Chapter 13

Electric Energy and Circuits

Solutions for Practice Problems

Student Textbook page 610

1. Frame the Problem

- By definition the potential difference between anode and cathode is the quotient of the change in the electric potential energy of charges passing between electrodes and the quantity of the charge.
- The electric potential energy is equal to the amount of work done.
- The expression that defines potential difference applies to this problem.

Identify the Goal

The potential difference of the battery, V

Variables and Constants

Involved in the Problem	Known	Unknown
W	$W = 7.50 \times 10^{-2}$ J	V
ΔE_Q	$Q = 3.75 \times 10^{-3}$ J	ΔE_Q
V		
Q		

Strategy	Calculations
Use the expression for potential difference.	$V = \frac{\Delta E_Q}{Q}$
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$
Substitute in the variables.	$W = 7.50 \times 10^{-2}$ J $\Delta E_Q = 3.75 \times 10^{-3}$ C
Divide	$V = \frac{7.5 \times 10^{-2}\ \text{J}}{3.75 \times 10^{-3}}$
Since $1\frac{\text{J}}{\text{C}}$ is equivalent to 1 V, thus	$V = 20.0$ V
The potential difference is 20.0 V.	

Validate

The unit for potential difference is the volt.

2. Frame the Problem

- The work done transforms chemical potential energy into electric potential energy. Thus, the electric potential energy is equal to the amount of work done.
- The expression that defines potential difference applies to this problem.

Identify the Goal

The amount of work that has been done on the charge

Variables and Constants

Involved in the Problem	Known	Unknown
W	$V = 9\text{ V}$	W
ΔE_Q	$Q = 4.20 \times 10^{-2}\text{ C}$	ΔE_Q
V		
Q		

Strategy	Calculations
Use the expression for the potential difference.	$V = \frac{\Delta E_Q}{Q}$
Solve for ΔE_Q.	Substitute first $9\text{V} = \frac{\Delta E_Q}{4.20 \times 10^{-2}\text{ C}}$ $(9\text{V})(4.20 \times 10^{-2}\text{ C}) = \frac{\Delta E_Q}{\cancel{4.20 \times 10^{-2}\text{ C}}}$
Since 1 V·C is equal to 1 J, then	$\Delta E_Q = 0.378\text{ J}$
	Solve for ΔE_Q first $VQ = \frac{\Delta E_Q}{\cancel{Q}}\cancel{Q}$ $\Delta E_Q = (9\text{ V})(4.20 \times 10^{-2}\text{ C})$
Since 1 V·C is equal to 1 J, then	$\Delta E_Q = 0.378\text{ J}$
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$
Since 1 V·C is equivalent to 1 J, thus	$W = 0.378\text{ J}$

The amount of work done on the charge is 0.378 J.

Validate

The units combined to give joules, which is the correct unit for work.

3. Frame the Problem

- The electric potential energy is equal to the amount of work done.
- The expression that defines potential difference applies to this problem.

Identify the Goal

The amount of charge that was moved

Variables and Constants

Involved in the Problem	Known	Unknown
W	$W = 0.75\text{ J}$	Q
ΔE_Q	$V = 12\text{ V}$	ΔE_Q
V		
Q		

Strategy	Calculations
Use the expression for the potential difference.	$V = \frac{\Delta E_Q}{Q}$
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$ $W = 0.75\text{ J}$

Solve for the charge.	Substitute first	Solve for Q first
	$(12\text{V})Q = \frac{0.75\text{ J}}{\cancel{Q}}\cancel{Q}$	$VQ = \frac{\Delta E_Q}{\cancel{Q}}\cancel{Q}$
	$\frac{\cancel{(12\text{ V})}Q}{\cancel{12\text{ V}}} = \frac{0.75\text{ J}}{12\text{ V}}$	$\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_Q}{V}$
	$Q = \frac{0.75\text{ J}}{12\text{ V}}$	$Q = \frac{0.75\text{ J}}{12\text{ V}}$
Since $1\frac{\text{J}}{V}$ is equivalent to 1 C, thus	$Q = 6.3 \times 10^{-2}\text{ C}$	

The charge is 6.3×10^{-2} C.

Validate
The answer is in coulombs, which is the correct unit for charge.

Solutions for Practice Problems

Student Textbook page 614

4. Frame the Problem

- The potential difference drives a current through the circuit.
- The amount of work done by the current is the same as the change in the potential energy of the charges as they move through the circuit.
- The expressions that define potential difference and current apply to this problem.

Identify the Goal
To find the potential difference of the battery

Variables and Constants

Involved in the Problem	Known	Unknown
I	$I = 2.25\text{ A}$	V
ΔE_Q	$W = 8.10 \times 10^2\text{ J}$	ΔE_Q
W	$\Delta t = 1.5\text{ min}$	Q
V		
Δt		
Q		

Strategy	Calculations	
Convert time to SI units.	$1.5\ \cancel{\text{min}}\frac{60\text{ s}}{\cancel{\text{min}}} = 90\text{ s}$	
Use the definition for current to find the amount of charge.	$I = \frac{Q}{\Delta t}$	
	Substitute first	Solve for Q first
	$(2.25\text{ A})(90\text{ s}) = \frac{Q}{\cancel{90\text{ s}}}(\cancel{90\text{ s}})$	$I\Delta t = \frac{Q}{\cancel{\Delta t}}\cancel{\Delta t}$
	$Q = (2.25\text{ A})(90\text{ s})$	$Q = (2.25\text{ A})(90\text{ s})$
Since 1 A·s is equivalent to 1 C, thus	$Q = 202.5\text{ C}$	
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$ $W = 8.10 \times 10^2\text{ J}$ $\Delta E_Q = 8.10 \times 10^2\text{ J}$	
Use the expression for potential difference.	$V = \frac{\Delta E_Q}{Q}$	
Substitute in the values.	$V = \frac{8.10 \times 10^2\text{ J}}{202.5\text{ C}}$	

Divide	$4.0\ \frac{\text{J}}{\text{C}}$
Since $1\ \frac{\text{J}}{\text{C}}$ is equivalent to 1 V, thus	$V = 4.0\ \text{V}$

The potential difference is 4.0 V.

Validate
The units combined to give volts, which is the correct unit for potential difference.

5. Frame the Problem

- The battery is sending a current that does a known amount of work by moving an amount of charge through the circuit.
- The amount of work done by the current is the same as the change in the potential energy of the charges as they move through the circuit.

Identify the Goal
The time required to do a given amount of work

Variables and Constants

Involved in the Problem	Known	Unknown
I	$I = 5.0\ \text{A}$	Δt
ΔE_{Q}	$W = 680\ \text{J}$	ΔE_{Q}
W	$V = 17\ \text{V}$	Q
V		
Δt		
Q		

Strategy	Calculations	
The amount of work done is equal to the potential energy.	$W = \Delta E_{\text{Q}}$ $W = 680\ \text{J}$ $\Delta E_{\text{Q}} = 680\ \text{J}$	
Use the expression for potential difference.	$V = \frac{\Delta E_{\text{Q}}}{Q}$	
	Substitute first	Solve for Q first
	$(17\ \text{V})Q = \frac{680\ \text{J}}{\cancel{Q}}\cancel{Q}$	$VQ = \frac{\Delta E_{\text{Q}}}{\cancel{Q}}\cancel{Q}$
	$\frac{\cancel{(17\ \text{V})}Q}{\cancel{17\ \text{V}}} = \frac{680\ \text{J}}{17\ \text{V}}$	$\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_{\text{Q}}}{V}$
	$Q = \frac{680\ \text{J}}{17\ \text{V}}$	$Q = \frac{680\ \text{J}}{17\ \text{V}}$
Since $1\ \frac{\text{J}}{\text{V}}$ is equivalent to 1 C, therefore	$Q = 40\ \text{C}$	
Use the definition for current to solve for the amount of time.	$I = \frac{Q}{\Delta t}$	
	Substitute first	Solve for Δt first
	$(5.0\ \text{A})\Delta t = \frac{40\ \text{C}}{\cancel{\Delta t}}\cancel{\Delta t}$	$I\Delta t = \frac{Q}{\cancel{\Delta t}}\cancel{\Delta t}$
	$\Delta t = \frac{40\ \text{C}}{5.0\ \text{A}}$	$\frac{\cancel{I}\Delta t}{\cancel{I}} = \frac{Q}{I}$
		$\Delta t = \frac{40\ \text{C}}{5.0\ \text{A}}$
Since 1 C is equal to 1 A·s, $1\ \frac{\text{C}}{\text{A}}$ is equivalent to 1 s.	$\Delta t = 8\text{s}$	

It would take 8 s for the battery to do the amount of work.

Validate

The work and the potential difference were used to find the charge. Then the amount of charge and the value of the current were used to find the time that was needed to do the work. The answer is in seconds, which is the correct unit for time.

6. **Frame the Problem**

- The battery is sending a current that does an unknown amount of work by moving an amount of charge through the circuit.
- The amount of work done by the current is the same as the change in the potential energy of the charges as they move through the circuit.

Identify the Goal

To find the amount of work done by the battery

Variables and Constants

Involved in the Problem	Known	Unknown
I	$I = 4.70\text{ A}$	Q
ΔE_Q	$V = 25.0\text{ V}$	ΔE_Q
W	$\Delta t = 36.0\text{ s}$	W
V		
Δt		
Q		

Strategy	Calculations	
Use the definition for current to find the amount of charge.	$I = \frac{Q}{\Delta t}$	
	Substitute first	Solve for Q first
	$(4.70\text{ A})(36.0\text{ s}) = \frac{Q}{\cancel{36.0\text{ s}}}(\cancel{36.0\text{ s}})$	$I\Delta t = \frac{Q}{\cancel{\Delta t}}\cancel{\Delta t}$
	$Q = (4.70\text{ A})(36.0\text{ s})$	$Q = (4.70\text{ A})(36.0\text{ s})$
Since 1 A·s is equivalent to 1 C, therefore	$Q = 169.2\text{ C}$	
Use the expression for potential difference.	$V = \frac{\Delta E_Q}{Q}$	
	Substitute first	Solve for ΔE_Q first
	$25.0\text{ V} = \frac{\Delta E_Q}{169.2\text{ C}}$	$VQ = \frac{\Delta E_Q}{\cancel{Q}}\cancel{Q}$
	$(25.0\text{ V})(169.2\text{ C}) = \frac{\Delta E_Q}{\cancel{169.2\text{ C}}}(\cancel{169.2\text{ C}})$	$\Delta E_Q = (25.0\text{ V})(169.2\text{ J})$
Since 1 V·C is equivalent to 1 J, thus	$\Delta E_Q = 4.23 \times 10^3\text{ J}$	$\Delta E_Q = 4.23 \times 10^3\text{ J}$
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$ $W = 4.23 \times 10^3\text{ J}$	

The amount of work done is 4.23×10^3 J.

Validate

The current and the time were used to find the charge. Then the amount of charge and the value of the potential difference were used to find the work.

The units combined to give joules, which is the correct unit for work.

7. Frame the Problem

- The battery is sending a current that does a known amount of work by moving an amount of charge through the circuit.
- Potential energy, potential difference, and charge are all related.
- Charge, current, and time are all related.

Identify the Goal

To find the current through the battery

Variables and Constants

Involved in the Problem	Known	Unknown
I	$W = 9.6 \times 10^5$ J	Q
Q	$V = 160$ V	I
V	$\Delta t = 2$ min	
Δt		
W		

Strategy	Calculations	
Convert time to SI units.	$2 \cancel{\text{min}} \frac{60 \text{ s}}{\cancel{\text{min}}} = 180 \text{ s}$	
Use the expression for potential difference to solve for the charge. Remember that W is equal to ΔE_Q.	$V = \frac{W}{Q}$	
	Substitute first	Solve for Q first
	$(160\text{V})Q = \frac{9.6 \times 10^5 \text{ J}}{\cancel{Q}} \cancel{Q}$	$VQ = \frac{\Delta E_Q}{\cancel{Q}} \cancel{Q}$
	$\frac{\cancel{(160 \text{ V})}Q}{\cancel{160 \text{ V}}} = \frac{9.6 \times 10^5 \text{ J}}{160 \text{ V}}$	$\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_Q}{V}$
	$Q = \frac{9.6 \times 10^5 \text{ J}}{160 \text{ V}}$	$Q = \frac{9.6 \times 10^5 \text{ J}}{160 \text{ V}}$
Since $1 \frac{\text{J}}{\text{V}}$ is equivalent to 1 C, therefore	$Q = 6000$ C	
Use the definition of current.	$I = \frac{Q}{\Delta t}$	
Divide	$I = \frac{6000 \text{ C}}{180 \text{ s}}$	
Since $1 \frac{\text{C}}{\text{s}}$ is equivalent to 1 A,	$I = 50$ A	
The current is 50 A.		

Validate

The answer is in amperes, which is the correct unit for current.

8. Frame the Problem

- The light draws a current through it.
- Charge, current, and time are all related.

Identify the Goal

To find the time it will take for the light to draw a charge of 36 C.

Variables and Constants

Involved in the Problem	Known	Unknown
I	$I = 0.48$ A	Δt
Q	$Q = 36$ C	
Δt		

Strategy
Use the definition for current to find the amount of time.

Calculations

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

Substitute first

$(0.48\text{A})\Delta t = \frac{36\text{ C}}{\cancel{\Delta t}}\cancel{\Delta t}$

$\Delta t = \frac{36\text{ C}}{0.48\text{ A}}$

$\Delta t = 75$ s

Solve for Δt first

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

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

$\Delta t = \frac{36\text{ C}}{0.48\text{ A}}$

$\Delta t = 75$ s

Since 1 $\frac{\text{C}}{\text{A}}$ is equivalent to 1 s,

The time it takes for 36 C of charge to pass through the wire is 75 s.

Validate
The answer is in seconds, which is the correct unit for time.

9. Frame the Problem
- The electric circuit draws a current through it.
- Charge, current, and time are all related.

Identify the Goal
To find the time it will take for the light to draw a charge of 36 C.

Variables and Constants

Involved in the Problem	Known	Unknown
I	$\Delta t = 1$ h	Q
Q	$I = 20$ A	
Δt	$V = 120$ V	
V		

Strategy
Convert time to SI units.

Use the definition for current to solve for the charge. Remember that A·s is equivalent to 1 C.

Calculations

$1\ \cancel{\text{h}}\left(\frac{60\ \cancel{\text{min}}}{\cancel{\text{h}}}\right)\left(\frac{60\text{ s}}{\cancel{\text{min}}}\right) = 3600\text{ s}$

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

Substitute first

$(20\text{ A})(3600\text{ s}) = \frac{Q}{\cancel{3600\text{ s}}}(\cancel{3600\text{ s}})$

$Q = 7.2 \times 10^4$ C

Solve for Δt first

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

$Q = (20\text{ A})(3600\text{ s})$

$Q = 7.2 \times 10^4$ C

The total charge that will pass through the wire in one hour is 7.2×10^4 C.

Validate
The answer is in coulombs, which is the correct unit for charge. The potential difference was not needed to solve the problem.

10. Frame the Problem

- The cellular phone battery draws a current through it.
- Charge, current, and time are all related.

