Unit 5 Review, pages 626–633

Knowledge

1. (b)
2. (a)
3. (d)
4. (c)
5. (b)
6. (c)
7. (b)
8. (c)
9. (b)
10. (a)
11. (c)
12. (b)
13. (d)
14. (b)
15. (c)
16. False. *Voltage* is a measure of the amount of electrical potential energy associated with each charge.
17. False. In a circuit, electrons flow from *negative* to *positive*.
18. True
19. True
20. True
21. False. Then two like magnetic poles are brought close one another, they *repel*.
22. True
23. False. Adding a soft-iron core will *increase* the strength of a DC motor.
24. True
25. True
26. False. A step-up transformer increases the *voltage* in the secondary circuit.
OR
A step-up transformer *decreases* the current in the secondary circuit.
27. True
28. (a) (v)
(b) (viii)
(c) (i)
(d) (ii)
(e) (iii)
(f) (ix)
(g) (vii)
(h) (iv)
(i) (vi)

Understanding

29. The nuclear power plant has an efficiency of 32 %, so 32 % of the total power is transformed into electrical energy. 32 % of 14 000 MW is:
$0.32 \times 14\,000 \text{ MW} = 4500 \text{ MW}$
So, the power plant produces 4500 MW of electrical power.

30. Given: $P = 35$ W; $\Delta t = 220$ 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:

$$\Delta t = 220 \cancel{\text{h}} \times \frac{3600 \text{ s}}{1 \cancel{\text{h}}}$$
$$\Delta t = 792\,000 \text{ s}$$

$$\begin{aligned}\Delta E &= (35 \text{ W})(792\,000 \text{ s}) \\ &= 2.772 \times 10^7 \text{ W}\bullet\text{s}\end{aligned}$$
$$\Delta E = 2.772 \times 10^7 \text{ J (two extra digits carried)}$$

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

$$2.772 \times 10^7 \cancel{\text{J}} \times \frac{1 \text{ kWh}}{3.6 \times 10^6 \cancel{\text{J}}} = 7.7 \text{ kWh}$$

Statement: The light bulb requires 7.7 kWh or 28 MJ of energy to operate for 220 h.

31. Given: $\Delta E = 1400$ J; $\Delta t = 7.0$ 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:

$$\Delta t = 7 \text{ min}\left(\frac{60 \text{ s}}{1 \text{ min}}\right)$$
$$\Delta t = 420 \text{ s}$$

$$\begin{aligned}P &= \frac{\Delta E}{\Delta t} \\ &= \frac{1400 \text{ J}}{420 \text{ s}}\end{aligned}$$
$$P = 3.3 \text{ W}$$

Statement: The amount of power required to charge the battery is 3.3 W.

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32. Given: $V = 120$ V; $\Delta E = 540$ J
Required: Q

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

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

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

$$= \frac{540 \text{ J}}{120 \text{ V}}$$

$$Q = 4.5 \text{ C}$$

Statement: The total amount of charge moved across the terminals is 4.5 C.

33. Given: $Q = 0.65$ C; $\Delta t = 1.5$ min
Required: I

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

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

$$\Delta t = 1.5 \cancel{\text{min}} \times \frac{60 \text{ s}}{1 \cancel{\text{min}}}$$

$$\Delta t = 90 \text{ s}$$

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

$$= \frac{0.65 \text{ C}}{90 \text{ s}}$$

$$I = 7.2 \times 10^{-3} \text{ A}$$

Convert the current to milliamperes:

$$I = 7.2 \times 10^{-3} \cancel{\text{A}} \times \frac{1000 \text{ mA}}{1 \cancel{\text{A}}}$$

$$I = 7.2 \text{ mA}$$

Statement: The amount of current in the wire is 7.2 mA.

34. Given: $Q = 4.0$ C; $I = 5.0 \times 10^2$ 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:

$$I = 5.0 \times 10^2 \cancel{\text{mA}} \times \frac{1 \text{ A}}{1000 \cancel{\text{mA}}}$$

$$I = 0.50 \text{ A}$$

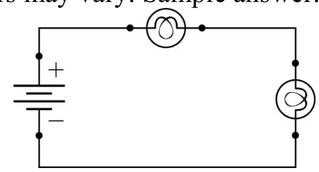
$$\Delta t = \frac{Q}{I}$$

$$= \frac{4.0 \text{ C}}{0.50 \text{ A}}$$

$$\Delta t = 8.0 \text{ s}$$

Statement: It takes 8.0 s for the charge to pass through the resistor.

35. Answers may vary. Sample answer:



36. (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 $I_1 = 8.5$ mA. Using these values and KCL, you can find I_{source}:

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

$$I_{\text{source}} = 8.5 \text{ mA}$$

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:

$$I_{\text{parallel}} = I_2 + I_3$$

$$8.5 \text{ mA} = 2.1 \text{ mA} + I_3$$

$$I_3 = 6.4 \text{ mA}$$

So I_3 is 6.4 mA.

(b) The current in a series circuit is constant and the same as the source current. From part (a), $I_{\text{source}} = 8.5$ 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:

$$I_{\text{parallel}} = I_2 + I_3$$

$$I_{\text{parallel}} = I_3 + I_3$$

$$I_{\text{parallel}} = 2I_3$$

$$I_3 = \frac{I_{\text{parallel}}}{2}$$

$$= \frac{8.5 \text{ mA}}{2}$$

$$I_3 = 4.2 \text{ mA}$$

So I_3 is 4.2 mA.

