SECTION 8

Energy Consumption: Cold Shower

Section Overview

Students investigate the amount of energy needed to heat a cup of water using an electrical resistor. They calculate the amount of heat transferred to the water using measurements of temperature and the specific heat of water. They also calculate the energy consumption of the heating device by using the power rating and measuring the time that they used the device. Based on the law of conservation of energy, students consider the energy transformations and calculate the efficiency of the heating device. The *Physics Talk* discusses energy consumption, power ratings, heat transfers, and efficiency, as well as the mechanical equivalent of heat energy. Students apply their knowledge of the concepts of energy consumption, power ratings, and efficiency to solve problems involving electrical appliances.

Background Information

The efficiency of a device is the ratio of the useful energy output of the device to the energy input. Many of the newer electrical appliances have energy efficiency ratings. An appliance that provides the same output for a lower power rating (wattage) is more energy efficient. For example, a 60-W incandescent bulb uses less than 5% of the input energy toward lighting and has a lifetime of about 1000 hours. An LED light source with similar light output (equivalent to a 60-W incandescent bulb) lasts up to 30,000 hours and uses only 1 W. LED light sources are more efficient and safer than the compact fluorescent light bulbs (CFL's) and halogen bulbs. CFL's contain mercury and halogen bulbs get very hot.

Crucial Physics

- The efficiency of a system is calculated by the useful energy output divided by the total energy supplied.
- The energy in an electrical circuit can be calculated using the relationship $E = Pt = VIt$.
- A common unit of electric energy is the kilowatt-hour.
- Energy is a conserved quantity. By tracking the energy flow during interactions one can describe how the energy is transferred from one object to another and transformed from one type to another, but the total energy does not change. Energy is neither created nor destroyed.

Learning Outcomes	Location in the Section	Evidence of Understanding
Calculate the heat gained by a sample of water.	***Investigate*** Step 3	Students measure the change in temperature of water heated by a resistor and then calculate the heat energy transferred to the water.
Calculate the electrical energy converted into heat by a resistor.	***Investigate*** Step 4	Students calculate the energy converted into heat energy by a resistor using the power rating listed on the appliance and the time they measured for the heating of the water.
Calculate the efficiency of a transformation of electrical energy to heat.	***Investigate*** *Step 5* ***Physics Talk***	Students calculate the efficiency of the resistor used to heat the water using their calculations of the increase of thermal energy of the water and the energy output of the resistor. Students also consider what happened to the energy that is not considered to be useful energy for different situations.
Explore the power ratings and energy consumption levels of a variety of electrical appliances.	***Physics to Go*** Questions 5-8	Students apply the concepts of energy consumption and power to explore how much energy is used by a variety of appliances described to them, and others they select on their own.

Section 8 Materials, Preparation, and Safety

Materials and Equipment

PLAN A		
Materials and Equipment	**Group (4 students)**	**Class**
Graduated cylinder, plastic, 100 mL	1 per group	
Stirring rod, glass, 8 in.-12 in.	1 per group	
Thermometer	1 per group	
Heater, electric immersion	1 per group	
Stopwatch	1 per group	
Scale, electronic, 0.1-g readability, 0-1500 g		1 per class
Wire gauze, square, 4 in. x 4 in. (w/ ceramic center)		2 per class
Cup, styrene foam, 12 oz	2 per group	
Access to an electrical outlet*		1 per class
Calorimeter, electrical*	1 per group	
Water, cold, 1 L*	1 per group	

*Additional items needed not supplied

Time Requirements

- If electric calorimeters and power supplies are used for the *Investigate*, allow one full class period or 45 minutes. If a heating coil is used, the *Investigate* may be completed in 30 minutes or less.

Teacher Preparation

- Go over the proper use of the heating coils with the students prior to starting the lab.
- If the wattage of the heating coils is not known (it may be stamped right on the plastic or on a paper tag), either measure the current the coil uses and multiply by 120 V to obtain the power, or run the experiment several times yourself to get a good approximate value.
- Instruct students to not allow the coil to touch the side of the styrene-foam cup if possible, since it can melt the cup.
- Raising the water temperature to 50°C is sufficient for the experiment.
- Either a stopwatch or the wall clock may be used to measure the time.
- Test all equipment (voltmeters, ammeters, power sources, heating coils) to make sure they are working properly and have the correct range or values.

Safety Requirements

- The heating coil uses 120-V current. Caution the students not to touch any part of the heating coil except to plug it in.
- The heating coil must not be plugged in unless the coil is submerged in water. Failure to follow this procedure will burn out the coil.
- Observe the safety requirements for the thermometer listed above.
- Make certain the students unplug the heating coil prior to removing it from the water.
- Goggles are required.

Materials and Equipment

PLAN B		
Materials and Equipment	**Group (4 students)**	**Class**
Graduated cylinder, plastic, 100 mL		1 per class
Stirring rod, glass, 8 in.-12 in.		1 per class
Thermometer		1 per class
Heater, electric immersion		1 per class
Stopwatch		1 per class
Scale, electronic, 0.1-g readability, 0-1500 g		1 per class
Wire gauze, square, 4 in. x 4 in. (w/ ceramic center)		2 per class
Cup, styrene foam, 12 oz		2 per class
Access to an electrical outlet*		1 per class
Calorimeter, electrical*		1 per class
Water, cold, 1 L*		1 per class

*Additional items needed not supplied

Time Requirements

- Allow one class period or 45 minutes to complete the *Investigate* and other parts of the section listed in the *Pacing Guide* when done as a teacher-led section.

Teacher Preparation

- If the wattage of the heating coils is not known (it may be stamped right on the plastic or on a paper tag), either measure the current the coil uses and multiply by 120 V to obtain the power, or run the experiment several times yourself to get a good approximate value.
- Instruct the student to not allow the coil to touch the side of the styrene-foam cup if possible, since it can melt the cup.
- Raising the water temperature to 50°C is sufficient for the experiment.
- Either a stopwatch or the wall clock may be used to measure the time.
- Have the circuit equipment available for quick setup in a location easily visible for all students.
- If large demonstration meters are available, use these in place of student meters to enhance visibility.
- Test all equipment (voltmeters, ammeters, power sources, heating coils) to make sure they are working properly and have the correct range or values.
- Make a Blackline Master of the data table in the *Investigate* of the student text to record the data needed and for the students to record in their logs.