Identify the Goal

To find the amount of current that the battery draws

Variables and Constants

Involved in the Problem	Known	Unknown
I	$\Delta t = 0.25$ h	I
Q	$Q = 2.5 \times 10^3$ C	
Δt		

Strategy	Calculations
Convert time to SI units.	$0.25\ \not{\text{h}}\left(\frac{60\ \not{\text{min}}}{\not{\text{h}}}\right)\left(\frac{60\ \text{s}}{\not{\text{min}}}\right) = 900$ s
Use the definition for current.	$I = \frac{Q}{\Delta t}$
Divide and round up.	$I = \frac{2.5 \times 10^3\ \text{C}}{900\ \text{s}}$
	$I = 2.8\ \frac{\text{C}}{\text{s}}$
Since $1\ \frac{\text{C}}{\text{s}}$ is equivalent to 1 A, thus	$I = 2.8$ A

The cellular phone battery draws 2.8 A of current during recharging.

Validate

The answer is in amperes, which is the correct unit for current.

11. Frame the Problem

- The lights consume electric energy.
- Power, time, and electric energy are all related.

Identify the Goal

To find the electric energy consumed

Variables and Constants

Involved in the Problem	Known	Unknown
P_{tot}	$\Delta t = 16$ h	P_{tot}
V	$V = 240$ V	ΔE_Q
Δt	$P = 40$ W	
ΔE_Q	$N_{lights} = 200$	
P		
N_{lights}		

(**Note:** P_{tot} refers to the total power and N_{lights} refers to the number of lights)

Strategy	Calculations
Convert time to SI units.	$16\ \not{\text{h}}\left(\frac{60\ \not{\text{min}}}{\not{\text{h}}}\right)\left(\frac{60\ \text{s}}{\not{\text{min}}}\right) = 5.74 \times 10^4$ s
Find the total power.	$P_{tot} = (N_{lights})(\text{P})$
	$P_{tot} = (200)(40\ \text{W})$
	$P_{tot} = 8000$ W

Use the definition of power to obtain the electric energy consumed.	$P_{tot} = \frac{\Delta E_Q}{\Delta t}$	
	Substitute first	Solve for ΔE_Q first
	$(8000\text{ W})(5.76 \times 10^4\text{ s}) = \frac{\Delta E_Q}{\cancel{(5.76 \times 10^4\text{ s})}}\cancel{5.76 \times 10^4\text{ s}}$	$P_{tot}\Delta t = \frac{\Delta E_Q}{\cancel{\Delta t}}\cancel{\Delta t}$
	$\Delta E_Q = (5.76 \times 10^4\text{ s})(8000\text{ W})$	$\Delta E_Q = (5.76 \times 10^4\text{ s})(8000\text{ W})$
Since 1 s·W is equivalent to 1 J, thus	$\Delta E_Q = 4.6 \times 10^8\text{ J}$	

The energy consumed is 4.6×10^8 J.

Validate
The answer is in joules, which is the correct unit for energy. The potential difference was not needed to solve the problem.

Solutions for Practice Problems

Student Textbook page 618

12. Frame the Problem
- When elementary charges pass a point in a circuit there is current.
- If you know the time it took for a number of elementary charges to pass that point, you can calculate the current.

Identify the Goal
To calculate the current

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
I	$N = 2.85 \times 10^{20}$	$e = 1.60 \times 10^{-19}$ C	I
N	$\Delta t = 5.70$ min		Q
e			
Δt			
Q			

Strategy	Calculations
Use the relationship between amount of charge and elementary charge.	$Q = Ne$
Multiply	$Q = (2.85 \times 10^{20})(1.60 \times 10^{-19}\text{ C})$ $Q = 45.6$ C
Convert time to SI units.	$5.70\ \cancel{\text{min}}\ \frac{60\text{ s}}{\cancel{\text{min}}} = 342$ s
Use the definition for current.	$I = \frac{Q}{\Delta t}$
Divide	$I = \frac{45.6\text{ C}}{342\text{ s}}$
Since 1 $\frac{\text{C}}{\text{s}}$ is equivalent to 1 A, thus	$I = 0.133$ A

The current is 0.133 A.

Validate
The answer is in amperes, which is the correct unit for current.

13. (a) Frame the Problem

- The battery does a known amount of work at a known potential difference by moving an unknown amount of charge through a circuit in a known amount of time.
- Potential difference, work, and charge are all related.
- Current, charge, and time are all related.

Identify the Goal

To determine the current through the battery

Variables and Constants

Involved in the Problem	Known	Unknown
I	$\Delta t = 360.0$ s	I
ΔE_Q	$W = 5.40 \times 10^4$ J	ΔE_Q
W	$V = 16.0$ V	Q
V		
Δt		
Q		

Strategy	Calculations	
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$ $W = 5.40 \times 10^4$ J $\Delta E_Q = 5.40 \times 10^4$ J	
Use the expression for potential difference to find the amount of charge.	$V = \frac{\Delta E_Q}{Q}$	
	Substitute first $(16.0\text{ V})Q = \frac{5.40 \times 10^4\text{ J}}{\cancel{Q}}\cancel{Q}$ $\frac{\cancel{(16.0\text{ V})}Q}{\cancel{16.0\text{ V}}} = \frac{5.40 \times 10^4\text{ J}}{16.0\text{ V}}$ $Q = \frac{5.40 \times 10^4\text{ J}}{16.0\text{ V}}$	Solve for Q first $VQ = \frac{\Delta E_Q}{\cancel{Q}}\cancel{Q}$ $\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_Q}{V}$ $Q = \frac{5.40 \times 10^4\text{ J}}{16.0\text{ V}}$
Since 1 $\frac{\text{J}}{\text{V}}$ is equivalent to 1 C, therefore	$Q = 3375$ C	
Round up	$Q = 3380$ C	
Use the definition for current.	$I = \frac{Q}{\Delta t}$	
Divide	$I = \frac{3380\text{ C}}{360.0\text{ s}}$	
Since 1 $\frac{\text{C}}{\text{s}}$ is equivalent to 1 A,	$I = 9.38$ A	

The current through the battery is 9.38 A.

Validate

The answer is in amperes, which is the correct unit for current.

(b) Frame the Problem

- When elementary charges pass a point in a circuit there is current.
- If you know the amount of charge that passes through the battery, you can use this magnitude to find the number of elementary charges (electrons).

Identify the Goal
The number (*N*) of elementary charges (electrons) passing through the bulb

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
N	$Q = 3380$ C	$e = 1.6 \times 10^{-19}$ C	N
e			
Q			

Strategy
Use the relationship between amount of charge and the elementary charge to find the number of electrons.

Calculations

$Q = Ne$

Substitute first

$3380 \text{ C} = N(1.60 \times 10^{-19} \text{ C})$

$\frac{3380 \not{\text{C}}}{1.60 \times 10^{-19} \not{\text{C}}} = \frac{N(1.60 \times 10^{-19} \text{ C})}{1.60 \times 10^{-19} \text{ C}}$

$N = 2.11 \times 10^{22}$

Solve for *N* first

$\frac{Q}{e} = \frac{Ne}{e}$

$N = \frac{3380 \not{\text{C}}}{1.60 \times 10^{-19} \not{\text{C}}}$

$N = 2.11 \times 10^{22}$

The number of elementary charges is 2.11×10^{22}.

Validate
The units cancel to give a pure number, as they should.

14. **Frame the Problem**
- When elementary charges pass a point in a circuit there is current.
- If you know the current at that point and the time it took to pass, you can calculate the number of elementary charges.

Identify the Goal
The number (*N*) of elementary charges that pass through a point in the circuit

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
I	$I = 3.50$ A	$e = 1.6 \times 10^{-19}$ C	N
N	$\Delta t = 24.0$ s		Q
e			
Δt			
Q			

Strategy
Use the definition for current to solve for the amount of charge.

Calculations

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

Substitute first

$(3.50 \text{ A})(24.0 \text{ s}) = \frac{Q}{24.0 \text{ s}}(24.0 \text{ s})$

$Q = (3.50 \text{ A})(24.0 \text{ s})$

Solve for *Q* first

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

$Q = (3.50 \text{ A})(24.0 \text{ s})$

Since 1 A·s, thus

$Q = 84.0$ C

Use the relationship between amount of

$Q = Ne$

charge and elementary charge to find the number of electrons.

Substitute first

$84.0\ \text{C} = N(1.60 \times 10^{-19}\ \text{C})$

$\frac{84.0\ \cancel{\text{C}}}{1.60 \times 10^{-19}\ \cancel{\text{C}}} = \frac{N\cancel{(1.60 \times 10^{-19}\ \text{C})}}{\cancel{1.60 \times 10^{-19}\ \text{C}}}$

$N = 5.25 \times 10^{20}$

Solve for N first

$\frac{Q}{e} = \frac{N\cancel{e}}{\cancel{e}}$

$N = \frac{84.0\ \cancel{\text{C}}}{1.60 \times 10^{-19}\ \cancel{\text{C}}}$

$N = 5.25 \times 10^{20}$

The number of elementary charges is 5.25×10^{20}.

Validate

The units cancel out to yield a pure number, which is correct.

15. (a) Frame the Problem

- When elementary charges pass a point in a circuit there is current.
- If you know the time it took for a quantity of elementary charges to pass that point you can calculate the current.

Identify the Goal

To calculate the current

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
I	$N = 2.5 \times 10^{20}$	$e = 1.6 \times 10^{-19}$ C	I
N	$\Delta t = 5.70$ min		Q
e			
Δt			
Q			

Strategy	Calculations
Use the relationship between amount of charge and elementary charge.	$Q = Ne$
Multiply	$Q = (2.5 \times 10^{20})(1.60 \times 10^{-19}\ \text{C})$ $Q = 40\ \text{C}$
Use the definition for current.	$I = \frac{Q}{\Delta t}$
Divide	$I = \frac{40\ \text{C}}{12\ \text{s}}$
Since 1 $\frac{\text{C}}{\text{s}}$ is equivalent to 1 A, thus	$I = 3.3$ A

The current is 3.3 A.

Validate

The answer is in amperes, which is the correct unit for current.

(b) Frame the Problem

- The potential difference drives a current through the circuit.
- The amount of work done by the current is the same as the change in the potential energy of the charges as they move through the circuit.
- The expressions that define potential difference and work done apply to this problem.

Identify the Goal

To find the potential difference of the battery

Variables and Constants

Involved in the Problem	Known	Unknown
ΔE_Q	$W = 68$ J	ΔE_Q
W	$Q = 40$ C	V
V		
Q		

Strategy	Calculations
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$ $W = 68$ J $\Delta E_Q = 68$ J
Use the expression for potential difference.	$V = \frac{\Delta E_Q}{Q}$
Substitute in the values.	$V = \frac{68\text{ J}}{40\text{ C}}$
Divide	$V = 1.7\frac{\text{J}}{\text{C}}$
Since $1\,\frac{\text{J}}{\text{C}}$ is equivalent to 1 V, thus	$V = 1.7$ V
The potential difference is 1.7 V.	

Validate
The answer is in volts, which is the correct unit for potential difference.

Solutions for Practice Problems

Student Textbook page 626

16. Frame the Problem

- The electrical resistance of a conductor depends on its length, its cross-sectional area, the resistivity of the conducting material, and the temperature.
- These variables are related by the equation for resistance of a conductor.
- The resistivity of aluminum at 20°C is listed in Table 13.1 of the textbook.

Identify the Goal
Resistance, R, of the aluminum conductor

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
R	$d = 2.0$ mm	$\rho = 2.7 \times 10^{-8}\ \Omega\cdot\text{m}$	R
L	$L = 250$ m		
d			
A			
ρ			

Strategy	Calculations
Use the equation relating resistance to resistivity and dimensions of the conductor.	$R = \rho\frac{L}{A}$
Convert time to SI units. (All others are in SI units.)	$2.0\ \cancel{\text{mm}}\ \frac{\text{m}}{1000\ \cancel{\text{mm}}} = 2.0 \times 10^{-3}$ m

Find the cross-sectional area from the diameter.	$A = \pi r^2$ $r = \frac{d}{2}$ $r = \frac{2.0 \times 10^{-3}\ \text{m}}{2} = 1.0 \times 10^{-3}\ \text{m}$ $A = \pi(1.0 \times 10^{-3}\ \text{m})^2$ $A = 3.1 \times 10^{-6}\ \text{m}^2$
Values are all known, so substitute into the equation for resistance and round up.	$R = (2.7 \times 10^{-8}\ \Omega\cdot\text{m})\frac{250\ \text{m}}{3.1 \times 10^{-6}\ \text{m}^2}$ $R = 2.15\frac{\Omega\cdot\text{m}\cdot\text{m}}{\text{m}^2}$ $R = 2.2\ \Omega$

The resistance is 2.2 Ω.

Validate

The units combined to give ohms, which is correct.

17. Frame the Problem

- The electrical resistance of a conductor depends on its length, its cross-sectional area, the resistivity of the conducting material, and the temperature.
- These variables are related by the equation for resistance of a conductor.
- The diameter of the wire is listed in p. 624 of the textbook.
- The resistivity of Nichrome™ at 20°C is listed in Table 13.1 of the textbook.

Identify the Goal

The length, L, of the Nichrome wire

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
R	$R = 5.0\ \Omega$	$\rho = 100 \times 10^{-8}\ \Omega\cdot\text{m}$	L
L		$d = 1.02\ \text{mm}$	A
d			
A			
ρ			

Strategy	Calculations
Use the equation relating resistance to resistivity and dimensions of the conductor.	$R = \rho\frac{L}{A}$
Convert time to SI units. (All others are in SI units.)	$1.02\ \cancel{\text{mm}}\ \frac{\text{m}}{1000\ \cancel{\text{mm}}} = 1.02 \times 10^{-3}\ \text{m}$
Find the cross-sectional area from the diameter.	$A = \pi r^2$ $r = \frac{d}{2}$ $r = \frac{1.02 \times 10^{-3}\ \text{m}}{2} = 0.51 \times 10^{-3}\ \text{m}$ $A = \pi(0.51 \times 10^{-3}\ \text{m})^2$ $A = 8.17 \times 10^{-7}\ \text{m}^2$
Solve for the length of the wire.	Substitute first $500\ \Omega = (100 \times 10^{-8}\ \Omega \cdot \text{m})\frac{L}{8.17 \times 10^{-7}\ \text{m}^2}$

$$500\ \Omega \frac{8.17 \times 10^{-7}\ \text{m}^2}{100 \times 10^{-8}\ \Omega\cdot\text{m}}$$
$$= (100 \times 10^{-8}\ \Omega\cdot\text{m})\frac{L}{8.17 \times 10^{-7}\ \text{m}^2}\frac{8.17 \times 10^{-7}\ \text{m}^2}{100 \times 10^{-8}\ \Omega\cdot\text{m}}$$
$$L = 500\ \Omega \frac{8.17 \times 10^{-7}\ \text{m}^2}{100 \times 10^{-8}\ \Omega\cdot\text{m}}$$
$$L = 4.08\ \text{m}$$

Solve for L first

$$R\frac{A}{\rho} = \cancel{\rho}\frac{L}{\cancel{A}}\frac{\cancel{A}}{\cancel{\rho}}$$
$$L = 500\ \Omega \frac{8.17 \times 10^{-7}\ \text{m}^2}{100 \times 10^{-8}\ \Omega\cdot\text{m}}$$
$$L = 4.08\ \text{m}$$

The length of the wire is 4.08 m.

