the circuit are in series. Using KCL for a series circuit, you can find I_1 and I_{parallel}.

$$I_{\text{source}} = I_1 = I_{\text{parallel}}$$
$$I_1 = I_{\text{parallel}} = 0.250\ \text{A}$$

Now, note that $I_2 = I_{2,3}$, since the current through the path containing resistor 2 and resistor 3 must be constant. Since $2I_2 = 3I_4$, let $I_2 = I_{2,3} = \frac{3I_4}{2}$ and use KCL for a parallel circuit to solve for I_4.

$$I_{\text{parallel}} = I_{2,3} + I_4 = \frac{3I_4}{2} + I_4$$
$$I_{\text{parallel}} = \frac{5I_4}{2}$$
$$I_4 = \frac{2I_{parallel}}{5} = \frac{2(0.250\ \text{A})}{5}$$
$$I_4 = 0.100\ \text{A}$$

You can now find I_2:

$$I_2 = \frac{3I_4}{2} = \frac{3(0.100\ \text{A})}{2}$$
$$I_2 = 0.150\ \text{A}$$

Now find R_4 using Ohm's law in the form $R = \frac{V}{I}$.

$$R_4 = \frac{V_4}{I_4} = \frac{25.0\ \text{V}}{0.100\ \text{A}}$$
$$R_4 = 2.50 \times 10^2\ \Omega$$

So the value of R_4 is 2.50×10^2 Ω, the value of I_1 is 0.250 A, the value of I_2 is 0.150 A, and the value of I_4 is 0.100 A.

(b) Now find R_{total} using Ohm's law in the form $R = \frac{V}{I}$.

$$R_{\text{total}} = \frac{V_{\text{source}}}{I_{\text{source}}} = \frac{50.0\ \text{V}}{0.250\ \text{A}}$$
$$R_{\text{total}} = 200\ \Omega$$

Now find R_{parallel}.

$$R_{\text{total}} = R_{\text{series}} + R_{\text{parallel}}$$
$$R_{\text{parallel}} = R_{\text{total}} - R_{\text{series}} = R_{\text{total}} - R_1 = 200\ \Omega - 100.0\ \Omega$$
$$R_{\text{parallel}} = 100\ \Omega$$

$R_{parallel}$ is the equivalent resistance of resistors 2, 3, and 4. Let $R_2 = 2R_3$ and use the value for R_4 found in part (a) to find R_3.

$$\frac{1}{R_{parallel}} = \frac{1}{R_{2,3}} + \frac{1}{R_4}$$
$$= \frac{1}{R_2 + R_3} + \frac{1}{R_4}$$
$$= \frac{1}{2R_3 + R_3} + \frac{1}{R_4}$$
$$= \frac{1}{3R_3} + \frac{1}{R_4}$$
$$\frac{1}{R_{parallel}} = \frac{1}{3R_3} + \frac{1}{R_4}$$
$$\frac{1}{3R_3} = \frac{1}{R_{parallel}} - \frac{1}{R_4}$$
$$\frac{1}{R_3} = \frac{3}{R_{parallel}} - \frac{3}{R_4}$$
$$\frac{1}{R_3} = \frac{3}{100\ \Omega} - \frac{3}{2.5\times10^2\ \Omega}$$
$$R_3 = 55.56\ \Omega \text{ (two extra digits carried)}$$

You can now find R_2:

$$R_2 = 2R_3$$
$$= 2(55.56\ \Omega)$$
$$R_2 = 111.1\ \Omega \text{ (two extra digits carried)}$$

Resistor 2 and resistor 3 are in series. Using KCL for a series circuit and the value found for I_2 in part (a), you can find I_3.

$$I_2 = I_3$$
$$I_3 = 0.150\text{ A}$$

Now find V_2 and V_3 using the value found for I_2 in part (a) and Ohm's law in the form $V = IR$.

$$V_2 = I_2R_2$$
$$= (0.150\text{ A})(111.1\ \Omega)$$
$$V_2 = 16.7\text{ V}$$

$$V_3 = I_3R_3$$
$$= (0.150\text{ A})(55.55\ \Omega)$$
$$V_3 = 8.33\text{ V}$$

So the value of V_2 is 16.7 V and the value of V_3 is 8.33 V.