37. Given: $R = 9.0 \times 10^2\ \Omega$; $A = 0.72$ mA.
Required: V

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

Solution: Convert the current to amperes to get the answer in volts:

$$I = 0.72\ \cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\ \cancel{\text{mA}}}$$
$$I = 7.2 \times 10^{-4}\ \text{A}$$

$$R = \frac{V}{I}$$
$$\begin{aligned} V &= IR \\ &= (7.2 \times 10^{-4}\ \text{A})(9.0 \times 10^{2}\ \Omega) \\ &= 6.48 \times 10^{-1}\ \text{V} \\ &= 6.48 \times 10^{-1}\ \cancel{\text{V}} \times \frac{1000\ \text{mV}}{1\ \cancel{\text{V}}} \end{aligned}$$
$$V = 650\ \text{mV}$$

Statement: The potential difference across the resistor is 650 mV.

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

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_2} + \frac{1}{R_3}$$
$$\frac{1}{R_{\text{parallel}}} = \frac{1}{11.4\ \Omega} + \frac{1}{32.2\ \Omega}$$
$$R_{\text{parallel}} = 8.42\ \Omega$$

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

$$\begin{aligned} R_{\text{total}} &= R_1 + R_{\text{parallel}} \\ &= 7.0\ \Omega + 8.42\ \Omega \end{aligned}$$
$$R_{\text{total}} = 15\ \Omega$$

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

39. Earth's magnetic field causes a force that is nearly parallel to the Earth's surface at positions not near its magnetic poles and is directed from the south magnetic pole to the north magnetic pole. At positions near its magnetic poles, it causes a force that is nearly perpendicular to the Earth's surface and is directed toward the Earth at its south magnetic pole and away from the Earth at its north magnetic pole. Earth's gravitational field causes a force that is always directed toward Earth's centre.

40. Magnet diagrams should resemble the bar magnet and horseshoe magnet in Figure 3 on page 549 of the student book.
The bar magnet diagram most closely resembles the magnetic field lines of Earth.

41. A magnetic field exerts a force on an iron filing. Iron filings are light and can be moved independently, so when placed in the presence of a magnetic field the filings are easily forced into position along the magnetic field lines.

42. (a) By the right-hand rule for a straight conductor, the direction of the current is into the page.
(b) By the right-hand rule for a straight conductor, the direction of the magnetic field is counter-clockwise.
(c) By the right-hand rule for a straight conductor, the magnetic field is coming out of the page.

43. Oersted placed a compass near a conducting wire that was aligned with Earth's north and south magnetic poles. The compass was aligned with the wire. When current was turned on the compass needle pointed perpendicular to the wire. When the current was switched off the compass needle returned to normal.

44. Answers may vary. Diagrams should resemble Figure 4 on page 560 of the Student Book.

45. Conventional current is directed from positive to negative, which is in the opposite direction to the flow of electrons in a circuit. For conventional current, use the right hand to determine the direction of the magnetic field produced by the current; for electron flow, use the left hand. The magnetic field points in the same direction regardless of which model is used.

46. Using the right-hand rule for a straight conductor, my right fingers curl around the conductor in a clockwise direction and my thumb points into the page, which is the direction of the conventional current. So the direction of the current is into the page.

47. Ampère performed an experiment with two parallel current-carrying wires. He found that they repelled each other when the currents were in opposite directions and that they attracted each other when the currents flowed in the same direction.

48. (a) For the two parallel wires to experience a magnetic force of repulsion the magnetic field lines between them must point in the same direction. For this to happen, the currents in the wires must be in opposite directions.

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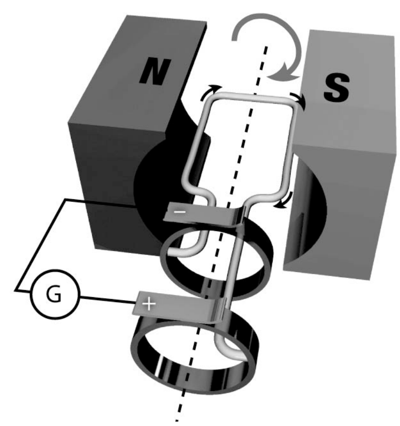
(b) If both currents in the wires were reversed the currents would still be in opposite directions so the magnetic force would still be repulsion.
(c) If the currents were increased the wires would experience more repulsion.
(d) If one current were switched off there would only be magnetic field lines around the other wire. There would be no interacting magnetic field lines so there would be no magnetic force between the wires.
49. The right-hand rule for a solenoid states that if the fingers of your right hand wrap around a coil in the direction of the conventional current, your thumb will point in the direction of the north magnetic pole of the coil. The right-hand rule helps to understand the operation of a solenoid by showing how to determine which end of the electromagnet is a magnetic north pole and which end is a magnetic south pole.
The magnetic field around a solenoid has a shape similar to that of a bar magnet.
50. The motor principle states that a current-carrying conductor that cuts across external magnetic field lines experiences a force perpendicular to both the magnetic field and the direction of the electric current.
To determine the direction of the force on a current carrying conductor placed in an external magnetic field, point the fingers of your open right hand in the direction of the external magnetic field and your thumb in the direction of the conventional current. Your palm will now face the direction of the force on the conductor.
51. Diagrams should resemble Figure 2 on page 567 of the Student Book.
52. A split ring commutator was used to make the transition between a galvanometer and a DC motor. The split ring commutator works by interrupting the current through the circuit when the wire loop in the DC motor is perpendicular to the external magnetic field, and then allowing the current to flow in the opposite direction through the wire loop once the split ring comes in contact with the circuit again. This allows the wire loop to continuously rotate.
53. Coil A will induce more current than coil B because it has more windings, and the greater number of windings in a coil, the more electric current that can be induced for a given change in the magnetic field.
54. Ground fault circuit interrupters will prevent short circuits due to water.
55. The rotation of the loop in a clockwise direction in the magnetic field causes a conventional current in the loop in the direction shown:



The plane of the loop is parallel to the external magnetic field so the induced current is at a maximum.
56. For coil B to generate the sane amount of electricity as coil A in a changing magnetic field, it should have the same number of windings as coil A, which has 300 windings.
300 – 150 = 150
So coil B should have 150 windings added.
57. The transformer in Figure 5 has fewer secondary windings than primary windings so it decreases the voltage in the secondary coil. Since it decreases the voltage it is a step-down transformer.
58. Solve for I in the power equation $P = VI$ and then substitute the values given for P and V to find I, which is the amount of current produced:

$$P = VI$$

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

P = 1800 MW; $V = 5.0 \times 10^4$ V

$$\begin{aligned} I &= \frac{P}{V} \\ &= \frac{1800 \text{ MW}}{5.0 \times 10^4 \text{ V}} \\ &= \frac{1.8 \times 10^9 \text{ W}}{5.0 \times 10^4 \text{ V}} \\ &= 3.6 \times 10^4 \text{ A} \end{aligned}$$

I = 36 kA
So the amount of current produced is 36 kA.

59. Substitute the values given for V and I in the power equation $P = VI$ to find P, which is the amount of power produced:

$P = VI$

$V = 180$ kV; $I = 35$ A

$$\begin{aligned} P &= VI \\ &= (180\ \text{kV})(35\ \text{A}) \\ &= (1.8\times 10^5\ \text{V})(35\ \text{A}) \\ &= 6.3\times 10^6\ \text{W} \\ P &= 6.3\ \text{MW} \end{aligned}$$

So the amount of power produced is 6.3 MW.

60. Use the power equation in the form $P = I^2R$:

$$\begin{aligned} P &= I^2R \\ &= (3.0\ \text{kA})^2(0.40\ \Omega) \\ &= (3.0\times 10^3\ \text{A})^2(0.40\ \Omega) \\ &= 3.6\times 10^6\ \text{W} \\ P &= 3.6\ \text{MW} \end{aligned}$$

So the total power loss due to transmission through the wire is 3.6 MW.

61. First determine the amount of power lost in transmission in watts:

0.60 % of 2100 MW = 12.6 MW (one extra digit carried)

So the amount of power lost in transmission, P, is 12.6 MW.

Now solve for R in the power equation in the form $P = I^2R$ and then substitute the value given for I and the value found for P to find R, which is the total resistance in the transmission wire:

$$\begin{aligned} P &= I^2R \\ R &= \frac{P}{I^2} \\ &= \frac{12.6\ \text{MW}}{(5.0\ \text{kA})^2} \\ &= \frac{1.26\times 10^7\ \text{W}}{(5.0\times 10^3\ \text{A})^2} \\ R &= 0.50\ \Omega \end{aligned}$$

So the total resistance in the transmission wire is 0.50 Ω.

Analysis and Application

62. The hydroelectric power plant has an efficiency of 88 % and produces 1500 MW of electrical power, so 88 % of the input power, P_{in}, is 1500 MW. This is 0.88 × P_{in} = 1500 MW, which can be used to solve for P_{in}:

$$\begin{aligned} 0.88\times P_{in} &= 1500\ \text{MW} \\ P_{in} &= \frac{1500\ \text{MW}}{0.88} \\ P_{in} &= 1700\ \text{MW} \end{aligned}$$

The power wasted is P_{in} - P_{out}, and P_{out} is 1500 MW, so the power wasted is 1700 MW – 1500 MW = 200 MW

The nuclear power plant has an efficiency of 30 % and produces 1500 MW of electrical power, so 30 % of the input power, P_{in}, is 1500 MW. This is 0.30 × P_{in} = 1500 MW, which can be used to solve for P_{in}:

$$\begin{aligned} 0.30\times P_{in} &= 1500\ \text{MW} \\ P_{in} &= \frac{1500\ \text{MW}}{0.30} \\ P_{in} &= 5000\ \text{MW} \end{aligned}$$

The power wasted is P_{in} - P_{out}, and P_{out} is 1500 MW, so the power wasted is 5000 MW – 1500 MW = 3500 MW

The difference in the amounts of power wasted is 3500 MW – 200 MW = 3300 MW.

So, the nuclear power plant wastes 3300 MW more power than the hydroelectric power plant.

63. The coal power plant has an efficiency of 47 % and produces 3500 MW of electrical power, so 47 % of the input power, P_{in}, is 3500 MW. This is 0.47 × P_{in} = 3500 MW, which can be used to solve for P_{in}:

$$\begin{aligned} 0.47\times P_{in} &= 3500\ \text{MW} \\ P_{in} &= \frac{3500\ \text{MW}}{0.47} \\ P_{in} &= 7447\ \text{MW}\ \ \text{(two extra digits carried)} \end{aligned}$$

The coal power plant with carbon capture technology installed has an efficiency of 41 % and still has an input of 7447 MW of electrical power, so 41 % of 7447 MW, is P_{out}. This is 0.41 × 7447 MW = P_{out}, which can be used to solve for P_{out}:

$$\begin{aligned} 0.41\times 7447\ \text{MW} &= P_{out} \\ P_{out} &= 3053\ \text{MW}\ \ \text{(two extra digits carried)} \end{aligned}$$

The difference in the amount of output power is 3500 MW – 3053 MW = 450 MW.

So the amount of extra power lost to the carbon capture technology is 450 MW.