Validate

The units combined to give meters, which is correct.

18. Frame the Problem

- The electric resistance of a 100 W tungsten filament depends on its length, its cross-sectional area, the resistivity of the conducting material, and the temperature.
- These variables are related by the equation for resistance of a conductor.
- The resistivity of tungsten at 20°C is listed in Table 13.1 of the textbook.

Identify the Goal

The radius, r, of the tungsten wire

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
R	$R = 144\ \Omega$	$\rho = 5.6 \times 10^{-8}\ \Omega\cdot\text{m}$	r
L	$L = 2.0$ cm		A
r	$P = 100$ W		
d			
A			
ρ			

Strategy	**Calculations**
Use the equation relating resistance to resistivity and dimensions of the conductor.	$R = \rho\frac{L}{A}$
Convert time to SI units. (All others are in SI units.)	$2.0\ \cancel{\text{cm}}\ \frac{\text{m}}{100\ \cancel{\text{cm}}} = 2.0 \times 10^{-2}\ \text{m}$
Solve for the area of the wire.	Substitute first

$$144\ \Omega\cdot A = (5.6 \times 10^{-8}\ \Omega\cdot\text{m})\frac{2.0 \times 10^{-2}\ \text{m}}{\cancel{A}}\cancel{A}$$
$$144\ \Omega\cdot\frac{A}{144\ \Omega} = (5.6 \times 10^{-8}\ \Omega\cdot\text{m})\frac{2.0 \times 10^{-2}\ \text{m}}{144\ \Omega}$$
$$A = (5.6 \times 10^{-8}\ \Omega\cdot\text{m})\frac{2.0 \times 10^{-2}\ \text{m}}{144\ \Omega}$$
$$A = 7.8 \times 10^{-12}\ \text{m}^2$$

Solve for A first

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

$$A = 5.6 \times 10^{-8}\ \Omega\cdot\text{m}\ \frac{2.0 \times 10^{-2}\ \text{m}}{144\ \Omega}$$
$$A = 7.8 \times 10^{-12}\ \text{m}^2$$

Find the radius of the filament.

Substitute first

$$7.8 \times 10^{-12}\ \text{m}^2 = \pi r^2$$
$$\frac{7.8 \times 10^{-12}\ \text{m}^2}{\pi} = r^2\frac{\cancel{\pi}}{\cancel{\pi}}$$
$$r = \sqrt{\frac{7.8 \times 10^{-12}\ \text{m}^2}{\pi}}$$
$$r = 1.6 \times 10^{-6}\ \text{m}$$

Solve for r first

$$A = \pi r^2$$
$$\frac{A}{\pi} = r^2\frac{\cancel{\pi}}{\cancel{\pi}}$$
$$r = \sqrt{\frac{7.8 \times 10^{-12}\ \text{m}^2}{\pi}}$$
$$r = 1.6 \times 10^{-6}\ \text{m}$$

The radius of the tungsten wire is 1.6×10^{-6} m.

Validate

The units combined to give meters, which is correct. Also notice that the radius is very small which is what we would want so that it has a large resistance. Finally, note that the power, P, was not needed in the problem.

19. Frame the Problem

- The electrical resistance of a conductor depends on its length, its cross-sectional area, the resistivity of the conducting material, and the temperature.
- These variables are related by the equation for resistance of a conductor.
- The resistivity of aluminum at 20°C is listed in Table 13.1 of the textbook.

Identify the Goal

Resistance, R, of the aluminum conductor

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
R	$L = 250$ cm	$\rho = 2.7 \times 10^{-8}\ \Omega\cdot\text{m}$	R
L		$d = 1.63$ mm	A
d			
A			
ρ			

Strategy	**Calculations**
Use the equation relating resistance to resistivity and dimensions of the conductor.	$R = \rho\frac{L}{A}$
Convert time to SI units. (All others are in SI units.)	$1.63\ \cancel{\text{mm}}\ \frac{\text{m}}{1000\ \cancel{\text{mm}}} = 1.63 \times 10^{-3}\ \text{m}$

Find the cross-sectional area from the diameter.	$A = \pi r^2$ $r = \frac{d}{2}$ $r = \frac{1.63 \times 10^{-3}\ \text{m}}{2} = 8.15 \times 10^{-4}\ \text{m}$ $A = \pi(8.15 \times 10^{-4}\ \text{m})^2$ $A = 2.08 \times 10^{-6}\ \text{m}^2$
Values are all known, so substitute into the equation for resistance.	$R = (2.7 \times 10^{-8}\ \Omega{\cdot}\text{m})\frac{35\ \text{m}}{2.08 \times 10^{-6}\ \text{m}^2}$ $R = 0.45\frac{\Omega{\cdot}\text{m}{\cdot}\text{m}}{\text{m}^2}$ $R = 0.45\ \Omega$

The resistance is 0.45 Ω.

Validate

The units combined to give ohms, which is correct.

20. Frame the Problem

- The electrical resistance of a small carbon rod depends on its length, its cross-sectional area, the resistivity of the conducting material, and the temperature.
- These variables are related by the equation for resistance of a conductor.
- The resistivity of carbon at 20°C is listed in Table 13.1 of the textbook.

Identify the Goal

The width, w, of the square carbon rod

Variables and Constants

Involved in the Problem	Known	Implied	Unknown
R	$R = 140\ \Omega$	$\rho = 3500 \times 10^{-8}\Omega{\cdot}\text{m}$	w
L	$L = 24\ \text{m}$		A
w			
A			
ρ			

Strategy	Calculations
Use the equation relating resistance to resistivity and dimensions of the conductor.	$R = \rho\frac{L}{A}$
Solve for the area of the wire.	Substitute first $140\ \Omega{\cdot}A = (3500 \times 10^{-8}\ \Omega{\cdot}\text{m})\frac{24\ \text{m}}{\cancel{A}}\cancel{A}$ $140\ \Omega{\cdot}\frac{A}{140\ \Omega} = (3500 \times 10^{-8}\ \Omega{\cdot}\text{m})\frac{24\ \text{m}}{140\ \Omega}$ $A = (3500 \times 10^{-8}\ \Omega{\cdot}\text{m})\frac{24\ \text{m}}{140\ \Omega}$ $A = 6.0 \times 10^{-6}\ \text{m}^2$ Solve for A first $RA = \rho\frac{L}{\cancel{A}}\cancel{A}$ $\frac{\cancel{R}}{\cancel{R}}A = \rho\frac{L}{R}$ $A = 3500 \times 10^{-8}\ \Omega{\cdot}\text{m}\frac{24\ \text{m}}{140\ \Omega}$ $A = 6.0 \times 10^{-6}\ \text{m}^2$
Find the width of the carbon square.	Substitute first $6.0 \times 10^{-6}\ \text{m}^2 = w^2$

$$w = \sqrt{6.0 \times 10^{-6}\ \text{m}^2}$$
$$w = 2.4 \times 10^{-3}\ \text{m}$$

Solve for w first

$$A = w^2$$
$$w = \sqrt{6.0 \times 10^{-6}\ \text{m}^2}$$
$$w = 2.4 \times 10^{-3}\ \text{m}$$

The width of the square carbon rod is 2.4×10^{-3} m or 2.4 mm.

Validate

The units combined to give meters, which is correct.

Solutions for Practice Problems

Student Textbook page 632

21. Frame the Problem

- The power supply creates a potential difference that provides energy to cause a current to flow in the electric kettle.
- You can find the resistance of the element by Ohm's law.

Identify the Goal

Resistance, R, of the element

Variables and Constants

Involved in the Problem	Known	Unknown
R	$I = 7.5$ A	R
I	$V = 120$ V	
V		

Strategy

Apply Ohm's law.

Calculations

$$V = IR$$

Substitute first

$$120\ \text{V} = (7.5\ \text{A})R$$
$$120\ \text{V} \cdot \frac{1}{7.5\ \text{A}} = (7.5\ \text{A})\frac{R}{7.5\ \text{A}}$$
$$R = \frac{120\ \text{V}}{7.5\ \text{A}}$$
$$R = 16\ \Omega$$

Solve for R first

$$V = IR$$
$$V \cdot \frac{1}{I} = \cancel{I}\frac{R}{\cancel{I}}$$
$$R = \frac{120\ \text{V}}{7.5\ \text{A}}$$
$$R = 16\ \Omega$$

The resistance is 16 Ω.

Validate

The units combined to give ohms, which is correct.

22. Frame the Problem

- The toaster has a potential difference that provides energy to cause a current to flow through it.
- You can find the current through the toaster by Ohm's law.

Identify the Goal

The current, I, through the toaster

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 9.60\ \Omega$	I
I	$V = 120$ V	
V		

Strategy
Apply Ohm's law.

Calculations

$V = IR$

Substitute first

$$120\text{ V} = I(9.60\ \Omega)$$
$$120\text{ V}\cdot\frac{1}{9.60\ \Omega} = (9.60\ \Omega)\frac{1}{9.60\ \Omega}$$
$$I = \frac{120\text{ V}}{9.60\ \Omega}$$
$$I = 12.5\text{ A}$$

Solve for I first

$$V = IR$$
$$V\cdot\frac{1}{R} = \cancel{R}\frac{1}{\cancel{R}}$$
$$I = \frac{120\text{ V}}{9.60\ \Omega}$$
$$I = 12.5\text{ A}$$

The current is 12.5 A.

Validate
The units combined to give amperes, which is correct.

23. Frame the Problem
- The light bulb has a potential difference that provides energy to cause a current to flow through it.
- You can find the operating potential difference by Ohm's law.

Identify the Goal
The operating potential difference, V

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 36\ \Omega$	V
I	$I = 140$ mA	
V		

Strategy
Apply Ohm's law.

Calculations

$$V = IR$$
$$V = (140\text{ mA})(36\ \Omega)$$
$$V = 5.0\text{ V}$$

The potential difference is 5.0 V.

Validate
The units combined to give volts, which is correct.

24. Frame the Problem
- The light bulb in the tail-light of an automobile has a potential difference that provides energy to cause a current to flow through it.
- You can find the current through the tail-light by Ohm's law.
- You can find the quantity of charge that passes through the bulb by the definition of current.
- The work done transforms chemical potential energy into electric potential energy. Thus, the electric potential energy is equal to the amount of work done.
- The expression that defines potential difference applies to this problem.

Identify the Goal

(a) The quantity of charge, Q, through the bulb

(b) The amount of work that has been done on the charge.

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 5.8\ \Omega$	I
I	$V = 12\ \text{V}$	Q
V	$\Delta t = 8.0\ \text{min}$	W
Δt	$V = 12\ \text{V}$	ΔE_{Q}
Q		
W		
ΔE_{Q}		
V		

Strategy

Apply Ohm's law.

Calculations

$V = IR$

Substitute first

$12\ \text{V} = I(5.8\ \Omega)$

$12\ \text{V}\cdot\frac{1}{5.8\ \Omega} = (5.8\ \text{A})\frac{I}{12\ \Omega}$

$I = \frac{12\ \text{V}}{5.8\ \Omega}$

$I = 2.07\ \text{A}$

Solve for I first

$V = IR$

$V\cdot\frac{1}{R} = \cancel{R}\frac{I}{\cancel{R}}$

$I = \frac{12\ \text{V}}{5.8\ \Omega}$

$I = 2.07\ \text{A}$

Use the expression for the electric current to solve for the charge and use the fact that A·s is equivalent to C.

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

Substitute first

$(2.07\ \text{A})(480\ \text{s}) = \frac{Q}{480\ \text{s}}(480\ \text{s})$

$Q = (2.07\ \text{A})(480\ \text{s})$

$Q = 990\ \text{C}$

Solve for Q first

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

$Q = (2.07\ \text{A})(480\ \text{s})$

$Q = 990\ \text{C}$

(a) The charge is 990 C and the current is 2.0 A.

Strategy

Use the expression for the potential difference.

Calculations

$V = \frac{\Delta E_{\text{Q}}}{Q}$

Solve for ΔE_{Q}; V·C is 1 J.

Substitute first

$12V = \frac{\Delta E_{\text{Q}}}{990\ \text{C}}$

$(12V)(990\ \text{C}) = \frac{\Delta E_{\text{Q}}}{990\ \text{C}}(12\ \text{C})$

$\Delta E_{\text{Q}} = 1.2 \times 10^4\ \text{J}$

Solve for ΔE_{Q} first

$VQ = \frac{\Delta E_{\text{Q}}}{\cancel{Q}}\cancel{Q}$

$\Delta E_{\text{Q}} = (12\ \text{V})(990\ \text{J})$

$\Delta E_{\text{Q}} = 1.2 \times 10^4\ \text{J}$

The amount of work done is equal to the potential energy.

$W = \Delta E_{\text{Q}}$

1 V·C is equivalent to 1 J, thus

$W = 1.2 \times 10^4\ \text{J}$

(b) The amount of work done on the charge is 1.2×10^4 J.

Validate
The units combined to give coulombs for the charge and joules for the work, which is correct.

25. Frame the Problem
- The electric potential energy is equal to the amount of work done.
- The expression that defines potential difference applies to this problem.
- From the charge you can obtain the current.
- From the current you can obtain the resistance.

Identify the Goal
The resistance of the iron

Variables and Constants

Involved in the Problem	Known	Unknown
W	$W = 3.35 \times 10^5$ J	Q
ΔE_Q	$V = 120$ V	R
V	$\Delta t = 4.50$ min	I
Q		ΔE_Q
I		
R		
Δt		

Strategy	Calculations
Use the expression for the potential difference.	$V = \frac{\Delta E_Q}{Q}$
The amount of work done is equal to the potential energy.	$W = \Delta E_Q$ $W = 3.35 \times 10^5$ J
Solve for the charge.	Substitute first $(120\text{ V})Q = \frac{3.35 \times 10^5\text{ J}}{\cancel{Q}}\cancel{Q}$ $\frac{(120\text{ V})Q}{120\text{ V}} = \frac{3.35 \times 10^5\text{ J}}{120\text{ V}}$ $Q = \frac{3.35 \times 10^5\text{ J}}{120\text{ V}}$ Solve for Q first $VQ = \frac{\Delta E_Q}{\cancel{Q}}\cancel{Q}$ $\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_Q}{V}$ $Q = \frac{3.35 \times 10^5\text{ J}}{120\text{ V}}$
$1\ \frac{\text{J}}{\text{V}}$ is equivalent to 1 C, thus	$Q = 2.80 \times 10^3$ C
Convert time to SI units.	$4.50\text{ min}\ \frac{60\text{ s}}{\text{min}} = 270$ s
Use the expression for the electric current to solve for the current.	$I = \frac{Q}{\Delta t}$
Substitute and divide.	$I = \frac{2.80 \times 10^3\text{ C}}{270\text{ s}}$
$1\ \frac{\text{C}}{\text{s}}$ is equivalent to 1 A, thus	$I = 10.3$ A
Apply Ohm's law.	$V = IR$ Substitute first

$$120\text{ V} = (10.3\text{ A})R$$
$$120\text{ V}\cdot\frac{1}{10.3\text{ A}} = (10.3\text{ A})\frac{R}{10.3\text{ A}}$$
$$R = \frac{120\text{ V}}{10.3\text{ A}}$$
$$R = 11.6\ \Omega$$

Solve for R first

$$V = IR$$
$$V\cdot\frac{1}{I} = \cancel{I}\frac{R}{\cancel{I}}$$
$$R = \frac{120\text{ V}}{10.3\text{ A}}$$
$$R = 11.6\ \Omega$$

The resistance is 11.6 Ω.