65. (a) The source and R_1 are in series. Using KCL for a series circuit, you can find I_{source}.

$$I_{source} = I_1$$
$$I_{source} = 110\text{ mA}$$

Now find R_{total} using Ohm's law in the form $R = \frac{V}{I}$. Convert current to amperes to get the answer in ohms.

$$I_{source} = 110\ \cancel{\text{mA}} \times \frac{1\text{ A}}{1000\ \cancel{\text{mA}}}$$
$$I_{source} = 0.110\text{ A}$$
$$R_{total} = \frac{V_{source}}{I_{source}}$$
$$= \frac{34\text{ V}}{0.110\text{ A}}$$
$$R_{total} = 3.0\times10^2\ \Omega$$

You can now find an expression for each resistance in terms of R_1.

$$R_2 = 2R_3$$
$$R_3 = \frac{R_2}{2}$$
$$2R_1 = 5R_3$$
$$2R_1 = 5\left(\frac{R_2}{2}\right)$$
$$R_2 = \frac{4R_1}{5}$$

$$2R_1 = 5R_3$$
$$R_3 = \frac{2R_1}{5}$$

$$R_1 = R_4$$
$$R_4 = R_1$$

Now find the equivalent resistance of the parallel part of the circuit in terms of R_1.

$$\begin{aligned}\frac{1}{R_{\text{parallel}}} &= \frac{1}{R_{2,3}} + \frac{1}{R_4}\\ &= \frac{1}{R_2 + R_3} + \frac{1}{R_4}\\ &= \frac{1}{\frac{4R_1}{5} + \frac{2R_1}{5}} + \frac{1}{R_1}\\ &= \frac{1}{\frac{6R_1}{5}} + \frac{1}{R_1}\\ &= \frac{\frac{11}{5}}{\frac{6R_1}{5}}\\ \frac{1}{R_{\text{parallel}}} &= \frac{11}{6R_1}\\ R_{\text{parallel}} &= \frac{6R_1}{11}\end{aligned}$$

Now find R_1 using the equation for R_{total}.

$$\begin{aligned}R_{\text{total}} &= R_{\text{series}} + R_{\text{parallel}}\\ &= R_1 + \frac{6R_1}{11}\\ R_{\text{total}} &= \frac{17R_1}{11}\\ R_1 &= \frac{11R_{\text{total}}}{17}\\ &= \frac{11(300\ \Omega)}{17}\\ R_1 &= 2.0\times10^2\ \Omega\end{aligned}$$

The other resistance values can now be found, using the value found for R_1.

$$\begin{aligned}R_2 &= \frac{4R_1}{5}\\ &= \frac{4(2.0\times10^2\ \Omega)}{5}\\ R_2 &= 1.6\times10^2\ \Omega\end{aligned}$$

$$\begin{aligned}R_3 &= \frac{2R_1}{5}\\ &= \frac{2(2.0\times10^2\ \Omega)}{5}\\ R_3 &= 80\ \Omega\end{aligned}$$

$$\begin{aligned}R_4 &= R_1\\ R_4 &= 2.0\times10^2\ \Omega\end{aligned}$$

So the value of R_1 is 2.0 × 10^2 Ω, the value of R_2 is 1.6 × 10^2 Ω, the value of R_3 is 80 Ω, and the value of R_4 is 2.0 × 10^2 Ω.

(b) As found in part (a), I_{source} = 110 mA.

Evaluation

66. Answers may vary. Sample answer:
The electrical devices I checked had either the power and voltage or the voltage and the current. To solve for the current of the power, I used the fact that $I = \frac{P}{V}$:

$$\begin{aligned}I &= \frac{Q}{\Delta t}\\ &= \frac{\left(\frac{\Delta E}{V}\right)}{\Delta t} \quad \left(\text{since } V = \frac{\Delta E}{Q}\right)\\ &= \frac{\left(\frac{\Delta E}{\Delta t}\right)}{V}\\ I &= \frac{P}{V} \quad \left(\text{since } P = \frac{\Delta E}{\Delta t}\right)\end{aligned}$$

Item	Electrical power (W) $P = VI$	Voltage (V)	Current (A) $I = \frac{P}{V}$	Resistance (Ω) $R = \frac{V}{I}$
heater	800	120	$\frac{800}{120} = 6.7$	18
kettle	1500	120	$\frac{1500}{120} = 12.5$	9.6
computer	(100)(8) = 800	100	8	16.5
microwave	1350	120	$\frac{1350}{120} = 11.25$	10.9
mini-fridge	(115)(1.33) = 153	115	1.33	86

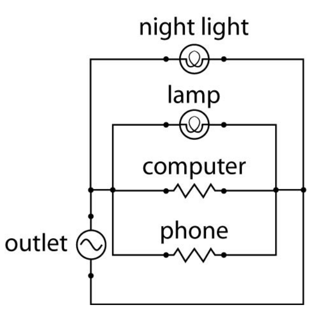
To determine the amount of energy each item consumes in a day, multiply its electrical power by the time it is on in a day.