Safety Requirements

- The heating coil uses 120-V current. Be careful not to touch any part of the heating coil except to plug it in.
- The heating coil must not be plugged in unless the coil is submerged in water. Failure to follow this procedure will burn out the coil.
- Observe the safety requirements for the thermometer listed above.
- Make certain you unplug the heating coil prior to removing it from the water.
- Goggles are required.

Meeting the Needs of All Students

Differentiated Instruction: Augmentation and Accommodations

Learning Issue	Reference	Augmentation and Accommodations
Using equipment appropriately	***Investigate*** Steps 1 and 2 ***Physics to Go*** Question 6	**Augmentation** • Students who struggle to read and follow directions or focus on tasks may have a difficult time using equipment that is dangerous or easily damaged if used incorrectly. Model appropriate use of the equipment with visual and auditory cues. **Accommodation** • For students with more serious gross motor difficulties or behavior concerns, complete this part of the *Investigate* as a demonstration.
Performing metric conversions	***Investigate*** Step 4	**Augmentation** • Converting from watt-seconds to kilowatt-hours can be confusing if students do not line up the numbers correctly. Provide graph paper or lined paper for students when they are asked to do metric conversions. • Show students how units should cancel each other out if the conversion factors are set up and used correctly. **Accommodation** • Provide a chart with common conversion factors, such as $1\text{ h} = 3600\text{ s}$ $1\text{ kW} = 1000\text{ W}$
Making connections	***Physics Talk***	**Augmentation** • Students may have an easier time understanding the conservation of energy and efficiency if a connection is made to electrical insulators and conductors as introduced in *Section 5*. If they can make the connection that similar materials conduct both electricity and heat well, they may be able to more easily understand why some heat was "lost" in their experiment.
Comparing numbers to find patterns	***Physics to Go*** Questions 5-6	**Augmentation** • Students with learning disabilities often do not notice patterns, and they have a difficult time generalizing information. One way to scaffold learning for these students is to provide a list of more specific questions to lead students to discovering patterns. An example question is, "How do the power ratings of appliances that provide light and the appliances that provide heat compare to each other?"
Organizing data Performing a series of calculations	***Physics to Go*** Question 6	**Augmentation** • For students to make a six-column chart with five to ten rows, ask them to turn their paper to landscape format in order to fit all of this data. • Students need to use this data in *Section 9*. It is important that they complete the calculations accurately and in an organized way, so it can be shared with other group members. Ask students to perform calculations independently and then compare with a partner. **Accommodation** • Provide a blank data table with six columns and five to ten rows.

Strategies for Students with Limited English-Language Proficiency

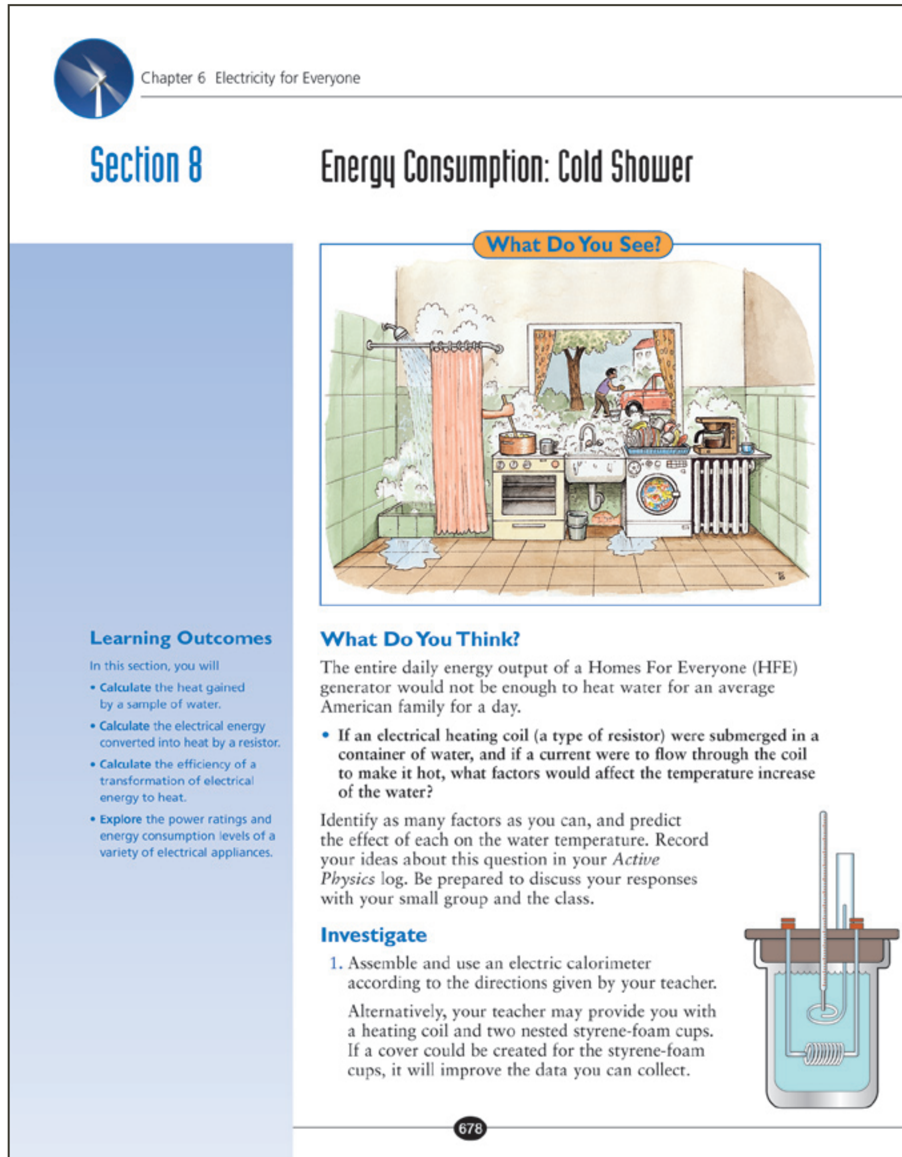
Learning Issue	Reference	Augmentation
Vocabulary comprehension	***Investigate*** Step 1 ***Active Physics Plus*** Question 2	Students likely will be familiar with the term "calorie" as related to food. But they probably will not know that it is a unit of energy. One food calorie (a kilocalorie) equals 4.185 joules. The equation is written as $1 C = 4185 J$. You may wish to tell students that the calorie is also defined as the amount of heat needed to increase the temperature of one gram of water by one degree Celsius at one atmosphere of pressure. Once you have shared this information with students, have them infer the meaning of "calorimeter." Then, after they have used one in their investigations, ask if they want to revise their inference. Finally, let them know that a calorimeter is defined as an instrument used to measure absorbed heat.
Vocabulary comprehension	***Investigate*** Step 1	If you do not have a calorimeter available and use a heating coil and styrene foam cups instead, explain that "nested" as used here means one cup inside the other. Explain the term by referring to a stack of bowls, which can be described as nested, and relate this to an image of doing the same with bird nests.
Vocabulary comprehension Using prefixes	***Investigate*** Step 2 (safety issue)	Help students with the term "submerged," if necessary. Tell students the prefix "sub" means "below" or "under." Explain that a submarine is a boat that is under (sub) the ocean (marine).
Higher order thinking	***Investigate*** Step 4.a)	Ask students: "Is energy ever really lost?" This might be a good time to review the law of conservation of energy, along with the terminology involved.
Comprehension	***Active Physics Plus*** Step 1.a)	Students may benefit from a brief review of gravitational potential energy. You might want to discuss the term and concept "potential" as it applies to the students themselves. You could ask what it means when a teacher tells them they have "potential."
Vocabulary comprehension	***Active Physics Plus*** Question 2	"Staggering" may be unfamiliar to students in the context here. You might want to illustrate by miming a person being "staggered" by an astonishing fact or circumstance.
Comprehension	Throughout	Spend some time during this lesson to check students' ability to work through the math. Be sure they are doing the calculations correctly, and are identifying and using the correct units. There are many equations in this section, and students may benefit from creating a table in which they record these equations for handy reference.
Understanding concepts Higher order thinking	***Physics to Go*** Question 5	Allow students time to look for a relationship between an appliance's power rating and the type of energy the appliance provides. Challenge them to come up with a way to represent the pattern mathematically.
Answering higher order questions	***Reflecting on the Section and the Challenge***	Challenge students to answer this question: "What is the difference between electric power consumption and electric energy consumption?"