Alternative strategy: use two formulas for power, $P = \frac{\Delta EQ}{\Delta t}$ and $P = \frac{V^2}{R}$. Since $W = \Delta E_Q$, these formulas combine to give $\frac{W}{\Delta t} = \frac{V^2}{R}$. Substitute and solve for R, or rearrange to solve for R first.

Validate

The units combined to give ohms, which is correct.

26. Frame the Problem

- The electrical potential energy is equal to the amount of work done.
- The expression that defines potential difference applies to this problem.
- From Ohm's law you can obtain the current.
- From the definition of current you can obtain the time.

Identify the Goal

The time to produce 4.32×10^5 J of thermal energy

Variables and Constants

Involved in the Problem	Known	Unknown
W	$W = 4.32 \times 10^5$ J	Q
ΔE_Q	$V = 240$ V	Δt
V	$R = 60.0\ \Omega$	I
Q		ΔE_Q
I		
R		
Δt		

Strategy

Use the expression for the potential difference.

The amount of work done is equal to the potential energy.

Solve for the charge.

Calculations

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

$$W = \Delta E_Q$$
$$\Delta E_Q = 4.32 \times 10^5\text{ J}$$

Substitute first

$$(240\text{ V})Q = \frac{4.32 \times 10^5\text{ J}}{\cancel{Q}}\cancel{Q}$$
$$\frac{(240\text{ V})Q}{240\text{ V}} = \frac{4.32 \times 10^5\text{ J}}{240\text{ V}}$$
$$Q = \frac{4.32 \times 10^5\text{ J}}{120\text{ V}}$$

Solve for Q first

$$\frac{\cancel{V}Q}{V} = \frac{\Delta E_Q}{\cancel{Q}}\cancel{Q}$$

$$\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_Q}{V}$$

$$Q = \frac{4.32 \times 10^5 \text{ J}}{120 \text{ V}}$$

$\frac{\text{J}}{\text{V}}$ is equivalent to 1 C, thus $\quad Q = 1800 \text{ C}$

Apply Ohm's law. $\quad V = \frac{I}{R}$

Substitute first

$$240 \text{ V} = I(60.0\ \Omega)$$

$$240 \text{ V}\cdot\frac{1}{60.0\ \Omega} = (60.0 \text{ A})\frac{I}{12\ \Omega}$$

$$I = \frac{240 \text{ V}}{60.0\ \Omega}$$

$$I = 4.00 \text{ V}$$

Solve for I first

$$V = IR$$

$$V\cdot\frac{1}{R} = \cancel{R}\frac{I}{\cancel{R}}$$

$$I = \frac{240 \text{ V}}{60.0\ \Omega}$$

$$I = 4.00 \text{ A}$$

Use the expression for the electric current to obtain the time. $\quad I = \frac{Q}{\Delta t}$

Substitute first

$$(4.00 \text{ A})\Delta t = \frac{1800 \text{ C}}{\Delta t}\Delta t$$

$$\Delta t = \frac{1800 \text{ C}}{4.00 \text{ A}}$$

Solve for Δt first

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

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

$$\Delta t = \frac{1800 \text{ C}}{4.00 \text{ A}}$$

$1\ \frac{\text{C}}{\text{A}}$ is equivalent to 1 s. $\quad \Delta t = 450 \text{ s}$

It would take 450 s or 450 s $\frac{1 \text{ min}}{60 \text{ s}}$ = 7.50 min for the battery to do the amount of work.

Validate

The units combined to give seconds, which is correct.

Solutions for Practice Problems

Student Textbook pages 637 and 638

27. Frame the Problem

- Since all the resistors are in series, the formula for the equivalent resistance for a series circuit applies to the problem.
- Ohm's law applies to each individual circuit element.

Identify the Goal

The equivalent resistance, R_S

The potential differences V_1, V_2, and V_3 across the 15.0 Ω, 24.0 Ω, and 36.0 Ω resistances, respectively

The potential difference of the battery, V_S

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	V_1	$I_1 = 2.2$ A	V_1
R_2	V_2	$R_1 = 15.0\ \Omega$	V_2
R_S	V_3	$R_2 = 24.0\ \Omega$	V_3
R_S	V_S	$R_3 = 36.0\ \Omega$	V_S
I_1			I_2
I_2			I_3
I_3			I_S
I_S			R_S

Strategy
Since the circuit has only one closed loop the current is the same everywhere in the circuit.

Calculations
$I_1 = I_2 = I_3 = I_S = 2.2$ A

Use Ohm's law, the current, and the resistance of each resistor to find the potential drop across each resistor.

$V_1 = I_1R_1 = (2.2\text{ A})(15.0\ \Omega) = 33\text{ V}$
$V_2 = I_2R_2 = (2.2\text{ A})(24.0\ \Omega) = 53\text{ V}$
$V_3 = I_3R_3 = (2.2\text{ A})(36.0\ \Omega) = 79\text{ V}$

(a) The potential drops are 33 V, 53 V, and 79 V, respectively.

Strategy
Use the equation for resistance of a series circuit.

Calculations
$$R_S = R_1 + R_2 + R_3$$
$$= 15.0\ \Omega + 24.0\ \Omega + 36.0\ \Omega$$
$$= 75\ \Omega$$

(b) The equivalent resistance for the four resistors in series is 75 Ω.

Strategy
Use Ohm's law to find the potential difference of the battery.

Calculations
$$V_S = I_SR_S$$
$$= (2.2\text{ A})(75\ \Omega)$$
$$= 1.6 \leftrightarrow 10^2\text{ V}$$

(c) The potential difference of the battery is $1.6 \leftrightarrow 10^2$ V

Validate
If you combine the potential differences across the three loads found in part (a), the sum of the potential differences should equal $1.6 \leftrightarrow 10^2$ V.

$V_1 + V_2 + V_3 = 33\text{ V} + 53\text{ V} + 79\text{ V} = 1.6 \leftrightarrow 10^2\text{ V}$

28. Frame the Problem
- Since all the resistors are in series, the formula for the equivalent resistance of a series circuit applies to the problem.
- Ohm's law applies to each individual circuit element.

Identify the Goal
The potential difference V_2 across the 35.0 Ω resistance
The potential difference of the battery, V_S

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	V_1	$V_1 = 65.0$ V	V_2
R_2	V_2	$R_1 = 25.0\ \Omega$	I_1
R_S	V_S	$R_2 = 35.0\ \Omega$	I_2
I_1			V_S
I_2			I_S
I_S			R_S

Strategy	Calculations
Find the current through the first resistor using Ohm's law.	$V_1 = I_1 R_1$

Substitute first

$$65.0\text{ V} = I_1(25.0\ \Omega)$$
$$65.0\text{ V}\cdot\frac{1}{25.0\ \Omega} = (25.0\ \Omega)\frac{I_1}{25.0\ \Omega}$$
$$I_1 = \frac{65.0\text{ V}}{25.0\ \Omega}$$
$$I_1 = 2.60\text{ A}$$

Solve for I_1 first

$$V = I_1 R$$
$$V 3\frac{1}{R} = \not{R}\frac{I_1}{\not{R}}$$
$$I_1 = \frac{65.0\text{ V}}{25.0\ \Omega}$$
$$I_1 = 2.60\text{ A}$$

Since the circuit has only one closed loop the current is the same everywhere in the circuit.

$$I_1 = I_2 = I_3 = I_S = 2.60\text{ A}$$

Use Ohm's law, the current, and the resistance of 35.0 Ω resistor to find the potential drop across it.

$$V_2 = I_2 R_2 = (2.60\text{ A})(35.0\ \Omega) = 91.0\text{ V}$$

(a) The potential drop is 91.0 V.

Strategy	Calculations
Use the equation for resistance of a series circuit.	$R_S = R_1 + R_2$

$$= 25.0\ \Omega + 35.0\ \Omega$$
$$= 60.0\ \Omega$$

Use Ohm's law to find the potential difference of the battery.

$$V_s = IR_S$$
$$= (26.0\text{ A})(60.0\ \Omega)$$
$$= 1.56 \leftrightarrow 10^2\text{ V}$$

(b) The potential drop of the battery is $1.56 \leftrightarrow 10^2$ V.

Validate

If you combine the potential differences across the two loads, the sum of the potential differences should equal $1.56 \leftrightarrow 10^2$ V.

$$V_1 + V_2 = 1.56 \leftrightarrow 10^2\text{ V}$$

29. Frame the Problem

- Since all the resistors are in series, the formula for the equivalent resistance for a series circuit applies to the problem.
- Ohm's law applies to each individual circuit element.

Identify the Goal

The resistance R_2 of the second load

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	V_1	$V_1 = 40.0$ V	V_2
R_2	V_2	$R_1 = 48.0\ \Omega$	I_1
R_S	V_S	$V_S = 75.0$ V	I_2
I_1			R_2
I_2			I_S
I_S			R_S

Strategy

Find the current through the first resistor using Ohm's law.

Calculations

$V = I_1 R_1$

Substitute first

$$40.0\text{ V} = I_1(48.0\ \Omega)$$

$$40.0\text{ V}\cdot\frac{1}{48.0\ \Omega} = (48.0\ \Omega)\frac{I_1}{48.0\ \Omega}$$

$$I_1 = \frac{40.0\text{ V}}{48.0\ \Omega}$$

$$I_1 = 0.833\text{ A}$$

Solve for I first

$$V = I_1 R$$

$$V\cdot\frac{1}{R} = \cancel{R}\frac{I_1}{\cancel{R}}$$

$$I_1 = \frac{40.0\text{ V}}{48.0\ \Omega}$$

$$I_1 = 0.833\text{ A}$$

Since the circuit has only one closed loop the current is the same everywhere in the circuit.

$I_1 = I_2 = I_3 = 0.833$ A

Subtract the potential drop across the first load from the battery to obtain the potential drop across the second load.

$$V_2 = V_S - V_1$$
$$= 75.0\text{ V} - 40.0\text{ V}$$
$$= 35.0\text{ V}$$

Apply Ohm's law to find the resistance of the second load.

$V_2 = I_2 R_2$

Substitute first

$$35.0\text{ V} = (0.833\text{ A})R_2$$

$$35.0\text{ V}\cdot\frac{1}{0.833\text{ A}} = (0.833\text{ A})\frac{R_2}{0.833\text{ A}}$$

$$R_2 = \frac{35.0\text{ V}}{0.833\text{ A}}$$

$$R_2 = \frac{35.0\text{ V}}{0.833\text{ A}}$$

$$R_2 = 42.0\ \Omega$$

Solve for R_2 first

$$V_2 = I_2 R_2$$
$$V_2 \cdot \frac{1}{I_2} = \cancel{I_2}\frac{R_2}{\cancel{I_2}}$$
$$R_2 = \frac{35.0\ \text{V}}{0.833\ \text{A}}$$
$$R_2 = 42.0\ \Omega$$

The resistance is 42.0 Ω.

Validate

The units combined to give ohms, which is correct.

30. Frame the Problem

- Since all the resistors are in series, the formula for the equivalent resistance for a series circuit applies to the problem.
- Ohm's law applies to each individual circuit element.

Identify the Goal

The resistance R_1 of the first load
The potential difference of the battery, V_S
The equivalent resistance of the two loads, R_S

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	V_1	$I_1 = 7.00$ A	V_2
R_2	V_2	$R_2 = 24.0\ \Omega$	I_1
R_S	V_S	$V_1 = 56.0$ V	V_S
I_1			R_1
I_2			I_S
I_S			R_S

Strategy

Since the circuit has only one closed loop the current is the same everywhere in the circuit.

Calculations

$$I_1 = I_2 = I_S = 7.00\ \text{A}$$

Apply Ohm's law to find the resistance of the first load.

$$V_1 = I_1 R_1$$

Substitute first

$$56.0\ \text{V} = (7.00\ \text{A})R$$
$$56.0\ \text{V} \cdot \frac{1}{7.00\ \text{A}} = (7.00\ \text{A})\frac{R}{7.00\ \text{A}}$$
$$R_1 = \frac{56.0\ \text{V}}{7.00\ \text{A}}$$
$$R_1 = 8.00\ \Omega$$

Solve for R_1 first

$$V_1 = I_1 R_1$$
$$V_1 \cdot \frac{1}{I} = \cancel{I}\frac{R_1}{\cancel{I_1}}$$
$$R_1 = \frac{56.0\ \text{V}}{7.00\ \text{A}}$$
$$R_1 = 8.00\ \Omega$$

(a) The resistance is 8.00 Ω.

Strategy
Use Ohm's law, the current, and the resistance of the second load to obtain the potential drop across it.

Calculations
$V_2 = I_2R_2$
$= (7.00\ \text{A})(24.0\ \Omega)$
$= 168\ \text{V}$

Add the potential drops across each resistor to obtain the potential difference of the battery.

$V_s = V_2 + V_2$
$= 168\ \text{V} + 56\ \text{V}$
$= 2.24 \times 10^2\ \text{V}$

(b) The potential difference of the battery is 224 V.

Strategy
Use the equation for resistance of a series circuit.

Calculations
$R_s = R_1 + R_2$
$= 8.0\ \Omega + 24.0\ \Omega$
$= 32.0\ \Omega$

(c) The equivalent resistance is 32.0 Ω.

Validate
Using the equivalent resistance in part (c) and the current gives a check for the potential difference in part (b).

$V_s = I_s + R_s = (7.00\ \text{A}) + (32.0\ \Omega) = 224\ \text{V}$

Solutions for Practice Problems

Student Textbook page 638

31. Frame the Problem
- Since all the resistors are in series, the formula for the equivalent resistance for a series circuit applies to the problem.
- Ohm's law applies to each individual circuit element.

Identify the Goal
The resistance of the third load, R_3

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	V_1	$I_S = 1.50\ \text{A}$	V_1
R_2	V_2	$R_1 = 42.0\ \Omega$	V_3
R_3	V_3	$V_3 = 111\ \text{V}$	I_1
R_S	V_S	$V_S = 240\ \Omega$	I_2
I_1			I_3
I_2			R_2
I_3			R_3
I_S			R_S

Strategy
Since the circuit has only one closed loop the current is the same everywhere in the circuit.

Calculations
$I_1 = I_2 = I_3 = I_S = 1.50\ \text{A}$

Use Ohm's law, the current, and the resistance of the first resistor to find the potential drop across it.