Item	Electrical power (W)	Electrical power (kW)	Time of use in a day (h)	Energy (kWh)
heater	800	$\frac{800}{1000} = 0.8$	3.0	$0.8 \times 3.0 = 2.4$
kettle	1500	$\frac{1500}{1000} = 1.5$	0.2	$1.5 \times 0.2 = 0.3$
computer	800	$\frac{800}{1000} = 0.8$	6.0	$0.8 \times 6 = 4.8$
microwave	1350	$\frac{1350}{1000} = 1.35$	0.1	$1.35 \times 0.1 = 0.135$
mini-fridge	153	$\frac{153}{1000} = 0.153$	24	$0.153 \times 24 = 3.7$

The items in order of the energy they consume in an average day is:

- computer
- mini-fridge
- heater
- kettle
- microwave

67.



It is not a good idea to have the lamp and cell phone charger on the same power bar as the computer because you are overloading the power bar.

Reflect on Your Learning

68. Answers may vary. Sample answer:
I do not approve of nuclear power for the production of electrical energy. The uranium rods that are used in the generation of the energy have a long half-life so it takes a long time for them to break down. The rods are radioactive and so storage is a problem, and uranium is not a renewable resource. Eventually, we will not be able to rely on nuclear power for our electricity.
I would prefer that a renewable source of energy be used such as wind or solar power. Currently the technology to generate electricity using these sources is expensive but so is the technology for producing electricity through nuclear power.
As wind and solar technologies improve, it should become cheaper to produce electricity through these means. Furthermore, the carbon footprint of these technologies is less than for nuclear power.

69. Examples of electricity reduction may vary. Some possible examples are turning off the lights in rooms that are not in use, turning down the thermostat when heating the house in winter, turning up the thermostat up when cooling the house in summer, using a hanging line to dry clothes rather than the dryer, and limiting use of electronic devices such as desktop computers and land line telephones.
70. Answers may vary. Sample answer:
The part I found difficult about electric potential difference is that it is work done by an electric field. This concept is difficult to visualize unlike mechanical work, where you can see the results (in most cases). When I related electric potential difference to mechanical work and tried to visualize electrons moving, then the concept became easier for me to visualize.
71. Answers may vary. Sample answer:
I found trying to keep straight the rules for electric potential difference, current, and resistance for series and parallel circuits. With practice with questions and applying a structure to my solutions, I was better able to understand Kirchhoff's voltage law.
72. Answers may vary. Sample answer:
I understand how connecting resistors in parallel lowers the equivalent resistance as being analogous to sharing. When you share something with others, your portion will be less than the original amount.

Research

73. (a) Students' answers should include information about the overall amount of resources and energy used to produce each bulb, and whether or not this poses an environmental problem, i.e., if any resources are scarce, or if the refinement or use of resources causes a lot of pollution.
(b) Students should include the average amount of power each bulb uses for a given amount of light. A 60W incandescent bulb is roughly equivalent to a 14 W CFL and a 7 W LED.
(c) Students should note that CFL bulbs contain mercury and require special handling for disposal. They should also mention that the lifetime of an incandescent bulbs is only about 1500 h, compared to around 10 000 h for CFLs and 60 000 h for LEDs. This means that there is a lot more waste from incandescent bulbs. A comparison of recycling costs and reusability is also a plus.
74. Students' representations should include a simple diagram of a resistor, a detailed description of what a resistor is and how it is used in electronic devices.
75. Students' answers should include statistics about different energy forms and the amount of heat that each emits into the environment. Estimates should be made about the effect this waste heat has on water temperature and whether or not this affects the ecosystems involved. Sources should be cited to back up arguments.
76. The potential difference of a lightning strike ranges on the order of tens to thousands of megavolts and carries on the order of 30 000 A. Students answers should include information about the theories behind the causes of lightning including different types. All numerical estimates should follow from documented sources.
77. Students' answers should include information about the technologies available and how they work. Future technological ideas should also be included and used in their estimate of how much energy can be generated and at what cost. Any environmental impacts such as the destruction of habitats or death of marine animals should be included.