SECTION 8

Teaching Suggestions and Sample Answers

What Do You See?

Ask students to describe what they see in the illustration. Consider using the overhead of the illustration as a focal point for the discussion. Have the class discuss how they think the illustration connects with energy consumption. Students should use information from the previous section to support their ideas. This illustration is meant to make the students curious about water, its many uses, and how it is linked to energy consumption.



Chapter 6 Electricity for Everyone

Section 8 Energy Consumption: Cold Shower

What Do You See?

Learning Outcomes

In this section, you will

- **Calculate** the heat gained by a sample of water.
- **Calculate** the electrical energy converted into heat by a resistor.
- **Calculate** the efficiency of a transformation of electrical energy to heat.
- **Explore** the power ratings and energy consumption levels of a variety of electrical appliances.

What Do You Think?

The entire daily energy output of a Homes For Everyone (HFE) generator would not be enough to heat water for an average American family for a day.

- **If an electrical heating coil (a type of resistor) were submerged in a container of water, and if a current were to flow through the coil to make it hot, what factors would affect the temperature increase of the water?**

Identify as many factors as you can, and predict the effect of each on the water temperature. Record your ideas about this question in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

1. Assemble and use an electric calorimeter according to the directions given by your teacher.

Alternatively, your teacher may provide you with a heating coil and two nested styrene-foam cups. If a cover could be created for the styrene-foam cups, it will improve the data you can collect.

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Students' Prior Conceptions

Metacognitive research in how students learn about electricity does not directly support the consumption and use of electrical energy. Students are most likely to believe 'myths' about energy and consumption as presented by the public media, advertisements, and general exposure to everyday life. The *Students' Prior Conceptions* identified in *Sections 1* through *7* continue to apply to how students will apply the concepts learned in these sections and how they will process the input they gained in this chapter to the engineering process they employ to complete the *Chapter Challenge*. It is recommended that you encourage students to research and identify the common myths surrounding electric energy and its usage in everyday life as part of their background for the *Chapter Challenge*. Have the students look into the power ratings and energy consumption levels of several of the electrical appliances shown in the *Physics to Go*. Scrutinizing the costs of operating a variety of electrical appliances in terms of power ratings, amount of time each appliance is used, and billing rates in *Section 9* will be most instructive in uncovering myths about electrical energy and why students should care about these myths.

What Do You Think?

Emphasize to students that the daily energy allowed for an HFE home (3 kWh) would not be enough to heat water for the average family in the United States. The typical US household consumes about 30 kWh per day, about ten times the allowed amount for an HFE home. Have students record their ideas to the question in their *Active Physics* logs and discuss their ideas with their group members. Consider asking students what they think will be investigated in this section. Ask them how it might connect with electric circuits and the Housing for Everyone appliance package they are designing.

Investigate

Teaching Tip

Electric calorimeters are made to operate with low-voltage power supplies, and may take a relatively long time to heat the water. If an "immersion" coil is used, caution the students not to touch the coil, since they get very hot. Make certain that the coil does not touch the sides of the styrene-foam cup.

Have a pre-set maximum temperature you wish the students to reach with the heating coils. Generally, 50°C is sufficient to provide an adequate temperature rise, but is not hot enough to be a problem if the water is accidentally spilled.

What Do You Think?

A Physicist's Response

There are a number of factors that would affect the temperature increase of the water: the resistance of the resistor used (the higher the resistance, the warmer the coil will get); the specific heat of the metals used in the resistor and its coating (how easily the resistor will transfer heat energy to the coating, and how easily the coating will transfer heat energy to the water); the specific heat of water; the mass of the water; and whether or not the water would be in an isolated system (some of the heat energy transferred to the water may then get transferred to the surroundings).