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64. Given: P = 90 % of 60.0 W; $\Delta E = 3.0 \times 10^3$ J
Required: Δt

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

Solution:

$$P = 90\ \%\ \text{of}\ 60.0\ \text{W}$$
$$= 0.90 \times 60.0\ \text{W}$$
$$P = 54.0\ \text{W}$$

$$P = \frac{\Delta E}{\Delta t}$$
$$\Delta t = \frac{\Delta E}{P}$$
$$= \frac{3.0 \times 10^3\ \cancel{\text{J}}}{54.0\ \frac{\cancel{\text{J}}}{\text{s}}}$$
$$= 55.56\ \text{s}$$
$$\Delta t = 56\ \text{s}$$

Statement: It takes 56 s to charge the battery.

65. (a) Voltmeter should be placed in parallel to R_1.

(b) Ammeter should be placed in series with R_2.

66. Start by finding R_{total}.

$$R_{\text{total}} = R_1 + R_2$$
$$= 40\ \Omega + 15\ \Omega$$
$$R_{\text{total}} = 55\ \Omega$$

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

$$I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}}$$
$$= \frac{30.0\ \text{V}}{55\ \Omega}$$
$$I_{\text{source}} = 0.55\ \text{A}$$

The amount of charge in coulombs passing through the circuit in 10.0 s can now be found using $I = \frac{Q}{\Delta t}$.

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (0.55\ \text{A})(10.0\ \text{s})$$
$$Q = 5.5\ \text{C}$$

So, in 10.0 s, 5.5 C of charge that passes through the circuit.

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

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_2} + \frac{1}{R_3}$$
$$\frac{1}{R_{\text{parallel}}} = \frac{1}{20.0\ \Omega} + \frac{1}{30.0\ \Omega}$$
$$R_{\text{parallel}} = 12\ \Omega$$

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

$$R_{\text{total}} = R_1 + R_{\text{parallel}}$$
$$= 5.0\ \Omega + 12\ \Omega$$
$$R_{\text{total}} = 17\ \Omega$$

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

$$I_{\text{source}} = \frac{V_{\text{source}}}{R_{\text{source}}}$$
$$= \frac{15\ \text{V}}{17\ \Omega}$$
$$I_{\text{source}} = 0.8824\ \text{A}\ \text{(two extra digits carried)}$$

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

$$I = \frac{Q}{\Delta t}$$
$$Q = I\Delta t$$
$$= (0.8824\ \text{A})(8.0\ \text{s})$$
$$Q = 7.1\ \text{C}$$

So after 8.0 s, 7.1 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:

$$I_{\text{source}} = I_1$$
$$I_1 = 0.8824\ \text{A}\ \text{(two extra digits carried)}$$

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

$$V_1 = I_1R_1$$
$$= (0.8824\ \text{A})(5.0\ \Omega)$$
$$V_1 = 4.412\ \text{V}\ \text{(two extra digits carried)}$$

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

$$\begin{aligned} V_{\text{source}} &= V_1 + V_2 \\ V_2 &= V_{\text{source}} - V_1 \\ &= 15\text{ V} - 4.412\text{ V} \\ V_2 &= 10.59\text{ V (two extra digits carried)} \end{aligned}$$

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

$$\begin{aligned} I_2 &= \frac{V_2}{R_2} \\ &= \frac{10.59\text{ V}}{20.0\ \Omega} \\ I_2 &= 0.5295\text{ A} \end{aligned}$$

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

$$\begin{aligned} I &= \frac{Q}{\Delta t} \\ Q &= I\Delta t \\ &= (0.5295\text{ A})(10.0\text{ s}) \\ Q &= 5.3\text{ C} \end{aligned}$$

So after 10.0 s, 5.3 C of charge passes through R_2.

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

$$\begin{aligned} V_{\text{source}} &= V_1 + V_2 \\ V_2 &= V_{\text{source}} - V_1 \\ &= 20.0\text{ V} - 12.0\text{ V} \\ V_2 &= 8.0\text{ V} \end{aligned}$$

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

$$\begin{aligned} V_{\text{source}} &= V_1 + V_3 \\ V_3 &= V_{\text{source}} - V_1 \\ V_3 &= 20.0\text{ V} - 12.0\text{ V} \\ V_3 &= 8.0\text{ V} \end{aligned}$$

You can now find R_3 using Ohm's law written as $R = \frac{V}{I}$.

$$\begin{aligned} R_3 &= \frac{V_3}{I_3} \\ &= \frac{8.0\text{ V}}{0.50\text{ A}} \\ R_3 &= 16\ \Omega \end{aligned}$$

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

$$\begin{aligned} I_2 &= \frac{V_2}{R_2} \\ &= \frac{8.0\text{ V}}{40.0\ \Omega} \\ I_2 &= 0.20\text{ A} \end{aligned}$$

So the value of R_3 is 16 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.

$$\begin{aligned} I_{\text{parallel}} &= I_2 + I_3 \\ &= 0.20\text{ A} + 0.50\text{ A} \\ I_{\text{parallel}} &= 0.70\text{ A} \end{aligned}$$

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

$$\begin{aligned} I_{\text{source}} &= I_{\text{parallel}} \\ I_{\text{source}} &= 0.70\text{ A} \end{aligned}$$

The time it will take for 15 C of charge to pass through the circuit can now be found using $I = \frac{Q}{\Delta t}$.

$$\begin{aligned} I &= \frac{Q}{\Delta t} \\ \Delta t &= \frac{Q}{I} \\ &= \frac{15\text{ C}}{0.70\text{ A}} \\ \Delta t &= 21\text{ s} \end{aligned}$$

So it takes 21 s for 15 C of charge to pass through the circuit.