$V_1 = I_1R_1 = (1.5\ \text{A})(42.0\ \Omega) = 63.0\ \text{V}$

Calculate the potential drop across the third resistor by subtracting the potential difference of the battery with the potential drop across the first two loads.

$$V_3 = V_S - V_1 - V_2$$
$$= 240\text{ V} - 111\text{ V} - 63.0\text{ V}$$
$$= 66.0\text{ V}$$

Apply Ohm's law to find the resistance of the third load.

$$V_3 = I_3R_3$$

Substitute first

$$66.0\text{ V} = (1.50\text{ A})R_3$$
$$66.0\text{ V}\cdot\frac{1}{1.50\text{ A}} = (1.50\text{ A})\frac{R_3}{1.50\text{ A}}$$
$$R_3 = \frac{66.0\text{ V}}{1.50\text{ A}}$$
$$R_3 = 44.0\ \Omega$$

Solve for R_3 first

$$V_3 = I_3R_3$$
$$V_3\cdot\frac{1}{I_3} = \cancel{I_3}\frac{R_3}{\cancel{I_3}}$$
$$R_3 = \frac{66.0\text{ V}}{1.50\text{ A}}$$
$$R_3 = 44.0\ \Omega$$

The resistance of the third load is 44.0 Ω.

Validate

The units combine to give ohms, which is the correct unit for resistance.

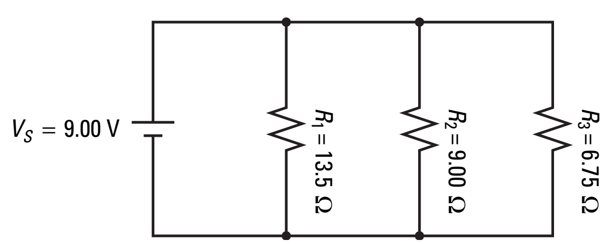
$\frac{1}{R_S} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{6220.8}{69\,984\ \Omega}$, and inverting, you get $R_S = 11.2\ \Omega$, as you should.

Solutions for Practice Problems

Student Textbook page 642

32. Frame the Problem

- Since all the resistors are in parallel, the potential difference across each load is the same as the potential difference provided by the battery.
- The potential difference across the battery and the current entering and leaving the battery would be unchanged if the three loads would be replaced with one load having the equivalent resistance.
- After the current leaves the battery, it reaches branch points where it separates, and part of the current runs through each load.
- Ohm's law applies to each individual load and to the combined load.



Identify the Goal

The current through each load

The equivalent resistance

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	V_1	$R_1 = 13.5\ \Omega$	V_1
R_2	V_2	$R_2 = 9.00\ \Omega$	V_2
R_3	V_3	$R_3 = 6.75\ \Omega$	V_3
R_S	V_S	$V_S = 9.00\text{ V}$	R_S
I_1			I_1
I_2			I_2
I_3			I_3
I_S			I_S

Strategy	Calculations
Use Ohm's law, in terms of the current to find the current through the three loads. Use the fact that $1\ \frac{\text{V}}{\Omega}$ is equivalent to 1 A.	$I_1 = \frac{9.00\text{ V}}{13.5\ \Omega} = 0.667\text{ A}$ $I_2 = \frac{9.00\text{ V}}{9.00\ \Omega} = 1.00\text{ A}$ $I_3 = \frac{9.00\text{ V}}{6.75\ \Omega} = 1.33\text{ A}$
Use the equation for resistors in parallel and apply it to the three loads.	$\frac{1}{R_S} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
Substitute the values and add.	$\frac{1}{R_S} = \frac{1}{13.5\ \Omega} + \frac{1}{9.00\ \Omega} + \frac{1}{6.75\ \Omega}$
Find a common denominator. Add.	$\frac{1}{R_S} = \frac{60.75}{820.125\ \Omega} + \frac{91.125}{820.125\ \Omega} + \frac{121.5}{820.125\ \Omega}$ $= \frac{273.375}{820.125\ \Omega}$
Invert both sides of the equation.	$R_S = \frac{820.375\ \Omega}{273.375}$
Divide	$R_S = 3.00\ \Omega$

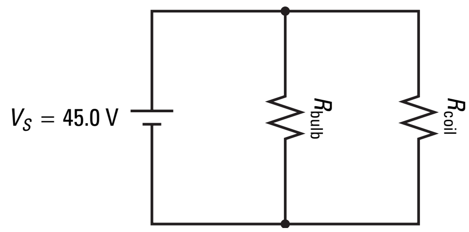
The currents are 0.667 A, 1.00 A and 1.33 A respectively. The equivalent resistance is 3.00 Ω.

Validate

If you add all the currents through each load ($I_1 + I_2 + I_3 = I_S = 3.0\text{ A}$) and multiply it by the equivalent resistance ($R_S I_S = (3.0\ \Omega)(3.00\text{ A}) = 9.00\text{ V}$) you get the applied voltage, as you should.

33. **Frame the Problem**

- Since all the resistors are in parallel, the potential difference across each load is the same as the potential difference provided by the battery.
- The potential difference across the battery and the current entering and leaving the battery would be unchanged if the two loads would be replaced with one load having the equivalent resistance.
- After the current leaves the battery, it reaches branch points where it separates, and part of the current runs through each load.
- Ohm's law applies to each individual load or to the combined load.



Identify the Goal
The resistance of the light bulb, R_{bulb}
The resistance of the coil, R_{coil}
The equivalent resistance of the circuit, R_S

Variables and Constants

Involved in the Problem		Known	Unknown
R_{coil}	R_{bulb}	$I_S = 9.75$ A	R_S
I_{bulb}	V_S	$I_{coil} = 7.50$ A	I_{bulb}
I_{coil}	I_S	$V_S = 45.0$ V	R_{bulb}
R_S			R_{coil}

Strategy	Calculations
Find the current through the bulb using the source current and the current through the coil.	$I_{bulb} = I_s - I_{coil} = 9.75\text{ A} - 7.50\text{ A} = 2.25\text{ A}$
Use Ohm's law, in term of the resistance, to solve resistance of the bulb and that of the coil.	$R_{bulb} = \frac{45.0\text{ V}}{2.25\text{ A}} = 20.0\ \Omega$ $R_{coil} = \frac{45.0\text{ V}}{7.50\text{ A}} = 6.00\ \Omega$
Use the equation for resistors in parallel and apply it to the two loads.	$\frac{1}{R_S} = \frac{1}{R_{bulb}} + \frac{1}{R_{coil}}$
Substitute the values and add.	$\frac{1}{R_S} = \frac{1}{20.0\ \Omega} + \frac{1}{6.00\ \Omega}$
Find a common denominator. Add.	$\frac{1}{R_S} = \frac{6.00}{120\ \Omega} + \frac{20.0}{120\ \Omega} = \frac{26.0}{120\ \Omega}$
Invert both sides of the equation.	$R_S = \frac{120\ \Omega}{26.0}$
Divide	$R_S = 4.62\ \Omega$

The resistance of the coil is 6.00 Ω and that of the bulb is 20.0 Ω. The equivalent resistance is 4.62 Ω.

Validate
If you multiply the source current by the equivalent resistance ($R_S I_S = (4.62\ \Omega)(9.75\text{ A}) = 45.0\text{ V}$), you get the applied voltage.

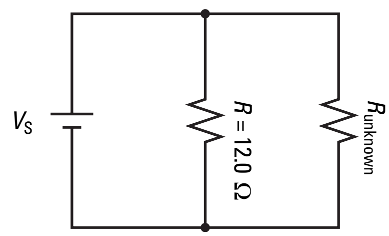
Solutions for Practice Problems

Student Textbook page 642

34. Frame the Problem

- Since all the resistors are in parallel, the potential difference across each load is the same as the potential difference provided by the battery.

- The potential difference across the battery and the current entering and leaving the battery would be unchanged if the two loads would be replaced with one load having the equivalent resistance.
- After the current leaves the battery, it reaches branch points where it separates, and part of the current runs through each load.
- Ohm's law applies to each individual load or to the combined load.



Identify the Goal
The unknown resistance, $R_{unknown}$
The equivalent resistance, R_S

Variables and Constants

Involved in the Problem		Known	Unknown
R_{known}	$R_{unknown}$	$I_{known} = 3.20$ A	R_S
$I_{unknown}$	V_S	$R_{known} = 12.0\ \Omega$	V_S
I_{known}	R_S	$I_{unknown} = 4.80$ A	$R_{unknown}$

Strategy	Calculations
Find the applied voltage using Ohm's law with the resistance and the current of the applied voltage.	$V_S = I_{known}R_{known} = (3.20\text{ A})(12.0\ \Omega)$ $V_S = 3.84\text{ V}$
Use Ohm's law, in term of the resistance, to solve resistance of the unknown load.	$R_{unknown} = \frac{38.4\text{ V}}{4.80\text{ A}} = 8.00\ \Omega$
Use the equation for resistors in parallel and apply it to the two loads.	$\frac{1}{R_S} = \frac{1}{R_{unknown}} + \frac{1}{R_{known}}$
Substitute the values and add.	$\frac{1}{R_S} = \frac{1}{8.00\ \Omega} + \frac{1}{12.0\ \Omega}$
Find a common denominator. Add.	$\frac{1}{R_S} = \frac{12.0}{96.0\ \Omega} + \frac{8.00}{96.0\ \Omega}$ $= \frac{20.0}{96.0\ \Omega}$
Invert both sides of the equation.	$R_S = \frac{96\ \Omega}{20.0}$
Divide	$R_S = 4.80\ \Omega$

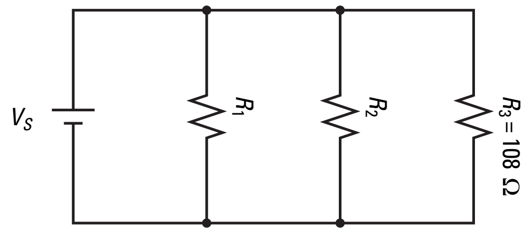
The resistance of the unknown load is 8.00 Ω. The equivalent resistance is 4.80 Ω.

Validate
If you add all the currents through each load ($I_S = I_{known} + I_{unknown} = 3.20\text{ A} + 4.80\text{ A} = 8.00\text{ A}$) and multiply it by the equivalent resistance ($R_S I_S = (4.80\ \Omega)(8.00\text{ A}) = 38.4\text{ V}$) you get the applied voltage, as it should be.

35. Frame the Problem

- Since all the resistors are in parallel, the potential difference across each load is the same as the potential difference provided by the battery.
- The potential difference across the battery and the current entering and leaving the battery would be unchanged if the three loads would be replaced with one load having the equivalent resistance.

- After the current leaves the battery, it reaches branch points where it separates, and part of the current runs through each load.
- Ohm's law applies to each individual load or to the combined load.



Identify the Goal
The currents through each load, I_1, I_2, and I_3
The equivalent resistance, R_S

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	I_1	$I_1 = 2.50$ A	R_1
R_2	I_2	$I_2 = 1.80$ A	R_2
R_3	I_3	$R_3 = 108\ \Omega$	R_S
R_S	I_S	$I_S = 4.80$ A	I_3
V_S			V_S

Strategy

Calculate the current through the third load.

Calculations

$$I_3 = I_S - I_1 - I_2$$
$$= 4.80\text{ A} - 2.50\text{ A} - 1.80\text{ A}$$
$$= 0.500\text{ A}$$

Use Ohm's law to find the voltage of the source using the resistance of the third load and the current through it.

$$V_S = I_3R_3$$
$$= (0.500\text{ A})(108\ \Omega)$$
$$= 54.0\text{ V}$$

Use Ohm's law, in term of the resistance, to solve resistance of the unknown load.

$$V_S = \frac{54.0\text{ V}}{4.80\text{ A}} = 11.2\ \Omega$$

(a) The equivalent resistance is 11.2 Ω.

Use Ohm's law, in term of the resistance, to solve resistance of the first and second load.

$$R_1 = \frac{54.0\text{ V}}{2.50\text{ A}} = 21.6\ \Omega$$
$$R_2 = \frac{54.0\text{ V}}{1.80\text{ A}} = 30.0\ \Omega$$

(b) The resistance of the first and second loads are 21.6 Ω and 30.0 Ω respectively.

Validate
If you use the three resistances to calculate the equivalent resistance, you get $\frac{1}{R_S} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{6220.8}{69\,984\ \Omega}$, and inverting, you get $R_S = 11.2\ \Omega$, as you should.

Solutions for Practice Problems

Student Textbook page 646

36. Frame the Problem

- The circuit consists of a battery and four loads. The battery generates a specific potential difference across the poles.

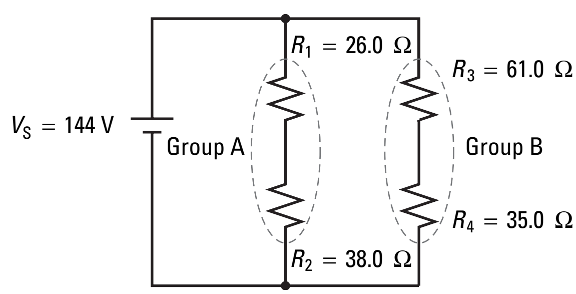
- The current driven by the potential difference of the battery depends on the effective resistance of the entire circuit.
- The circuit has three groups of resistors. Resistors R_1 and R_2 are in series with each other. Resistors R_3 and R_4 are in series with each other. Finally, the R_1–R_2 group is in parallel with the R_3–R_4 group.
- Define the R_1–R_2 group as Group A and the R_3–R_4 group as Group B. Sketch the circuit with equivalent loads, R_A and R_B.
- Now, define the parallel group consisting of R_A and R_B as Group C. Sketch the circuit with the equivalent load, R_C.
- Load R_C is the equivalent resistance of the entire circuit.
- The potentials across groups A and B are the same.
- The current through R_1 and R_2 is the same.

Identify the Goal

The equivalent resistance, R_C
The current through R_1
The potential difference across R_3

Variables and Constants

Involved in the Problem		Known	Unknown
R_1	I_1	$R_1 = 26.0\ \Omega$	R_A
R_2	I_2	$R_2 = 38.0\ \Omega$	R_B
R_3	I_3	$R_3 = 61.0\ \Omega$	R_C
R_4	I_4	$R_4 = 35.0\ \Omega$	V_3
R_A	I_S	$V_S = 144\ \text{V}$	I_1
R_B	I_A		I_2
R_C	I_B		I_3
V_3			I_4
V_S			I_A
			I_B



Strategy	Calculations
Find the equivalent resistance for the series Group A resistors.	$R_A = R_1 + R_2$ $= 26.0\ \Omega + 38.0\ \Omega$ $= 64.0\ \Omega$
Find the equivalent resistance for the series Group B resistors.	$R_B = R_3 + R_4$ $= 61.0\ \Omega + 35.0\ \Omega$ $= 96.0\ \Omega$
Use the equation for resistors in parallel and apply it to the two groups A and B.	$\frac{1}{R_C} = \frac{1}{R_A} + \frac{1}{R_B}$
Substitute the values and add.	$\frac{1}{R_C} = \frac{1}{64.0\ \Omega} + \frac{1}{96.0\ \Omega}$

Find a common denominator. Add. $\frac{1}{R_C} = \frac{96.0}{6144\ \Omega} + \frac{64.0}{6144\ \Omega}$

$= \frac{160}{6144\ \Omega}$

Invert both sides of the equation. $R_C = \frac{6144\ \Omega}{160}$

Divide. $R_C = 38.4\ \Omega$

(a) The equivalent resistance is 38.4 Ω.