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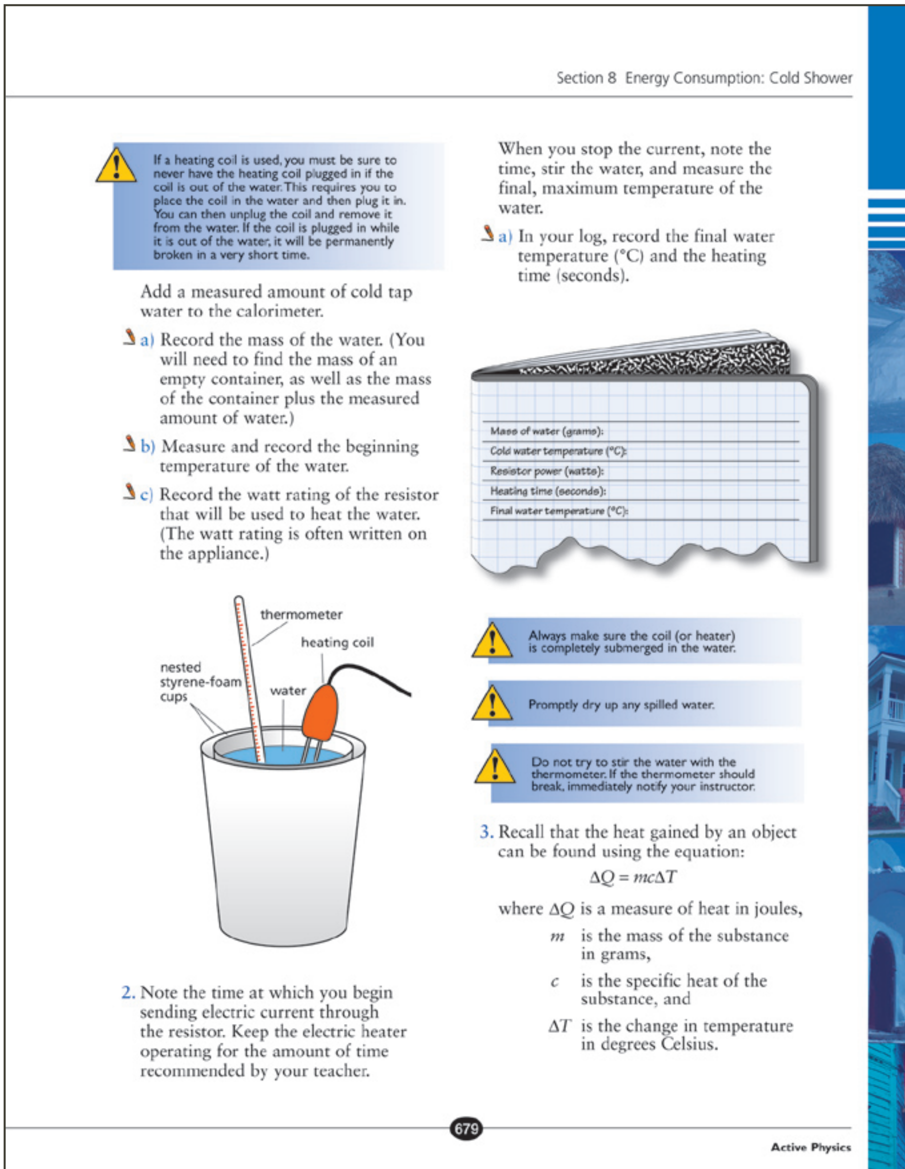

Section 8 Energy Consumption: Cold Shower

If a heating coil is used, you must be sure to never have the heating coil plugged in if the coil is out of the water. This requires you to place the coil in the water and then plug it in. You can then unplug the coil and remove it from the water. If the coil is plugged in while it is out of the water, it will be permanently broken in a very short time.

Add a measured amount of cold tap water to the calorimeter.

a) Record the mass of the water. (You will need to find the mass of an empty container, as well as the mass of the container plus the measured amount of water.)

b) Measure and record the beginning temperature of the water.

c) Record the watt rating of the resistor that will be used to heat the water. (The watt rating is often written on the appliance.)

thermometer
heating coil
nested styrene-foam cups
water

2. Note the time at which you begin sending electric current through the resistor. Keep the electric heater operating for the amount of time recommended by your teacher.

When you stop the current, note the time, stir the water, and measure the final, maximum temperature of the water.

a) In your log, record the final water temperature (°C) and the heating time (seconds).

Mass of water (grams):
Cold water temperature (°C):
Resistor power (watts):
Heating time (seconds):
Final water temperature (°C):

Always make sure the coil (or heater) is completely submerged in the water.

Promptly dry up any spilled water.

Do not try to stir the water with the thermometer. If the thermometer should break, immediately notify your instructor.

3. Recall that the heat gained by an object can be found using the equation:

$$\Delta Q = mc\Delta T$$

where ΔQ is a measure of heat in joules,
m is the mass of the substance in grams,
c is the specific heat of the substance, and
ΔT is the change in temperature in degrees Celsius.

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1.a)

Students record the mass of the water in the cup.

1.b)

Students record the initial temperature of the water in the cup prior to the heating element being added.

1.c)

Students record the wattage rating of the heating element. If a typical immersion heater for a coffee cup is used, this should be 300 watts.

2.a)

Students record the time they used the water heater in their logs. They should record the final temperature of the hot water after stirring and removing the heater.

6-8a Blackline Master

6-8b Blackline Master

CHAPTER 6

3.a)

Students calculate the heat gained by the hot water using the formula $\Delta Q = mc\Delta T$ and record their calculations in their log.

4.

Students read about the relationship between power and energy.