69. (a) The resistance of the bulb would be constant if the temperature remained the same. Since the bulb heats up when it is on, the resistance of the bulb changes, which is why the resistance values are not the same for the bulb on and off.

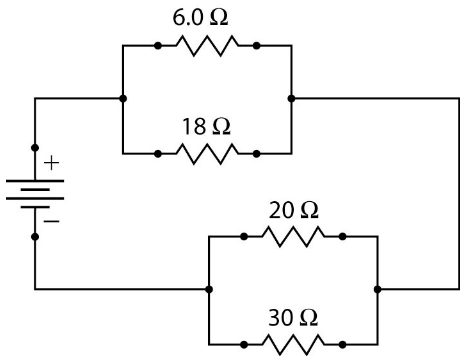
(b) If the filament breaks, then the circuit is broken. I would expect no resistance value.

70. Since the sum of the four resistances is 74 Ω, they cannot all be in series. If the first and fourth are in parallel and the second and third are in parallel, then R_{total} = 16.5 Ω:

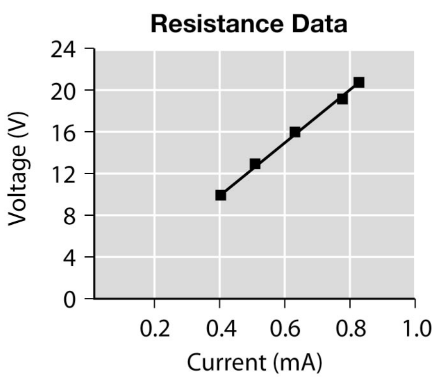
$$\frac{1}{6.0\ \Omega}+\frac{1}{18\ \Omega}=\frac{1}{4.5\ \Omega}$$

$$\frac{1}{20\ \Omega}+\frac{1}{30\ \Omega}=\frac{1}{12\ \Omega}$$

$$4.5\ \Omega+12\ \Omega=16.5\ \Omega$$



71. (a)



(b) The slope of the line connecting the data points represents the resistance. For example, the line passes through the data points (0.41 mA, 10 V) and (0.84 mA, 21 V). First convert the current to amperes to find the resistance in ohms:

$$I_1 = 0.84\ \cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\ \cancel{\text{mA}}}$$

$$I_1 = 8.4\times10^{-4}\ \text{A}$$

$$I_5 = 0.41\ \cancel{\text{mA}} \times \frac{1\ \text{A}}{1000\ \cancel{\text{mA}}}$$

$$I_5 = 4.1\times10^{-4}\ \text{A}$$

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:

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

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

$$= \frac{21\ \text{V} - 10\ \text{V}}{8.4\times10^{-4}\ \text{A} - 4.1\times10^{-4}\ \text{A}}$$

$$m = 2.6\times10^{4}\ \Omega$$

So the resistance of the circuit is 2.6 × 10^4 Ω.

72. (a) First apply KVL to the determine V_2, V_3, and V_4. Since the first two resistors are in parallel, $V_1 = V_2$, so V_2 = 3.0 V.

$$V_{source} = V_1 + V_3$$

$$V_3 = V_{source} - V_1$$

$$= 12\ \text{V} - 2.0\ \text{V}$$

$$V_3 = 9.0\ \text{V}$$

Since the second pair of resistors are in parallel, $V_3 = V_4$, so V_4 = 9.0 V.

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

$$I_3 = \frac{V_3}{R_3}$$

$$= \frac{9.0\ \text{V}}{250\ \Omega}$$

$$I_3 = 0.036\ \text{A}$$

Now find I_4 using Ohm's law in the form $I = \frac{V}{R}$.

$$I_4 = \frac{V_4}{R_4}$$

$$= \frac{9.0\ \text{V}}{300\ \Omega}$$

$$I_4 = 0.03\ \text{A}$$

The total current entering the second pair of resistors is:

0.036 A + 0.03 A = 0.066 A

By KCL for a series circuit, this is the same amount of current entering the first pair of resistors, and the current divides equally between them because they have the same resistance.

$$I_1 = \frac{I_3 + I_4}{2}$$

$$= \frac{0.066\ \text{A}}{2}$$

$$I_1 = 0.033\ \text{A}$$

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

$$R_1 = \frac{V_1}{I_1}$$
$$= \frac{3.0\ \text{V}}{0.033\ \text{A}}$$
$$R_1 = 91\ \Omega$$

Use the relationship between R_1 and R_2 to find R_2.

$$R_2 = R_1$$
$$R_2 = 91\ \Omega$$

So the resistance of R_1 and R_2 are both 91 Ω.

(b) As found in part (a), I_3 is 0.036 A.

73. (a) The magnetic field lines are in the incorrect direction; they should travel from north to south.

(b) The magnetic field decreases (not increases) in strength as you move away from the magnet. The magnetic field lines should be drawn farther apart (instead of closer together) as you move away magnet.

74. The aurora are caused by charged particles emitted from the Sun that interact with Earth's magnetic field and cause gases in the atmosphere to become excited and emit energy in the form of light. This only happens at the poles because that is where Earth's magnetic field is strongest.

75. An electromagnet is useful because it can be switched on and off. This makes it useful in electronic devices such as speakers, subwoofers, and electric bells. The electromagnet's strength can also be controlled by the amount of current and number of coils, which is useful in a DC motor. The polarity can also be switched, unlike in a permanent magnet.

76. Earth's magnetic field lines normally point from south to north, since the south pole is magnetically north, and the north pole is magnetically south. For this case the field lines have reversed so that facing westward reads east on a compass. Since the cables are buried below the car, using the right-hand rule determines that current must be travelling north.