Strategy
Use Ohm's law, in terms of current to find the current in group A and group B.

Calculations

$I_A = \frac{V_S}{R_A} = \frac{144\ \text{V}}{64.0\ \Omega} = 2.25\ \text{A} = I_1 = I_2$

$I_B = \frac{V_S}{R_B} = \frac{144\ \text{V}}{96.0\ \Omega} = 1.50\ \text{A} = I_3 = I_4$

(b) The current through resistance R_1 is 2.25 A.

Strategy
Use Ohm's law to find the voltage of R_3 using the resistance of the third load and the current through it.

Calculations

$V_3 = I_3R_3$

$= (1.50\ \text{A})(61.0\ \Omega)$

$= 91.5\ \text{V}$

(c) The potential difference across R_3 is 91.5 V.

Validate
If you add all the currents through each group ($I_S = I_B + I_A = 2.25$ A + 1.50 A = 3.75 A) and multiply it by the equivalent resistance ($R_C I_S = (38.4\ \Omega)(3.75\ \text{A}) = 144\ \text{V}$) you get the applied voltage.

Solutions for Practice Problems

Student Textbook page 646

37. Frame the Problem

- The circuit consists of a battery and three loads. The battery generates a specific potential difference across the poles.
- The current driven by the potential difference of the battery depends on the effective resistance of the entire circuit.
- The circuit has two groups of resistors. Resistors R_1 and R_2 are in parallel with each other. Load R_3 is in series with the R_1–R_2 group.
- Define the R_1–R_2 group as Group A and sketch the circuit with equivalent load, R_A.
- Now, define the parallel group consisting of R_A and R_1 as Group B. Sketch the circuit with the equivalent load, R_B.
- Load R_B is the equivalent resistance of the entire circuit.
- The potential across R_1 and R_2 are the same.

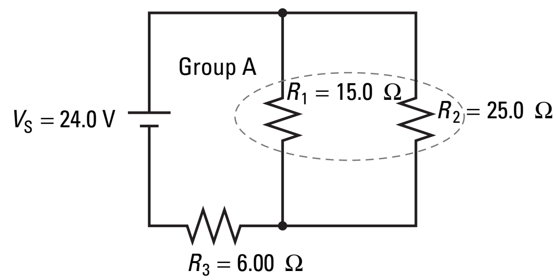
Identify the Goal
The equivalent resistance, R_B
The potential difference across R_3
The current through R_1

Variables and Constants

Involved in the Problem		Known	Unknown
V_1	I_1	$R_1 = 15.0\ \Omega$	I_1
V_2	I_2	$R_2 = 25.0\ \Omega$	I_2
V_3	I_3	$R_3 = 6.00\ \Omega$	I_3
V_S	I_S	$V_S = 25.0\ \text{V}$	I_S

R_1
R_2
R_3
R_A
R_B

R_A
R_B
V_1
V_2
V_3



Strategy | **Calculations**

Find the equivalent resistance for the series Group A resistors.

$$R_A = R_1 + R_2 = 26.0\ \Omega + 38.0\ \Omega = 64.0\ \Omega$$

Find the equivalent resistance for the series Group B resistors.

$$R_B = R_3 + R_4 = 61.0\ \Omega + 35.0\ \Omega = 96.0\ \Omega$$

Use the equation for resistors in parallel and apply it to find the equivalent resistance of the group A of resistors.

$$\frac{1}{R_A} = \frac{1}{R_1} + \frac{1}{R_2}$$

Substitute the values and add.

$$\frac{1}{R_A} = \frac{1}{15.0\ \Omega} + \frac{1}{25.0\ \Omega}$$

Find a common denominator. Add.

$$\frac{1}{R_A} = \frac{25.0}{375\ \Omega} + \frac{15.0}{375\ \Omega} = \frac{40}{375\ \Omega}$$

Invert both sides of the equation.

$$R_A = \frac{375\ \Omega}{40}$$

Divide

$$R_A = 9.37\ \Omega$$

Add the resistance of group A with the third load, which are in series.

$$R_B = 9.37\ \Omega + 6.00\ \Omega = 15.4\ \Omega$$

(a) The equivalent resistance is 15.4 Ω .

Strategy | **Calculations**

Use Ohm's law, in terms of current to find the source current.

$$I_S = \frac{V_S}{R_B} = \frac{25.0\ \text{V}}{15.4\ \Omega} = 1.63\ \text{A}$$

Use Ohm's law to find the voltage of R_3 using the resistance of the third load and the current through it.

$$V_3 = I_S R_3 = (1.63\ \text{A})(6.00\ \Omega) = 9.76\ \text{V}$$

(b) The potential difference across R_3 is 9.76 V.

Strategy | **Calculations**

Subtract the potential drop due to R_3 from the source voltage to obtain the potential drop across the parallel resistors.

$$V_1 = V_2 = V_S - V_3 = 25.0\ \text{V} - 9.76\ \text{V} = 15.2\ \text{V}$$

Use Ohm's law, in terms of current to find the current through R1.

$$I_S = \frac{V_S}{R_B} = \frac{25.0\ \text{V}}{15.4\ \Omega} = 1.63\ \text{A}$$

(c) The current through resistance R_1 is 1.02 A.

Validate
The equivalent resistance came out in amperes, the potential difference in volts and the equivalent resistance in ohms, which are all the correct units.

Solutions for Practice Problems

Student Textbook page 649

38. (a) Frame the Problem
- The battery has an internal resistance with an *emf* in a closed circuit.
- There is a current through the circuit so the terminal voltage will not be the *emf*.
- Therefore terminal voltage will be less than that of the *emf*.

Identify the Goal
The terminal voltage (V_S) of the battery

Variables and Constants

Involved in the Problem	Known	Unknown
E	$E = 15.0$ V	V_{int}
V_{int}	$r = 0.0800\ \Omega$	V_S
V_S	$I_S = 2.50$ A	
I_S		
r		

Strategy	Calculations
Use Ohm's law to find the internal potential drop across the battery using the internal resistance of the battery and the current through it.	$V_{int} = I_S r$
Multiply.	$V_{int} = (2.50\text{ A})(0.0800\ \Omega)$
1 A·Ω is equivalent to 1 V, thus	$V_{int} = 0.20$ V
Use this potential difference to find the Terminal voltage.	$V_S = E - V_{int}$
Subtract.	$V_S = 15.0\text{ V} - 0.20\text{ V}$

The terminal voltage is 14.8 V when the current is 2.50 A.

Validate
Since the potential difference loss due to the battery is small compared to the terminal voltage, the result is reasonable (just over 1% of terminal voltage).

(b) Frame the Problem
- The battery has an internal resistance with an *emf* in a closed circuit.
- There is a bigger current through the circuit than in part (a) so the terminal voltage will be smaller than in part (a).

Identify the Goal
The terminal voltage (V_S) of the battery

Variables and Constants

Involved in the Problem	Known	Unknown
E	$E = 15.0$ V	V_{int}
V_{int}	$r = 0.0800\ \Omega$	V_S

V_S	$I_S = 2.50$ A
I_S	
r	

Strategy	Calculations
Use Ohm's law to find the internal potential drop across the battery using the internal resistance of the battery and the current through it.	$V_{int} = I_S r$
Multiply.	$V_{int} = (5.00\text{ A})(0.0800\ \Omega)$
1 A·Ω is equivalent to 1 V, thus	$V_{int} = 0.40$ V
Use this potential difference to find the Terminal voltage.	$V_S = E - V_{int}$
Subtract.	$V_S = 15.0\text{ V} - 0.40\text{ V}$ $V_S = 14.6$ V

The terminal voltage is 14.6 V when the current is 5.00 A.

Validate

As expected, the potential difference loss due to the battery is larger than in part (a). However, it is still much smaller than the terminal voltage, just less than 3% of it.

39. (a) Frame the Problem

- The battery has an internal resistance with an *emf* in a closed circuit.
- There is a current through the circuit so the *emf* will be greater than the terminal voltage.
- The *emf* will depend directly on the current flowing through the circuit.

Identify the Goal

The *emf* of the battery, E

Variables and Constants

Involved in the Problem	Known	Unknown
E	$V_S = 10.6$ V	V_{int}
V_{int}	$r = 0.120\ \Omega$	E
V_S	$I_S = 7.00$ A	
I_S		
r		

Strategy	Calculations
Use Ohm's law to find the internal potential drop across the battery using the internal resistance of the battery and the current through it.	$V_{int} = I_S r$
Multiply.	$V_{int} = (7.00\text{ A})(0.120\ \Omega)$
1 A·Ω is equivalent to 1 V, thus	$V_{int} = 0.84$ V
Use this potential difference to find the terminal voltage.	$E = V_{int} + V_S$
Add.	$E = 10.6\text{ V} + 0.84\text{ V}$
Round up.	$E = 11.4$ V

The *emf* is 11.4 V when the potential drop across the battery is 0.84 V.

Validate

The *emf* of the battery is larger than the terminal voltage as it should be. Also, the potential difference loss due to the battery's internal resistance is small just over 7 percent of the *emf.*

(b) Frame the Problem

- The battery has an internal resistance with an *emf* in a closed circuit.
- There is a current through the circuit so the terminal voltage will be smaller than the *emf.*
- The terminal voltage will depend directly on the current flowing through the circuit.

Identify the Goal

The terminal voltage (V_S) of the battery from the *emf* solved for in part (a).

Variables and Constants

Involved in the Problem	Known	Unknown
E	$V_S = 11.4$ V	V_{int}
V_{int}	$r = 0.120\ \Omega$	E
V_S	$I_S = 2.20$ A	
I_S		
r		

Strategy	Calculations
Use Ohm's law to find the internal potential drop across the battery using the internal resistance of the battery and the current through it.	$V_{int} = I_S r$
Multiply.	$V_{int} = (2.20\text{ A})(0.120\ \Omega)$
1 A·Ω is equivalent to 1 V, thus	$V_{int} = 0.26$ V
Use this potential difference to find the terminal voltage.	$V_S = E - V_{int}$
Subtract.	$V_S = 11.44\text{ V} - 0.26\text{ V}$
Round up.	$V_S = 11.2\ V$

The terminal voltage is 11.2 V when the potential drop across the battery is 0.26 V.

Validate

The terminal voltage is smaller than the *emf* as it should be. Also, the potential difference loss due to the battery's internal resistance is small just over 2 % of the *emf.*

Solutions for Practice Problems

Student Textbook page 655

40. Frame the Problem

- The power in this case is the rate at which the electric energy is converted to heat when using the toaster.
- You can calculate the current from the power rating of the toaster and from its potential difference.
- The resistance of the toaster will be related to the potential difference and to the current drawn by the toaster.

Identify the Goal

(a) The current drawn from the toaster

(b) The resistance of the toaster

Variables and Constants

Involved in the Problem	Known	Unknown
P	$P = 875$ W	I
I	$V = 120$ V	R
V		
R		

Strategy	Calculations
Use the relation between the power, current and potential energy.	$P = IV$
Solve for the current.	$\frac{P}{V} = \cancel{V}\frac{I}{\cancel{V}}$
Divide.	$I = \frac{875\ \text{W}}{120\ \text{V}}$
$1\ \frac{\text{W}}{\text{V}}$ is equivalent to 1 A.	$I = 7.29$ A
Round up.	$I = 7.3$ A

(a) The current that the toaster draws is 7.3 A.

Strategy	Calculations
Use Ohm's law, which relates the potential difference to the current and the resistance.	$V = IR$
Solve for the resistance.	$\frac{V}{I} = \cancel{I}\frac{R}{\cancel{I}}$
Divide.	$R = \frac{120\ \text{V}}{7.3\ \text{A}}$
$1\ \frac{\text{V}}{\text{A}}$ is equivalent to Ω.	$R = 16.4\ \Omega$
Round down.	$R = 16\ \Omega$

The resistance of the toaster is 16 Ω.

Validate

The units give amperes, which is the correct unit of current.

Power over potential difference is current since $\frac{P}{V} = \frac{\cancel{\Delta E_Q}Q}{\cancel{\Delta E_Q}t}$ and this is the definition of current. For part (b), the units give ohms, which is the correct unit of resistance.

41. (a) Frame the Problem

- The light bulb has a resistance so when there is a potential difference there is a current.
- The power output of the light bulb will be related to the current and the voltage applied.

Identify the Goal

The power output of the light bulb

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 240\ \Omega$	P
I	$V = 120$ V	I
P		V
V		

Strategy	Calculations
Use Ohm's law that relates the potential difference to the current and the resistance.	$V = IR$
Solve for the current.	$\frac{V}{R} = \frac{\cancel{R}I}{\cancel{R}}$
Use the relation between the power, current and potential energy.	$P = IV$
Substitute I with its expression in terms of V and R into the equation of the power.	$P = \frac{V}{R}V$
Simplify.	$P = \frac{V^2}{R}$
Divide.	$P = \frac{(120\ \text{V})^2}{240\ \Omega}$
$1\ \frac{V^2}{\Omega}$ is equivalent to 1 W.	$P = 60\ \text{W}$
The power output of the bulb is 60 W.	

Validate

The units give watts, which is the correct unit of power.

(b) Frame the Problem

- The light bulb has a resistance so when there is a potential difference there is a current.
- The power output of the light bulb will be related to the current and the voltage applied but it will less than part (a) since there is less voltage applied to the bulb.

Identify the Goal

The power output of the light bulb

Variables and Constants

Involved in the Problem	Known	Unknown
R	$P = 7.3$ A	I
I	$V = 80.0$ V	P
P		
V		

Strategy	Calculations
Use Ohm's law, which relates the potential difference to the current and the resistance.	$V = IR$
Solve for the current.	$\frac{V}{R} = \frac{\cancel{R}I}{\cancel{R}}$
Use the relation between the power, current and potential energy.	$P = IV$
Substitute I with its expression in terms of V and R into the equation of the power.	$P = \frac{V}{R}V$
Simplify.	$P = \frac{V^2}{R}$
Divide.	$P = \frac{80.0\ \text{V}^2}{240\ \Omega}$
$1\ \frac{V^2}{\Omega}$ is equivalent to 1 W.	$P = 27\ \text{W}$
The power output of the bulb is 27 W.	

Validate

The units give watts, which is the correct unit of power.

(c) Frame the Problem

- The light bulb has a resistance so when there is a potential difference there is a current.
- The resistance of the bulb should be decreased to get the same power output as in part (a) (power is proportional to the inverse of resistance).

Identify the Goal

The resistance needed to get the same power output as in part (a) with the voltage in part (b)

Variables and Constants

Involved in the Problem	Known	Unknown
R	$P = 60\ \text{W}$	I
I	$V = 80.0\ \text{V}$	R
P		
V		

Strategy	Calculations
Use Ohm's law, which relates the potential difference to the current and the resistance.	$V = IR$
Solve for the current.	$\frac{V}{R} = \cancel{R}\frac{I}{\cancel{R}}$
Use the relation between the power, current and potential energy.	$P = IV$
Substitute I with its expression in terms of V and R into the equation of the power.	$P = \frac{V}{R}V$
Simplify.	$P = \frac{V^2}{R}$
Solve for R.	$\cancel{P}\frac{R}{\cancel{P}} = \frac{\cancel{R}}{P}\frac{V^2}{\cancel{R}}$
Divide.	$R = \frac{(80.0\ \text{V})^2}{60\ \text{W}}$
$1\frac{\text{V}^2}{\text{W}}$ is equivalent to 1 Ω.	$R = 1.1 \times 10^2\ \Omega$

The required resistance of the bulb is $1.1 \times 10^2\ \Omega$.