4.a)

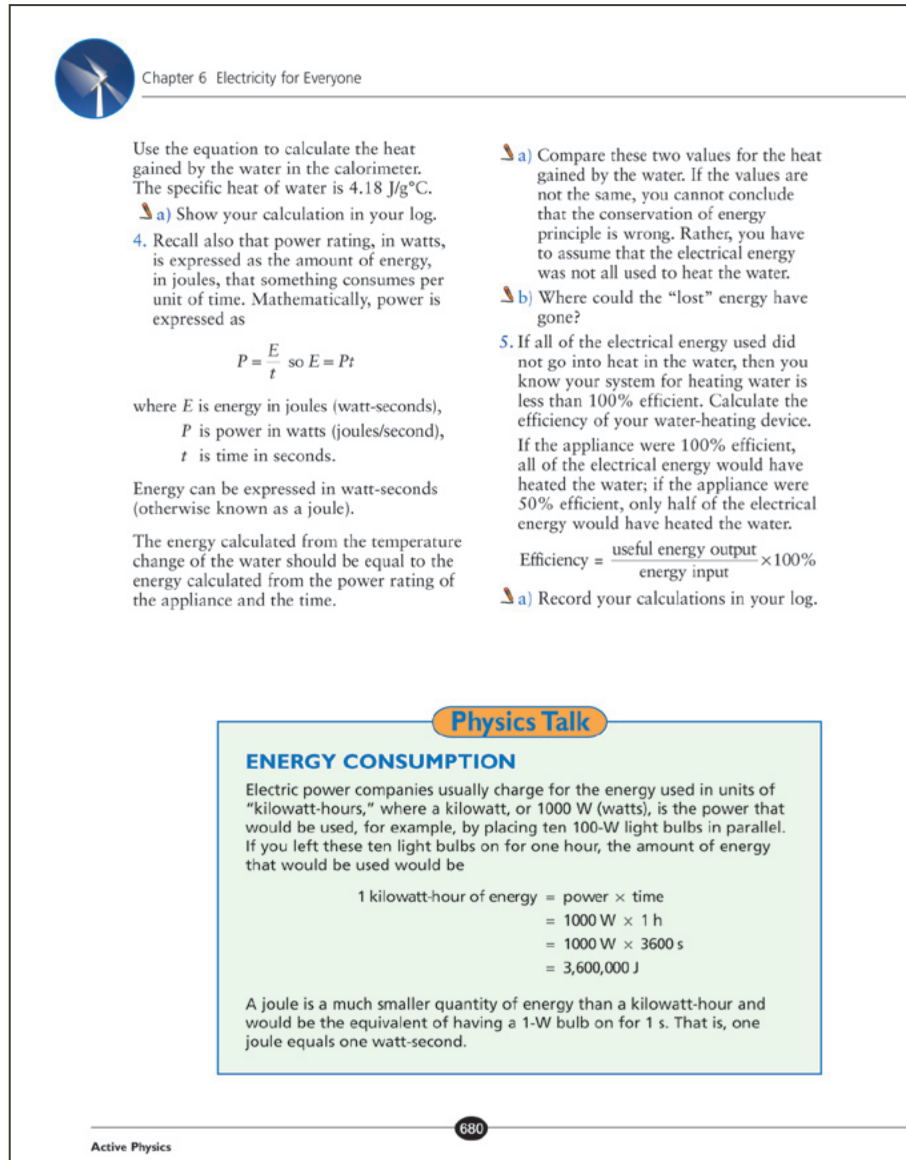
Students should calculate the energy added to the hot water by the immersion coil using $E = Pt$, and compare this number to the heat gained by the water in *Step 3*. Energy not accounted for has probably escaped from the water to the air, just as a cup of hot chocolate will cool off when it is exposed to cold air. A small amount of energy may be transferred to the warming of the other wires in the heating device, the warming of the thermometer, and so on.

5.

Students should calculate the efficiency of the heating process by dividing the energy gained by the water calculated in *Step 3* by the calculated energy supplied by the heater in *Step 4*.

5.a)

The students should record their findings in their logs. Efficiencies should be in the 80% range, which is good.



Chapter 6 Electricity for Everyone

Use the equation to calculate the heat gained by the water in the calorimeter. The specific heat of water is 4.18 J/g°C.

a) Show your calculation in your log.

4. Recall also that power rating, in watts, is expressed as the amount of energy, in joules, that something consumes per unit of time. Mathematically, power is expressed as

$$P = \frac{E}{t} \text{ so } E = Pt$$

where E is energy in joules (watt-seconds),
P is power in watts (joules/second),
t is time in seconds.

Energy can be expressed in watt-seconds (otherwise known as a joule).

The energy calculated from the temperature change of the water should be equal to the energy calculated from the power rating of the appliance and the time.

a) Compare these two values for the heat gained by the water. If the values are not the same, you cannot conclude that the conservation of energy principle is wrong. Rather, you have to assume that the electrical energy was not all used to heat the water.

b) Where could the "lost" energy have gone?

5. If all of the electrical energy used did not go into heat in the water, then you know your system for heating water is less than 100% efficient. Calculate the efficiency of your water-heating device.

If the appliance were 100% efficient, all of the electrical energy would have heated the water; if the appliance were 50% efficient, only half of the electrical energy would have heated the water.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

a) Record your calculations in your log.

Physics Talk

ENERGY CONSUMPTION

Electric power companies usually charge for the energy used in units of "kilowatt-hours," where a kilowatt, or 1000 W (watts), is the power that would be used, for example, by placing ten 100-W light bulbs in parallel. If you left these ten light bulbs on for one hour, the amount of energy that would be used would be

$$\begin{aligned} 1 \text{ kilowatt-hour of energy} &= \text{power} \times \text{time} \\ &= 1000 \text{ W} \times 1 \text{ h} \\ &= 1000 \text{ W} \times 3600 \text{ s} \\ &= 3{,}600{,}000 \text{ J} \end{aligned}$$

A joule is a much smaller quantity of energy than a kilowatt-hour and would be the equivalent of having a 1-W bulb on for 1 s. That is, one joule equals one watt-second.

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Active Physics

Physics Talk

Discuss energy consumption and how energy companies usually charge for kilowatt-hours of energy used, using the example of ten 100-W light bulbs in the student text. Emphasize the difference in the amount of energy a joule has compared to a kilowatt-hour. Ask students how much energy they used to heat the water based on their calculations in *Step 4* of the *Investigate*. Then ask them what this amount is in joules and kilowatt-hours.