77. (a) To determine the direction of the force on a current carrying conductor placed in an external magnetic field, point the fingers of your open right hand in the direction of the external magnetic field and your thumb in the direction of the conventional current. Your palm will now face the direction of the force on the conductor.

(b) Your right hand would be flat in a vertical plane, with your thumb pointing to the left and your fingers pointed downward.

(c) Since the direction of the force is toward you, it is directed out of the page.

78. In an ammeter, a galvanometer is placed in parallel with a resistor with lower resistance than the galvanometer.

In a voltmeter, a galvanometer is placed in series with a resistor with a very high resistance.

79. Answers may vary. Students' answers should name a household object, such as a electric lock, speaker, or doorbell, state whether the magnet it uses interacts with another magnet or produces a force on a conductor, and also whether it is a permanent magnet or an electromagnet.

80. Answers may vary. Sample answer:

The stove element of an induction cooker generates a rapidly changing magnetic field. When a metal pot is placed on the element, an electric current is induced in the metal by the changing magnetic field, in accordance with the law of electromagnetic induction. Metal has a high resistance, so the induced electric current in the pot produces a large amount of thermal energy that cooks the food.

Metal detectors also work by using a rapidly changing magnetic field. When the changing magnetic field is brought in the region of metal, by the law of electromagnetic induction it must induce an electric current in that metal. The induced electric current creates a magnetic field, which is then detected by the metal detector. The metal detector only detects metal because electric current cannot be induced in non-conductors.

81. First determine the total number of windings in the length of coil type A that the student has:

$$\frac{20\ \text{windings}}{1\ \cancel{\text{cm}}} \times 12\ \cancel{\text{cm}} = 240\ \text{windings}$$

The length, L, of coil type B must have the same number of windings as coil type A to produce the same amount of current in a changing magnetic field. So the length, L, of coil type B must have 240 windings and L can now be found:

$$\frac{15\ \text{windings}}{1\text{cm}} \times L = 240\ \text{windings}$$
$$L = 240\ \cancel{\text{windings}} \times \frac{1\ \text{cm}}{15\ \cancel{\text{windings}}}$$
$$L = 16\ \text{cm}$$

So the student needs 16 cm of coil type B.

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82. (a) Answers may vary. Sample answer:
Yes it is possible to create an AC motor. It works just like an AC generator but in reverse. If the wires from the AC generator in Figure 1, Section 13.4, were plugged into an outlet in North America it would spin at a frequency of 60 Hz.
(b) Answers may vary. Sample answer:
Yes, this set up would be practical for any device that uses a motor and can be plugged into an AC source. Any device that rotates in place could use this motor. An example of this could be a blow dryer or a fan.
83. As the shaded side of the armature moves away from the south pole of the external magnet, Lenz's law determines the left side of the armature to be a north magnetic pole. Using the right-hand rule for a coil, the direction of the conventional current is up across the front of the coil.
84. (a) Given: $V_p = 250$ V; $I_p = 5.0$ A; $I_s = 10.0$ A
Required: V_s
Analysis: $\frac{I_s}{I_p} = \frac{V_p}{V_s}$
Solve for V_s:
$$V_s = \frac{V_p I_p}{I_s}$$
Solution:
$$V_s = \frac{V_p I_p}{I_s} = \frac{(250\text{ V})(5.0\,\cancel{\text{A}})}{10.0\,\cancel{\text{A}}}$$
$$V_s = 125\text{ V} \quad \text{(one extra digit carried)}$$
Statement: The voltage in the secondary circuit is 120 V.
(b) Substitute the values given for V_p and the value found in part (a) for V_s in the relevant equation related to transformers to find the ratio of the windings:
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$
$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$
$V_p = 250$ V; $V_s = 125$ V
$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{250\,\cancel{\text{V}}}{125\,\cancel{\text{V}}}$$
$$\frac{N_p}{N_s} = 2$$
So the ratio of the primary windings to secondary windings in the transformer is 2 : 1.
85. (a) Given: $V_p = 80.0$ V; $N_p = 100$; $N_s = 160$ V; $I_s = 10.0$ A
Required: V_s
Analysis: $\frac{V_p}{V_s} = \frac{N_p}{N_s}$
$$V_s = \frac{V_p N_s}{N_p}$$
Solution:
$$V_s = \frac{V_p N_s}{N_p} = \frac{(80.0\text{ V})(160)}{100}$$
$$V_s = 128\text{ V}$$
Statement: The voltage of the secondary circuit is 128 V.
(b) Use the relevant equation related to transformers to find the current of the primary circuit, I_p:
$$\frac{I_s}{I_p} = \frac{N_p}{N_s}$$
$$I_p = \frac{I_s N_s}{N_p} = \frac{(10.0\text{ A})(160)}{100}$$
$$I_p = 16.0\text{ A}$$
So the current of the primary circuit, I_p, is 16.0 A.
86. (a) Given: $V_p = 3.0 \times 10^2$ V; $N_p = 150$; $V_s = 6.0 \times 10^1$ V
Required: N_s
Analysis: $\frac{V_p}{V_s} = \frac{N_p}{N_s}$
$$N_s = \frac{V_s N_p}{V_p}$$
Solution:
$$N_s = \frac{V_s N_p}{V_p} = \frac{(6.0 \times 10^1\,\cancel{\text{V}})(150)}{3.0 \times 10^2\,\cancel{\text{V}}}$$
$$N_s = 30$$
Statement: The secondary circuit has 30 coils.