Validate

The units give ohms, which is the correct unit of resistance.

42. (a) Frame the Problem

- The power in this case is the rate at which the electric energy is converted to heat when using the heater.
- You can calculate the power from the resistance and the current of the heater.

Identify the Goal

The power output of the heater

Variables and Constants

Involved in the Problem	Known	Unknown
P	$R = 15\ \Omega$	V
I	$I = 7.5\ \text{A}$	P
R		
V		

Strategy	**Calculations**
Use the relation between the power, current and potential energy.	$P = IV$
Use Ohm's law.	$V = IR$
Substitute V from Ohm's law in the expression for the power.	$P = I(IR)$ $P = RI^2$
Multiply.	$P = (15\ \Omega)((7.5\ \text{A})^2)$
$1\ \Omega{\cdot}\text{A}^2$ is equivalent to 1 W.	$P = 844\ \text{W}$
Round down.	$P = 840\ \text{W}$

The power output of the heater is 840 W.

Validate

The units give watts, which is the correct unit of power.

(b) Frame the Problem

- The power in this case is the rate at which the electric energy is converted to heat when using the heater.
- You can calculate the new current from part (a) and thus power from the resistance and the new current of the heater.

Identify the Goal

The power output of the heater

Variables and Constants

Involved in the Problem	Known	Unknown
P	$R = 15\ \Omega$	V
I		P
R		I
V		

Strategy	**Calculations**
Use the value of the current in part (a) and divide it by two to get the new current.	$I = \frac{7.5\ \text{A}}{2}$
Divide.	$I = 3.75\ \text{A}$
Use the relation between the power, current and potential energy.	$P = IV$
Use Ohm's law.	$V = IR$
Substitute V from Ohm's law in the expression for the power.	$P = I(IR)$ $P = RI^2$
Multiply.	$P = (15\ \Omega)((3.25\ \text{A})^2)$
$1\ \Omega{\cdot}\text{A}^2$ is equivalent to 1 W.	$P = 211\ \text{W}$

The power output of the heater is one quarter of its original value in part (a), or 211 W.

Validate

The units give watts, which is the correct unit of power.

Solutions for Practice Problems

Student Textbook page 658

43. Frame the Problem

- The power is the rate at which the electric energy is converted to another form of energy.
- You can calculate the power from the resistance and from the setting of the power supply.
- You can calculate the power outputs ratio and the potential differences ratio from the values found or given in part (a).

Identify the Goal

(a) The power output for two different power supplies

(b) The power outputs ratio, the potential differences ratio, and the relationship between the two ratios

Variables and Constants

Involved in the Problem	Known	Unknown
P_a	$R = 45\ \Omega$	P_a
P_b	$V_a = 180\ V$	P_b
V_a	$V_b = 270\ V$	I_a
V_b		I_b
R		P_a/P_b
I_a		V_a/V_b
I_b		
P_a/P_b		
V_a/V_b		

Strategy	Calculations
Use Ohm's law that relates the potential difference to the current and the resistance for the supply.	$V_a = I_a R$
Solve for the current.	$\frac{V_a}{R} = \frac{\cancel{R} I_a}{\cancel{R}}$
Use the relation between the power, current and potential energy.	$P_a = I_a V$
Substitute I_a with its expression in terms of V_a and R into the equation of the power.	$P_a = \frac{V_a}{R} V_a$
Simplify.	$P_a = \frac{V_a^2}{R}$
Divide.	$P_a = \frac{(180\ V)^2}{45\ \Omega}$
$1\frac{V^2}{\Omega}$ is equivalent to 1 W.	$P_a = 720\ W$
Use the corresponding expression for power source b in terms of the potential difference and the resistance.	$P_b = \frac{V_b^2}{R}$
Divide.	$P_b = \frac{(270\ V)^2}{45\ \Omega}$
$1\ \frac{V^2}{\Omega}$ is equivalent to 1 W.	$P_b = 1.62 \times 10^3\ W$
Round down.	$P_b = 1.6 \times 10^3\ W$

(a) Power source a outputs 720 W and power source b outputs 1.6×10^3 W.

Strategy	Calculations
Use the values for the power output calculated in part (a) for both power supplies and find their ratios.	$\frac{P_a}{P_b} = \frac{720\ \text{W}}{1.62 \times 10^3\ \text{W}}$
Factorize the numerator and the denominator.	$\frac{P_a}{P_b} = \frac{(180)(4\ \text{W})}{(180)(9\ \text{W})}$
Simplify.	$\frac{P_a}{P_b} = \frac{4}{9}$
Use the values for the potential difference given in part (a) for both power supplies and find their ratios.	$\frac{V_a}{V_b} = \frac{180\ \text{V}}{270\ \text{V}}$
Factorize the numerator and the denominator.	$\frac{V_a}{V_b} = \frac{(90)(2\ \text{V})}{(90)(3\ \text{V})}$
Simplify.	$\frac{V_a}{V_b} = \frac{2}{3}$
Use the relation relating power, voltage and resistance for power supply a derived in (a).	$P_a = \frac{V_a^2}{R}$
Use the corresponding expression for power source b.	$P_b = \frac{V_b^2}{R}$
Take the ratio of these last two expressions.	$\frac{P_a}{P_b} = \frac{\frac{V_a^2}{\cancel{R}}}{\frac{V_b^2}{\cancel{R}}}$
Simplify.	$\frac{P_a}{P_b} = \left(\frac{V_a}{V_b}\right)^2$

(b) The ratio of the powers output is 4/9 and the ratio of the potential differences is 2/3. The relationship relating the two ratios is $\frac{P_a}{P_b} = \left(\frac{V_a}{V_b}\right)^2$.

Validate

The power outputs are in watts, which is correct. The ratios are dimensionless which is correct.

Using the fact that $\frac{V_a}{V_b} = \frac{2}{3}$, and using the relationship between the ratios, we find that $\frac{P_a}{P_b} = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$, which confirms the formula relating the two ratios.

44. Frame the Problem

- The load has a resistance.
- The resistance will remain approximately the same even when a different current passes through it. Therefore, according to Ohm's law, the potential difference will be different.
- If both the current and the potential difference have changed, the power will probably be different.

Identify the Goal

The new power output

Variables and Constants

Involved in the Problem	Known	Unknown
P_6	$P_6 = 160$ W	P_{15}
P_{15}	$I_6 = 6$ A	R
V_6	$I_{15} = 15$ A	V_6
V_{15}		V_{15}
R		

I_6

I_{15}

Strategy	**Calculations**
Find the voltage at 6 A.	$P_6 = I_6 V_6$
	$V_6 = \frac{P_6}{I_6}$
	$V_6 = \frac{160\ \text{W}}{6.0\ \text{A}}$
	$V_6 = 26.7\ \text{V}$
Find the resistance.	$R = \frac{V_6}{I_6}$
	$R = \frac{26.7\ \text{V}}{6.0\ \text{A}}$
	$R = 4.44\ \Omega$
Find the voltage at 15 A.	$V_{15} = I_{15}R$
	$V_{15} = (15\ \text{A})(4.44\ \Omega)$
	$V_{15} = 66.7\ \text{V}$
Find the power output at 15 A.	$P_{15} = I_{15}V_{15}$
	$P_{15} = (15\ \text{A})(66.7\ \text{V})$
	$P_{15} = 1.0 \times 10^3\ \text{W}$

The power output is 1.0×10^3 W.

Validate

The power is in a watt, which is correct, and it increases which is to be expected. In fact, the ratio of the power outputs is equal to the square of the ratio of the currents, as in problem 43.

45. (a) Frame the Problem

- The power is the rate at which the electric energy is converted to another form of energy from the circuit.
- You can calculate the power from the resistance and from the setting of the power supply by using Ohm's law as an intermediate step.

Identify the Goal

The power output

Variables and Constants

Involved in the Problem	Known	Unknown
P	$R = 25\ \Omega$	I
V	$V = 100\ \text{V}$	P
I		
R		

Strategy	**Calculations**
Find the current using Ohm's law.	$V = RI$
	$I = \frac{V}{R}$
	$I = \frac{100\ \text{V}}{25\ \Omega}$
	$I = 4\ \text{A}$
Find the Power.	$P = VI$
	$P = (100\ \text{V})(4\ \text{A})$
	$P = 400\ \text{W}$

The power output of the circuit is 400 W.

Validate
The power has units of watts, which is correct.

(b) Frame the Problem

- The power is the rate at which the electric energy is converted to another form of energy from the circuit.
- You can calculate the power from the equivalent resistance and from the setting of the power supply by using Ohm's law as an intermediate step.

Identify the Goal
The power output

Variables and Constants

Involved in the Problem	Known	Unknown
P	$R_1 = 25\ \Omega$	I
V	$R_2 = 25\ \Omega$	P
I	$V = 100\ \text{V}$	R_{eq}
R_2		
R_1		
R_{eq}		

Strategy	Calculations
Find the equivalent resistance when R_1 and R_2 are connected in series.	$R_{eq} = R_1 + R_2$ $R_{eq} = 25\ \Omega + 25\ \Omega$ $R_{eq} = 50\ \Omega$
Find the current using Ohm's law and the equivalent resistance.	$V = R_{eq}I$ $I = \frac{V}{R_{eq}}$ $I = \frac{100\ \text{V}}{50\ \Omega}$ $I = 2\ \text{A}$
Find the Power.	$P = VI$ $P = (100\ \text{V})(2\ \text{A})$ $P = 200\ \text{W}$

The power is 200 W. Since the voltage is fixed and the resistance is increased, then (by Ohm's law) the current must decrease. Thus, the power must decrease.

Validate
The power comes out in watts, which is the correct unit.

Solutions for Practice Problems

Student Textbook page 662

46. Frame the Problem

- A light bulb will use energy at a rate of 192 W if it has a resistance of 12.0 Ω.
- Power, potential difference, and resistance are all related.

Identify the Goal
The potential difference at which the light bulb is designed to operate

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 12.0\ \Omega$	V
P	$P = 192\ \text{W}$	
V		

Strategy
Use the relationship between power, potential difference and resistance.

Calculations

$$P = \frac{V^2}{R}$$

Solve for V first

$$PR = \frac{(V)^2}{\cancel{R}}\cancel{R}$$
$$PR = V^2$$
$$\sqrt{PR} = \sqrt{V^2}$$
$$V = \sqrt{(192\ \text{W})(12.0\ \Omega)}$$
$$V = 48.0\sqrt{\text{W}\ \Omega}$$
$$V = 48.0\ \text{V}$$

Substitute first

$$192\ \text{W} = \frac{V^2}{12.0\ \Omega}$$
$$(192\ \text{W})(12.0\ \Omega) = \frac{V^2}{12.0\ \Omega}(12.0\ \Omega)$$
$$V^2 = (192\ \text{W})(12.0\ \Omega)$$
$$\sqrt{V^2} = \sqrt{(192\ \text{W})(12.0\ \Omega)}$$
$$V = \sqrt{(192\ \text{W})(12.0\ \Omega)}$$
$$V = 48.0\sqrt{\text{W}\ \Omega}$$
$$V = 48.0\ \text{V}$$

The potential difference is 48.0 V.

Validate
Unit Check: $\sqrt{\text{W}\Omega} = \sqrt{\frac{\text{VC}}{\text{s}}\frac{\text{V}}{\text{A}}} = \sqrt{\frac{\text{V}\cancel{\text{C}}}{\cancel{\text{s}}}\frac{\text{V}\cancel{\text{s}}}{\cancel{\text{C}}}} = \sqrt{\text{V}^2} = \text{V}$
The units give volts, which is the correct unit of potential difference.

47. Frame the Problem
- The electric kettle will use energy at a rate of 960 W if connected to a 120 V line.
- Power, potential difference, and resistance are all related.

Identify the Goal
The resistance of the kettle

Variables and Constants

Involved in the Problem	Known	Unknown
R	$V = 120\ \text{V}$	R
P	$P = 160\ \text{W}$	
V		

Strategy
Use the relationship between power, potential difference and resistance.

Calculations

$$P = \frac{V^2}{R}$$

Solve for R first

$$PR = \frac{(V)^2}{\cancel{R}}\cancel{R}$$
$$PR = V^2$$
$$\frac{\cancel{P}R}{\cancel{P}} = \frac{V^2}{P}$$
$$R = \frac{V^2}{P}$$

Substitute first

$$960\ \text{W} = \frac{(120\ \text{V})^2}{R}$$
$$(960\ \text{W})R = \frac{(120\ \text{V})^2}{\cancel{R}}\cancel{R}$$
$$\frac{(960\ \text{W})R}{960\ \text{W}} = \frac{(120\ \text{V})^2}{960\ \text{W}}$$

$$R = \frac{(120\ \text{V})^2}{960\ \text{W}} \qquad R = \frac{(120\ \text{V})^2}{960\ \text{W}}$$

$$R = 15\frac{\text{V}^2}{\text{W}} \qquad R = 15\frac{\text{V}^2}{\text{W}}$$

$$R = 15\ \Omega \qquad R = 15\ \Omega$$

The resistance is 15 Ω.

Validate

Unit Check: $\frac{\text{V}^2}{\text{W}} = \frac{\text{J}^2/\text{C}^2}{\text{J/s}} = \left(\frac{\text{J}\cdot\cancel{\text{J}}}{\text{C}^2}\right)\left(\frac{\text{s}}{\cancel{\text{J}}}\right) = \left(\frac{\text{J}}{\text{C}}\right)\left(\frac{\text{s}}{\text{C}}\right) = \text{V}\frac{1}{\text{A}} = \Omega$

The units give ohms, which is the correct unit for resistance.

48. Frame the Problem

- The current flowing through the resistor will cause a power output.
- Power, potential difference, current, and resistance are all related.

Identify the Goal

The power output

Variables and Constants

Involved in the Problem	Known	Unknown
R	$I = 3.50$ A	P
P	$R = 24.0\ \Omega$	
I		

Strategy	Calculations
Use the relation between the power output, the resistance and the current flowing through the resistor.	$P = I^2R$
Multiply.	$P = (3.50\ \text{A})^2(24.0\ \Omega)$
An A·Ω is equivalent to a W, thus	$P = 294$ W
The power output is 294 W.	

Validate

Unit Check: $\text{A}^2\Omega = \text{A}(\text{A}\Omega) = \text{AV} = \text{W}$

The units give watts, which is the correct unit for power.

49. Frame the Problem

- The toaster will have a charge due to the potential difference applied.
- Electric Energy, potential difference, and charge are all related.
- Power, potential difference, and current are all related.

Identify the Goal

The charge that passes through the toaster.