Discuss the thermos and how it works by utilizing the knowledge of how heat energy is transferred by conduction, convection, or radiation. A thermos has a glass lining that contains a vacuum between its inner and outer walls. This vacuum does not allow heat to be transferred by conduction or convection; however, it will allow heat to be transferred by radiation. To reduce the heat transfer by radiation, the glass is silvered to reflect much of the radiation. To further reduce heat transfer, insulating materials that

What is the world's greatest invention? A comedian once replied: "The thermos. When you put a cold drink in it, it stays cold. When you put a hot drink in it, it stays hot. How does the thermos know?"

A cup of hot water left on a table cools down. A cup of cold water left on the same table warms up. How can you change the temperature or keep the temperature constant?

Heat is a transfer of thermal energy. Energy in one form must come from energy in another form. Energy must be conserved. If you wish to heat up water, you must supply it with a source of energy like a flame, an electrical heater, or a hot metal.

If a system is isolated from outside sources of energy, one part of the system may warm up and another part may cool down, but the total energy must remain constant. In this *Investigate*, you calculated the electrical energy that was used to heat the water. Thermal energy, like all forms of energy, is measured in units of joules (J). You used the following equation.

Change in heat
= mass of object × specific heat of material × temperature change

$$\Delta Q = mc\Delta T$$

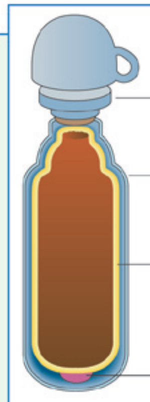
where ΔQ is a measure of change in heat in joules,
m is the mass of the substance in grams,
c is the specific heat of the substance, and
ΔT is the change in temperature in degrees Celsius.

Energy used to heat the object can also be calculated using the following equation:

Since energy = power × time
and power = voltage × current
then, energy = voltage × current × time

$$E = VIt$$

where E is the energy in joules (J),
V is the voltage in volts (V),
I is the current in amperes (A), and
t is the time in seconds (s).



do not conduct heat energy well (such as styrene foam and plastic) are used to support the glass from the outer walls.

Remind students of what an isolated system is and discuss how they calculated the energy transferred to the water and the energy supplied by the circuit. Then discuss the sample problems. Go through the example in the student text with the class. Ask them the two ways to calculate energy that they used in the *Investigate* and the equations that represent them.

Ask students how they calculated the efficiency of their system in the *Investigate*. Students should have calculated the efficiency by dividing their calculation of the heat transferred to the water by their calculation of the energy supplied by the circuit. Emphasize to the class that the law of conservation of energy states that no energy is created and no energy is destroyed. Then ask the class what happened to the energy provided by the circuit if it didn't get transferred to the water. Record the class's ideas and discuss them.

CHAPTER 6

Checking Up

1.

The energy used by a light bulb can be found by knowing the power of the light bulb because power is just the rate at which energy is being transferred or how many joules are transferred per second to the bulb. The equation describing this relationship is $E = Pt$.

2.

Physicists use the unit "joules" to measure energy, whether it is heat energy or electrical energy. You might want to note that there are many other units of energy that are commonly used, but the unit "joule" is the unit internationally accepted for energy by scientists.

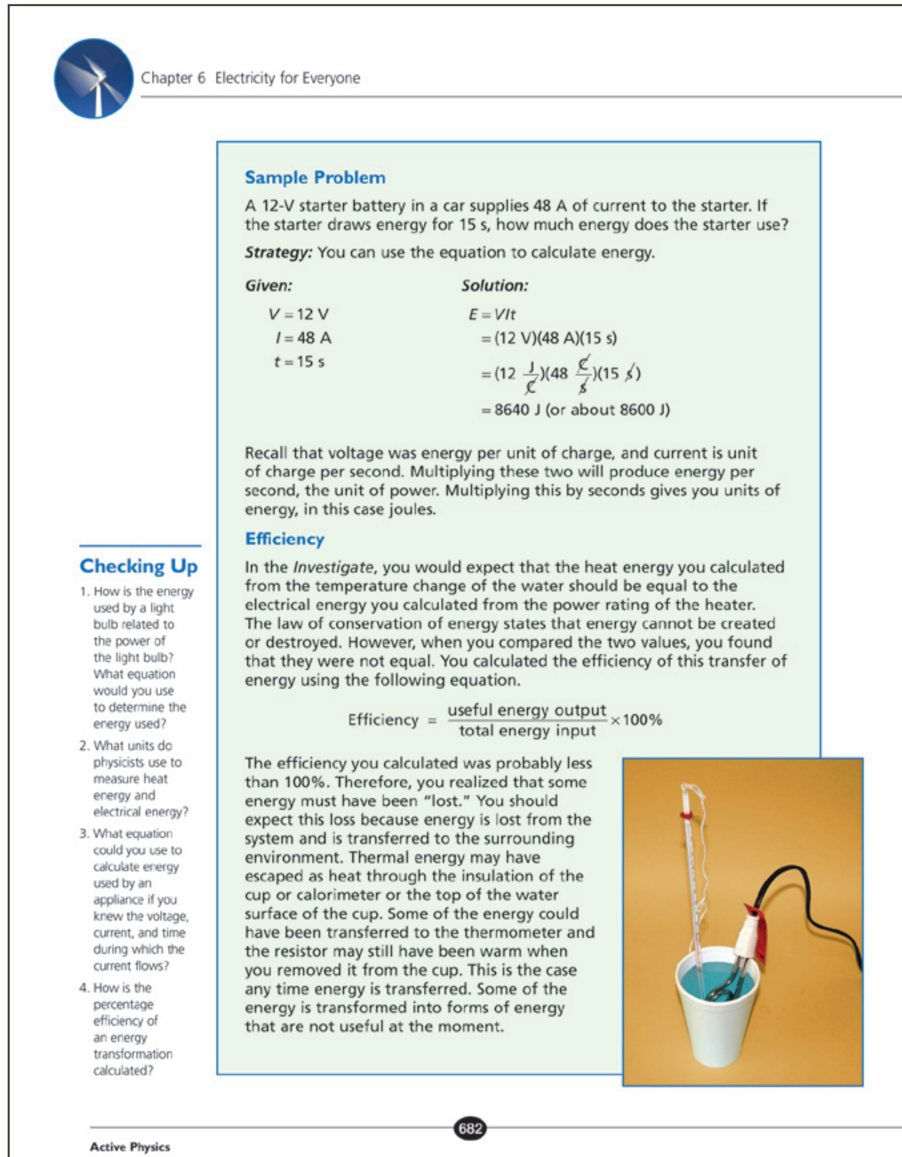
3.