(b) First use Ohm's law in the form $I = \frac{V}{R}$ and the values given for V_p and R_p to find I_p, the current in the primary circuit:

$$I_p = \frac{V_p}{R_p}$$
$$= \frac{3.0 \times 10^2 \text{ V}}{10.0 \, \Omega}$$
$$I_p = 3.0 \times 10^1 \text{ A}$$

So the current in the primary circuit, I_p, is 3.0×10^1 A.

Now use the relevant equation related to transformers to find the current in the secondary circuit, I_s:

$$\frac{I_s}{I_p} = \frac{N_p}{N_s}$$
$$I_s = \frac{I_p N_p}{N_s}$$
$$= \frac{(3.0 \times 10^1 \text{ A})(150)}{30}$$
$$I_s = 150 \text{ A}$$

So the current in the secondary circuit, I_s, is 150 A.

87. (a) Given: V_p = 3.0 kV; R_p = 750 Ω; $V_s = 1.0 \times 10^2$ V; N_s = 60

Required: N_p

Analysis: $\frac{V_p}{V_s} = \frac{N_p}{N_s}$

Solve for N_p:

$$N_p = \frac{V_p N_s}{V_s}$$

Solution:

$$N_p = \frac{V_p N_s}{V_s}$$
$$= \frac{(3.0 \text{ kV})(60)}{1.0 \times 10^2 \text{ V}}$$
$$= \frac{(3.0 \times 10^3 \cancel{\text{V}})(60)}{1.0 \times 10^2 \cancel{\text{V}}}$$
$$N_p = 1800$$

Statement: The primary circuit has 1800 coils.

(b) First use Ohm's law in the form $I = \frac{V}{R}$ and the values given for V_p and R_p to find I_p, the current in the primary circuit:

$$I_p = \frac{V_p}{R_p}$$
$$= \frac{3.0 \text{ kV}}{750 \, \Omega}$$
$$= \frac{3.0 \times 10^3 \text{ V}}{750 \, \Omega}$$
$$I_p = 4.0 \text{ A}$$

So the current in the primary circuit, I_p, is 4.0 A.

Now use the relevant equation related to transformers to find the current in the secondary circuit, I_s:

$$\frac{I_s}{I_p} = \frac{V_p}{V_s}$$
$$I_s = \frac{I_p V_p}{V_s}$$
$$= \frac{(4.0 \text{ A})(3.0 \text{ kV})}{1.0 \times 10^2 \text{ V}}$$
$$= \frac{(4.0 \text{ A})(3.0 \times 10^3 \cancel{\text{V}})}{1.0 \times 10^2 \cancel{\text{V}}}$$
$$I_s = 120 \text{ A}$$

So the current in the secondary circuit, I_s, is 120 A.

Now use Ohm's law in the form $R = \frac{V}{I}$ and the value found for I_s and the value given for V_s to find R_s, the resistance in the secondary circuit:

$$R_s = \frac{V_s}{I_s}$$
$$= \frac{1.0 \times 10^2 \text{ V}}{120 \text{ A}}$$
$$R_s = 0.83 \, \Omega$$

So the resistance in the secondary circuit is 0.83 Ω.

88. First determine the amount of power lost in transmission in watts:

0.80 % of 14 MW = 1.12×10^5 W (one extra digits carried)

So the amount of power lost in transmission, P, is 1.12×10^5 W.

Now determine the current that the power is transmitted with using the power equation in the form $P = VI$ and the values given for P and V:

$$P = VI$$
$$I = \frac{P}{V}$$
$$= \frac{14 \text{ MW}}{160 \text{ kV}}$$
$$= \frac{14\times 10^6 \text{ W}}{1.6\times 10^5 \text{ V}}$$
$$I = 87.5 \text{ A} \quad \text{(one extra digit carried)}$$

So the power is transmitted with a current of 87.5 A.

Now solve for R in the power equation in the form $P = I^2R$ and then substitute the value found for P and I to find R, which is the total resistance in the transmission wire:

$$P = I^2R$$
$$R = \frac{P}{I^2}$$
$$= \frac{1.12\times 10^5 \text{ W}}{(87.5 \text{ A})^2}$$
$$R = 15\ \Omega$$

So the total resistance in the transmission wire is 15 Ω.

89. First find an equation relating the power generated by the dam, the current that the power is transmitted with, and the total resistance. This equation is:

$$0.60\ \%\text{ of } P = I^2R$$
$$0.0060\times P = I^2R$$

Now rearrange for I in the power equation $P = VI$ and substitute the expression for I into the previous equation:

$$P = VI$$
$$I = \frac{P}{V}$$
$$0.0060\times P = I^2R$$
$$0.0060\times P = \left(\frac{P}{V}\right)^2 R$$

Now solve for P in this equation and substitute the values given for V and R to determine P, which is the total power generated by the dam:

$$0.0060\times P = \left(\frac{P}{V}\right)^2 R$$
$$\frac{P^2}{V^2}R = 0.0060\times P$$
$$\frac{P^{\not 2}}{V^2 \not P}R = 0.0060\times\frac{\not P}{\not P}$$
$$\frac{P}{V^2}R = 0.0060$$
$$P = \frac{0.0060V^2}{R}$$

$V = 240$ kV; $R = 0.50\ \Omega$

$$P = \frac{0.0060V^2}{R}$$
$$= \frac{0.0060(240 \text{ kV})^2}{0.50\ \Omega}$$
$$= \frac{0.0060(2.4\times 10^5 \text{ V})^2}{0.50\ \Omega}$$
$$P = 690 \text{ MW}$$

So the dam produces 690 MW of power.