Variables and Constants

Involved in the Problem	Known	Unknown
V	$P = 900$ W	V
P	$I = 7.50$ A	Q
Q	$\Delta E_Q = 2.40 \times 10^5$ J	
ΔE_Q		
I		

Strategy	**Calculations**
Use the relation between the power output, the potential difference and the current to solve for the potential difference.	$P = VI$ $\frac{P}{I} = \frac{V\cancel{I}}{\cancel{I}}$ $V = \frac{P}{I}$
Divide.	$V = \frac{900\ \text{W}}{7.50\ \text{A}}$
$1\ \frac{\text{W}}{\text{A}}$ is equivalent to 1 V, thus	$V = 120\ \text{V}$
Use the relation between the potential difference, the electric energy and the charge.	$V = \frac{\Delta E_{\text{Q}}}{Q}$
Solve for the charge.	$VQ = \frac{\Delta E_{\text{Q}}}{\cancel{Q}}\cancel{Q}$ $VQ = \Delta E_{\text{Q}}$ $\frac{\cancel{V}Q}{\cancel{V}} = \frac{\Delta E_{\text{Q}}}{V}$ $Q = \frac{\Delta E_{\text{Q}}}{V}$
Divide.	$Q = \frac{2.40 \times 10^5\ \text{J}}{120\ \text{V}}$
$1\ \frac{\text{J}}{\text{V}}$ is equivalent to 1 C, thus	$Q = 2000\ \text{C}$

The charge that passed through the toaster is 2.00×10^3 C.

Validate

The units give coulombs, which is the correct unit for charge.

50. Frame the Problem

- The floodlight filament will have a power rating.
- Power, potential difference, and resistance are all related.
- There will be energy consumed by the floodlight filament.
- Electric energy, power, and time are all related.

Identify the Goal

(a) The power rating of the floodlight filament

(b) The energy consumed by the floodlight filament

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 22.0\ \Omega$	P
P	$V = 110\ \text{V}$	ΔE_Q
V	$\Delta t = 2.5\ \text{h}$	
Δt		
ΔE_Q		

Strategy	**Calculations**
Use the relation between the power output, the resistance and the potential difference.	$P = \frac{V^2}{R}$
Divide.	$P = \frac{(110\ \text{V})^2}{22.0\ \Omega}$
$1\ \frac{V^2}{\Omega}$ is equivalent to 1 W, thus	$P = 550\ \text{W}$

(a) The power rating is 550 W.

Strategy	Calculations
Convert the time into seconds.	$\Delta t = (60\frac{\text{s}}{\text{min}})\cdot(60\frac{\text{min}}{\text{h}})\cdot 2.5\ \text{h}$
	$\Delta t = 9000\ \text{s}$
Use the definition of power.	$P = \frac{\Delta E_Q}{\Delta t}$
Solve for ΔE_Q.	$\Delta E_Q = P\Delta t$
Multiply.	$\Delta E_Q = (9000\ \text{s})(550\ \text{W})$
1 W·s is equivalent to 1 J, thus	$\Delta E_Q = 4.95 \times 10^6\ \text{J}$
Round up.	$\Delta E_Q = 5.0 \times 10^6\ \text{J}$

(b) The energy consumed is $\Delta E_Q = 5.0 \times 10^6\ \text{J}$.

Validate
The units give joules, which is the correct unit for energy.

Solutions for Practice Problems

Student Textbook page 664

51. Frame the Problem

- The total amount of electric energy the dryer uses in a specific amount of time depends on the power output.
- Power companies charge a specific amount of dollars per unit of energy used.

Identify the Goal
The cost, in cents, to dry a load of clothes

Variables and Constants

Involved in the Problem		Known	Unknown
Δt	Cost	$\Delta t = 25\ \text{min}$	Cost
P	ΔE_e	Rate = 7.20 cents/kW·h	ΔE_e
Rate		$P = 1280\ \text{W}$	

Strategy	Calculations
Find the total time, in hours, that the dryer is on to dry a load of clothes.	$t = (\frac{1}{60}\frac{\text{h}}{\text{min}})\cdot 25.0\text{min}$
	$t = 0.417\ \text{h}$
Find the total amount of energy consumed by using the definition of power.	$P = \frac{\Delta E_e}{\Delta t}$
	Solve for ΔE_e first
	$P\Delta t = \frac{\Delta E_e}{\Delta t}\Delta t$
	$P\Delta t = \Delta E_e$
	$\Delta E_e = (1250\ \text{W})(0.417\ \text{h})$
	$\Delta E_e = 520\ \text{W·h}$
	Substitute first
	$1250\ \text{W} = \frac{\Delta E_e}{0.417\ \text{h}}$
	$(1250\ \text{W})(0.417\ \text{h}) = \frac{\Delta E_e}{0.417\ \text{h}}(0.417\ \text{h})$
	$\Delta E_e = 520\ \text{W·h}$
Find the cost.	Cost = Rate · ΔE_e
Multiply.	$\text{Cost} = \frac{7.20\ \text{cents}}{\text{kW·h}} 520\text{W}\cdot\text{h}\frac{1\ \text{kW}}{1000\ \text{W}}$
	Cost = 3.75 cents

The cost is 3.75 cents.

Validate
The units combine and cancel to give cents. As we can see by comparing with the model problem, the cost of using a dryer is much higher than watching television.

52. Frame the Problem
- The total amount of electric energy the blow dryer uses in a specific amount of time depends on the power output.
- The blow dryer's power output depends on its resistance and its current which are all related.
- Power companies charge a specific amount of dollars per unit of energy used.

Identify the Goal
The cost, in cents, to dry your hair

Variables and Constants

Involved in the Problem		Known	Unknown
Δt	Cost	$\Delta t = 12.0$ min	Cost
P	ΔE_e	Rate = 8.50 cents/kW·h	ΔE_e
Rate	R	$R = 21.0\ \Omega$	P
I		$I = 5.50$ A	

Strategy	Calculations
Use the relation between the power output, the resistance and the current flowing through the resistor.	$P = I^2R$
Multiply.	$P = (5.50\text{ A})^2(21.0\ \Omega)$
An $A^2 \cdot \Omega$ is equivalent to a W, thus	$P = 635$ W
Find the total time, in hours, that the dryer is on to dry a load of clothes.	$t = (\frac{1}{60}\frac{\text{h}}{\text{min}}) \cdot 12.0$ min $t = 0.200$ h
Find the total amount of energy consumed by using the definition of power.	$P = \frac{\Delta E_e}{\Delta t}$ Solve for ΔE_e first $P\Delta t = \frac{\Delta E_e}{\Delta t}\Delta t$ $P\Delta t = \Delta E_e$ $\Delta E_e = (635\text{ W})(0.200\text{ h})$ $\Delta E_e = 127$ W·h Substitute first $635\text{ W} = \frac{\Delta E_e}{0.200\text{ h}}$ $(635\text{ W})(0.200\text{ h}) = \frac{\Delta E_e}{0.200\text{ h}}(0.200\text{ h})$ $\Delta E_e = 127$ W·h
Find the cost.	Cost = Rate · ΔE_e
Multiply.	Cost $= \frac{8.50}{\text{kW}\cdot\text{h}} 127\text{ W}\cdot\text{h}\frac{1\text{ kW}}{1000\text{ W}}$ Cost = 1.08 cents
The cost is 1.08 cents.	

Validate
The units combine and cancel to give cents. As we can see by comparing with the previous problem it cost less to dry your hair than to dry your clothes, which is reasonable.

53. Frame the Problem

- The electric kettle has a potential difference applied to it and a resistance, thus it has a power rating.
- The total amount of electric energy the electric kettle uses in a specific amount of time depends on the power output.
- Power companies charge a specific amount of dollars per unit of energy used.

Identify the Goal

(a) The power rating of the kettle

(b) The cost, in cents, to boil the water

Variables and Constants

Involved in the Problem	Known	Unknown
R	$R = 10.0\ \Omega$	P
P	$V = 120$ V	Cost
V	$\Delta t = 3.2$ min	ΔE_e
Δt	Rate = 6.5 cents/kW·h	
Cost		
ΔE_e		
Rate		

Strategy	Calculations
Use the relation between the power output, the resistance and the potential difference.	$P = \frac{V^2}{R}$
Divide.	$P = \frac{(120\ \text{V})^2}{10.0\ \Omega}$
$1\ \frac{\text{V}^2}{\Omega}$ is equivalent to 1 W, thus	$P = 1.4 \times 10^3$ W
(a) The power rating is 1.4×10^3 W.	

The answer here is correct. The textbook will be changed at next printing to reflect correct answer.

Strategy	Calculations
Find the total time, in hours, that the kettle is on.	$t = (\frac{1}{60}\frac{\text{h}}{\text{min}})\cdot 3.2\text{min}$ $t = 0.053$ h
Find the total amount of energy consumed by using the definition of power.	$P = \frac{\Delta E_e}{\Delta t}$
	Solve for ΔE_e first $P\Delta t = \frac{\Delta E_e}{\Delta t}\Delta t$ $P\Delta t = \Delta E_e$ $\Delta E_e = (1.4 \times 10^3\ \text{W})(0.053\ \text{h})$ $\Delta E_e = 76.8$ W·h
	Substitute first $1.4 \times 10^3\ \text{W} = \frac{\Delta E_e}{0.053\ \text{h}}$ $(1.4 \times 10^3\ \text{W})(0.053\ \text{h}) = \frac{\Delta E_e}{0.053\ \text{h}}(0.053\ \text{h})$ $\Delta E_e = 76.8$ W·h
Find the cost.	Cost = Rate $\cdot\ \Delta E_e$

Multiply and round up.

$$\text{Cost} = \frac{6.5\text{ cents}}{\text{kW·h}} 76.8\text{ W·h} \frac{1\text{ kW}}{1000\text{ W}}$$

$$\text{Cost} = 0.50\text{ cents}$$

(b) The cost is 0.50 cents.

Validate
The units combine and cancel to give cents.

Problems for Understanding

Student Textbook page 667

24. If the voltage increases from 32.0 V to 120 V, there will be 3.75 times more current.
The initial current $= \frac{\text{power}}{\text{voltage}} = \frac{200\text{ W}}{32.0\ V} = 6.25\ A$
The new current = 3.75 × 6.25 A = 23.4 A
The new power = VI = 120 V × 23.4 A = 2810 W

25. (a) $I = \frac{P}{V}$

$I = \frac{1400\text{ W}}{120\text{ V}}$

$I = 12\text{ A}$

(b) $Q = IT$

$Q = 11.7\text{ A} \times (60 \times 3.60)\text{ s}$

$Q = 2.5 \times 10^3\text{ C}$

(c) $E = PT$

$E = 1400\text{ W} \times (60 \times 3.60)\text{ s}$

$E = 3.0 \times 10^5\text{ J}$

26. $E = P\Delta t$

$P = IV$

$E = IV\Delta t$

$E = 6.25\text{ A} \times 240\text{ V} \times (60 \times 5.50)\text{ s}$

$E = 5.0 \times 10^5\text{ J}$

27. $E = PT$

$E = \frac{V^2}{R} \times T$

$E = \frac{(125\ V)^2}{15.0\ \Omega} \times (\frac{12.0}{60})\text{ h}$

$E = 208\text{ W·h}$

Cost = E × \$0.0850/kW·h

Cost = 0.208/kW·h × \$0.0850/kW·h

Cost = \$0.0177 = 1.77 cents

28.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{25\ \Omega} = \frac{1}{75\ \Omega} + \frac{1}{R_2}$$

$$\frac{1}{25\ \Omega} - \frac{1}{75\ \Omega} = \frac{1}{R_2}$$

$$R_2 = 37.5\ \Omega$$

29. $\frac{1}{R_{2+3}} = \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_{2+3}} = \frac{1}{30.0\ \Omega} + \frac{1}{6.00\ \Omega}$

$\frac{1}{R_{2+3}} = \frac{6}{30.0\ \Omega}$

$\frac{1}{R_{2+3}} = 5.00\ \Omega$

$R_{eq} = R_{2+3} + R_1$

$R_{eq} = 5.00\ \Omega + 25.0\ \Omega$

$R_{eq} = 30.0\ \Omega$

$I_T = I_1 = \frac{V_T}{R_{eq}} = \frac{180\ \text{V}}{30.0\ \Omega} = 6.0\ \text{A}$

$V_1 = I_1R_1 = 6.0\ \text{A} \times 25.0\ \Omega = 150\ \text{V}$

$V_{2+3} = V_T - V_1 = 180\ \text{V} - 150\ \text{V} = 30.0\ \text{V}$

$V_2 = 30.0\ \text{V}$

$V_3 = 30.0\ \text{V}$

$I_2 = \frac{V_2}{R_2} = \frac{30.0\ \text{V}}{30.0\ \Omega} = 1.0\ \text{A}$

$I_3 = \frac{V_3}{R_3} = \frac{30.0\ \text{V}}{6.00\ \Omega} = 5.0\ \text{A}$

30. Power in = Power out

$VI = \frac{mgh}{T}$

$T = \frac{mgh}{VI}$

$T = \frac{5.00\ \text{kg} \times 9.8\ \text{m/s}^2 \times 35.0\ \text{m}}{36.0\ \text{V} \times 4.80\ \text{A}}$

$T = 9.9\ \text{s}$

31. (a) $R = \rho\frac{L}{A} = (1.7 \times 10^{-8}\ \Omega\cdot\text{m})\frac{2 \times 45.0\ \text{m}}{3.14 \times (.00051\ \text{m})^2}$

$R = 1.9\ \Omega$

(b) $P = \frac{V^2}{R}$

$R = \frac{V^2}{P} = \frac{(120\ \text{V})}{100\ \text{W}} = 144\ \Omega = 1.4 \times 10^2\ \Omega$

(c) $I = \frac{V_T}{R_T} = \frac{120\ \text{V}}{(144 + 1.9)\Omega} = 0.8225\ \text{A} = 0.82\ \text{A}$

(d) $P = VI = 120\ \text{V} \times 0.082\ \text{A} = 98\ \text{W}$

32. The *emf* of the battery remains constant, regardless of the resistance in the circuit. Therefore:

$V_s + V_{int} = E$

$24.0\ \text{V} + (I_s \times r) = E$

$24.0\ \text{V} + (\frac{V_s}{R_s} \times r) = E$

$24.0\ \text{V} + (\frac{24.0\ \text{V}}{40.0\ \Omega)}r = E$

$24.0\ \text{V} + 0.60r = E$

Similarly for the second resistance of 15.0 Ω, we get:

$$V_s + V_{int} = E$$

$$23.5\text{ V} + (I_s \times r) = E$$

$$23.5\text{ V} + (\frac{V_s}{R_s} \times r) = E$$

$$23.5\text{ V} + (\frac{23.5\text{ V}}{15.0\ \Omega)}r = E$$

$$23.5\text{ V} + 1.57r = E$$

Solving for r in these simultaneous equations, we get

$$23.5\text{ V} + 1.57r = 24.0\text{ V} + 0.60r$$

$$0.97r = 0.50$$

$$r = 0.52\ \Omega$$

The internal resistance of the battery is 0.52 Ω.

The *emf* of the battery can be found by substitution of r in either equation:

$E = 23.5\text{ V} + 1.57r$

$E = 23.5\text{ V} + (1.57 \times 0.52\ \Omega)$

$E = 24.3\text{ V}$