If the voltage, current, and time during which the current flows is known for an appliance, then the equation $E = Pt$ should be used along with the relationship $P = IV$.

4.

The percentage efficiency of an energy transformation is calculated by finding the ratio of the output energy to the input energy and multiplying by 100%.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{useful energy input}} \times 100\%$$



Chapter 6 Electricity for Everyone

Sample Problem

A 12-V starter battery in a car supplies 48 A of current to the starter. If the starter draws energy for 15 s, how much energy does the starter use?

Strategy: You can use the equation to calculate energy.

Given:

$V = 12\text{ V}$
$I = 48\text{ A}$
$t = 15\text{ s}$

Solution:

$E = VIt$
$= (12\text{ V})(48\text{ A})(15\text{ s})$
$= (12\ \frac{\text{J}}{\text{C}})(48\ \frac{\text{C}}{\text{s}})(15\text{ s})$
$= 8640\text{ J}$ (or about 8600 J)

Recall that voltage was energy per unit of charge, and current is unit of charge per second. Multiplying these two will produce energy per second, the unit of power. Multiplying this by seconds gives you units of energy, in this case joules.

Efficiency

In the *Investigate*, you would expect that the heat energy you calculated from the temperature change of the water should be equal to the electrical energy you calculated from the power rating of the heater. The law of conservation of energy states that energy cannot be created or destroyed. However, when you compared the two values, you found that they were not equal. You calculated the efficiency of this transfer of energy using the following equation.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

The efficiency you calculated was probably less than 100%. Therefore, you realized that some energy must have been "lost." You should expect this loss because energy is lost from the system and is transferred to the surrounding environment. Thermal energy may have escaped as heat through the insulation of the cup or calorimeter or the top of the water surface of the cup. Some of the energy could have been transferred to the thermometer and the resistor may still have been warm when you removed it from the cup. This is the case any time energy is transferred. Some of the energy is transformed into forms of energy that are not useful at the moment.

Checking Up

1. How is the energy used by a light bulb related to the power of the light bulb? What equation would you use to determine the energy used?
2. What units do physicists use to measure heat energy and electrical energy?
3. What equation could you use to calculate energy used by an appliance if you knew the voltage, current, and time during which the current flows?
4. How is the percentage efficiency of an energy transformation calculated?

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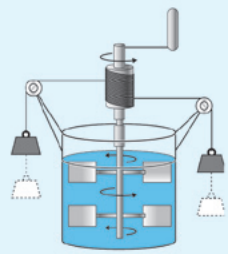
Active Physics *Plus*

+Math	+Depth	+Concepts	+Exploration
••	•	••	

Mechanical Equivalent of Heat

In this section, you were able to find the relationship between electrical energy and thermal energy. By stirring water, you can also increase its temperature. By measuring the amount of work that is done by stirring, you can find the mathematical relationship between mechanical work and heat.

The experiment was first performed by Sir James Joule. (Yes, the joule was named after him.) In his experiment, he had two weights fall to the ground. As they fell, they turned paddles that were immersed in water. He then measured the change in the temperature of the water. By calculating the change in energy of the falling weights and the increase in temperature of the water, Joule calculated the mechanical equivalent of heat.



The change in gravitational energy is equal to

$$m_f g \Delta h$$

where m_f is the mass of the falling object,

g is the acceleration of the object due to gravity in meters per second squared, and

Δh is the change in height in meters.