90. First find the potential difference of the primary circuit, V_p, using the relevant equation related to transformers:

$$\frac{V_p}{N_p} = \frac{V_s}{N_s}$$
$$V_p = \frac{V_sN_p}{N_s}$$
$$= \frac{(250 \text{ kV})(1000)}{6000}$$
$$V_p = 4.2\times 10^4 \text{ V}$$

So the potential difference of the primary circuit is 4.2×10^4 V.

Now use the power equation in the form $P = VI$ with the value found for V and the value given for I to find P, the power that the nuclear plant produces:

$$P = VI$$
$$= (4.2\times 10^4 \text{ V})(30.0 \text{ kA})$$
$$= (4.2\times 10^4 \text{ V})(3.00\times 10^4 \text{ A})$$
$$= 1.3\times 10^9 \text{ W}$$
$$P = 1300 \text{ MW}$$

So the power plant produces 1300 MW of power.

Evaluation

91. (a) To make an ammeter, place a galvanometer in parallel with a resistor with lower resistance than the galvanometer (to keep the current away from the galvanometer). The galvanometer measures the current passing through the resistor.
(b) To make a voltmeter, place a galvanometer in series with a resistor with a very high resistance (to keep the current away from the galvanometer). Then, knowing the resistance of the path the galvanometer is on, calculate the voltage by multiply the current by the resistance.

92. (a) Household circuits are set up with an AC power source and the devices plugged in are in parallel.
(b) Since the circuit is in parallel and all power strips and additional plugs create more parallel circuits, as more devices are plugged in the overall resistance decreases.
(c) The voltage of an outlet remains constant, so using Ohm's Law, as the resistance decreases there is a corresponding increase in current, which could melt or fray the wires. To prevent this, houses have safety devices such as circuit breakers, fuses, GFCIs, and AFCIs.

93. Yes, it is possible to create a DC motor without permanent magnets. Instead of magnets, add two solenoids to the circuit. Orient the solenoids so they have north and south magnetic poles in the former position of the magnets. Resistors are needed to control the amount of current in the circuit. If all three components are in parallel, then they will have the same voltage. By controlling the amount of current with the resistors you can control the strength of the magnetic fields and power of the motor.

94. (a) The current induced from a magnet in a coil or loop cannot result in a magnetic field that attracts the magnet because this violates the laws of conservation of energy. If the current created an attraction to the magnet then work could be done without any work put in. For example, we could lift a bar magnet through a horizontal loop and then the induced current would pull the weight of the magnet upward without any additional work being put in.
(b) We can control the current in a coil to attract or repel a magnet because in both cases the energy required to do so and thus the work done is supplied by an external power source. The power source must do work to create the potential difference necessary to maintain the current in the coil.

Reflect on Your Learning

95. Answers may vary. Sample answer:
I leave my computer on 24 hours a day at 450 W.
(24 h)(450 W) = 10 800 Wh or 10.8 kWh.
My computer uses 11 kWh of electricity in a day.

7(10.8 kWh) = 75.6 kWh
My computer uses 76 kWh in a week.

3657(10.8 kWh) = 394 275.6 kWh
My computer uses 3.9×10^5 kWh in a year.

96. Conventional current in a circuit is directed from positive to negative. Now we know that electrons are the actual particles moving in a wire and that they travel from negative to positive. This convention did not matter when scientists were developing electrical devices. It just set the standard for the right-hand rule conventions in determining many of the formulas relating electromagnetic phenomena.

97. Answers may vary. Students should explain the key concepts of the electrical power grid, including power supply and distribution so that the electrical needs of everyone on the grid are met.

Research

98. Answers may vary. Students may choose to write about James Watt, James Prescott Joule, Charles-Augustin de Coulomb, Alessandro Volta, André-Marie Ampère, or Georg Simon Ohm. Biographies should include details about when and where the scientist lived and what contributions he made to science.

99. (a) Answers may vary. The United States, China, and Japan rank among the world's top energy consumers with most of the energy being derived from fossil fuels. The United States uses 22 % of the total global energy, China uses 20 %, while Japan uses 7 %. Students may mention France, which gets 80 % of its power from nuclear energy but only uses 3 % of the total global energy.
(b) Answers may vary. Switzerland and Denmark rank among the greenest industrialized nations by experts at Yale and Columbia universities. These rankings are based on carbon emission reductions, reforestation efforts, and use of hydropower and geothermal energy. Japan is ranked as one of the most energy efficient. Other countries students may mention include Hong Kong, Ireland, and the U.K.

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100. Answers may vary. Students should research at least two methods of improving coal power plants, such as coal washing, wet scrubbers, electrostatic precipitators, and gasification. Emphasis should be put on benefits and cost to upgrade existing coal power plants.

101. Answers may vary. Students should describe how fuel cells use stored chemical energy converted to electrical energy, primarily by using hydrogen. Students should describe how the energy is converted and how the fuel cells get recharged, and include the costs of buying and operating a fuel cell vehicle.

102. Answers may vary. Students should describe how photovoltaic cells work. Light is absorbed by semiconducting materials, which then generate a current. Students should discuss reasons why this is so limited, including the impurities in the material and different wavelengths of light. They should also report on any new developments that might make solar power a more economic energy source and give estimates as to how much energy might be obtained.

103. Answers may vary. Students should research Tesla's ideas on wireless electricity, his successful experiments, and the lack of funding for his Wardenclyffe Tower that could supply electricity but not keep track of how to bill for its use.

104. Answers may vary. Students should describe how most transformers used in power transmission have multiple step down ratios so that the transformer can be used for different purposes. They should explain how the winding-to-voltage ratios still hold, as does conservation of power. They should include a diagram of a transformer as an example.