The change in thermal energy is equal to

$$m_w c \Delta T$$

where m_w is the mass of the water in grams,

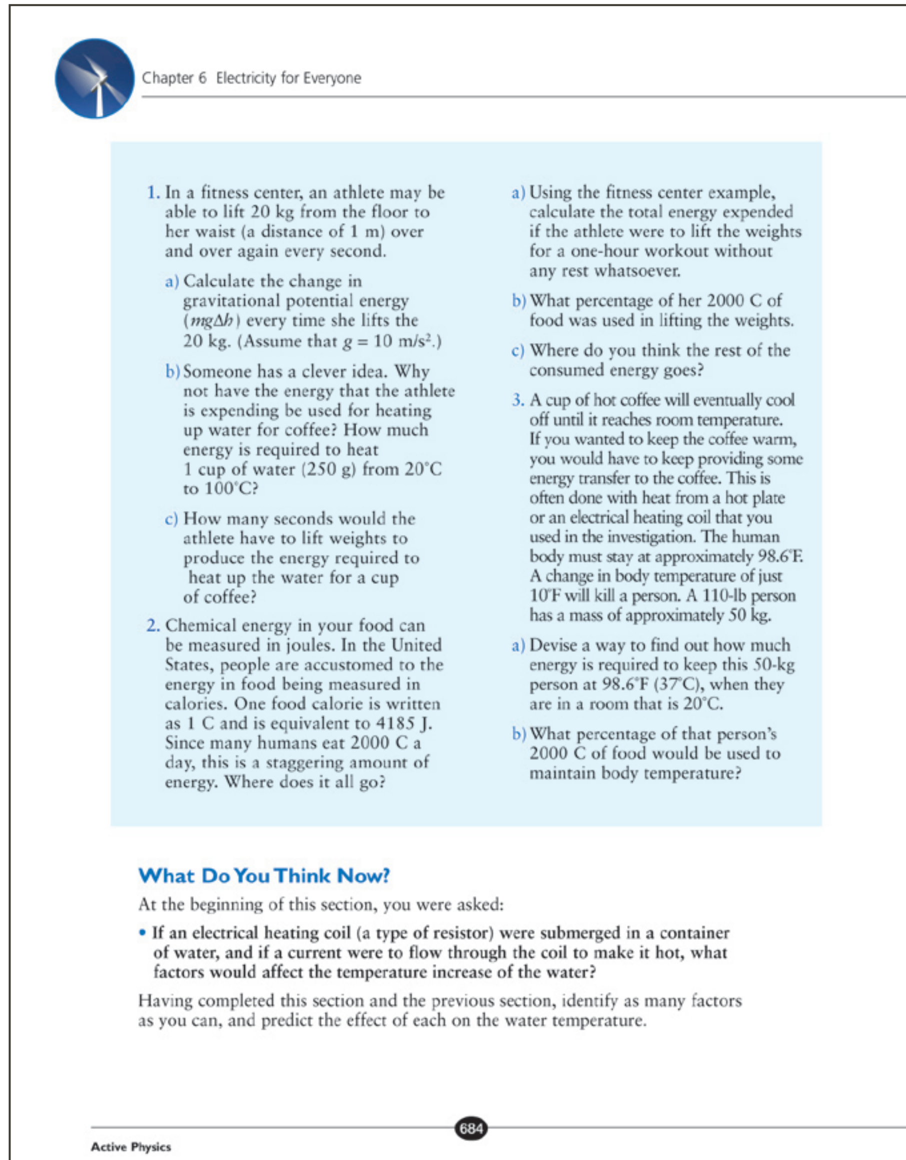
c is the specific heat of the water,

ΔT is the change in temperature in degrees Celsius.

Joule found that 4.18 J of work were required to raise the temperature of 1 g of water 1°C.

Active Physics Plus

This *Active Physics Plus* provides an opportunity for students to deepen their understanding of the concept of heat transfer as they are introduced to the relationship between mechanical work and heat. Students consider the relationship between mechanical work and heat conceptually and mathematically, and apply the ideas presented to solve various problems.



Chapter 6 Electricity for Everyone

1. In a fitness center, an athlete may be able to lift 20 kg from the floor to her waist (a distance of 1 m) over and over again every second.

   a) Calculate the change in gravitational potential energy ($mg\Delta h$) every time she lifts the 20 kg. (Assume that $g = 10\ m/s^2$.)

   b) Someone has a clever idea. Why not have the energy that the athlete is expending be used for heating up water for coffee? How much energy is required to heat 1 cup of water (250 g) from 20°C to 100°C?

   c) How many seconds would the athlete have to lift weights to produce the energy required to heat up the water for a cup of coffee?

2. Chemical energy in your food can be measured in joules. In the United States, people are accustomed to the energy in food being measured in calories. One food calorie is written as 1 C and is equivalent to 4185 J. Since many humans eat 2000 C a day, this is a staggering amount of energy. Where does it all go?

   a) Using the fitness center example, calculate the total energy expended if the athlete were to lift the weights for a one-hour workout without any rest whatsoever.

   b) What percentage of her 2000 C of food was used in lifting the weights.

   c) Where do you think the rest of the consumed energy goes?

3. A cup of hot coffee will eventually cool off until it reaches room temperature. If you wanted to keep the coffee warm, you would have to keep providing some energy transfer to the coffee. This is often done with heat from a hot plate or an electrical heating coil that you used in the investigation. The human body must stay at approximately 98.6°F. A change in body temperature of just 10°F will kill a person. A 110-lb person has a mass of approximately 50 kg.

   a) Devise a way to find out how much energy is required to keep this 50-kg person at 98.6°F (37°C), when they are in a room that is 20°C.

   b) What percentage of that person's 2000 C of food would be used to maintain body temperature?

What Do You Think Now?

At the beginning of this section, you were asked:

- **If an electrical heating coil (a type of resistor) were submerged in a container of water, and if a current were to flow through the coil to make it hot, what factors would affect the temperature increase of the water?**

Having completed this section and the previous section, identify as many factors as you can, and predict the effect of each on the water temperature.

Active Physics 684

1.a)

The change in gravitational potential energy each time 20 kg is lifted 1 m from the floor is

$\Delta U_g = mg\Delta h =$

$(20\ \text{kg})(10\ \text{m/s}^2)(1\ \text{m}) = 200\ \text{J}.$

1.b)

The amount of energy required to heat up 1 cup (250 g) of water is

$\Delta Q = mc\Delta T =$

$(250\ \text{g})\left(4.18\dfrac{\text{J}}{\text{g}\ ^\circ\text{C}}\right)\times$

$(100\ ^\circ\text{C} - 20\ ^\circ\text{C}) = 83{,}600\ \text{J}.$

1.c)

The athlete lifts the 20 kg mass every second. Each time the mass is lifted, the athlete does 200 J of work, and then gravity can do 200 J of work on the weight bringing it down. This 200 J can be transformed to heat energy to warm the water. Assuming all the gravitational potential energy eventually is transferred to thermal energy of the water, the number of lifts required will be

$$\text{Number of lifts} = \frac{(\text{heat energy needed})}{\left(\begin{array}{c}\text{gravitational energy}\\ \text{available per lift}\end{array}\right)} =$$

$$\frac{83{,}600\ \text{J}}{200\ \text{J/lift}} = 418\ \text{lifts}$$

Because each lift requires 1 s of time, the total time needed would be 418 s or about 7 min.

2.

Students' should list the many different transformations of energy that occur in humans. Energy is needed to maintain our body temperature, all the systems (circulatory, digestive, respiratory, neural, immune, etc.) of the body as well as create new cells, and defend the systems from invaders.

2.a)

Students should change an hour to seconds.

$E_{\text{total/hour}} =$

$\left(200\dfrac{\text{J}}{\text{s}}\right)(3600\ \text{s}) = 720{,}000\ \text{J}$

2.b)

Students should first figure out how many joules are in a 2000-C day. This is found by using the conversion provided.

$$(2000\ \text{C})\left(\frac{4185\ \text{J}}{1\ \text{C}}\right) = 8{,}370{,}000\ \text{J}$$

The percentage of the athletes energy input to the amount of energy used to lift the weights nonstop for an hour is

Percentage of food =

$$\frac{\text{energy output}}{\text{energy input}} \times 100\% =$$

$$\frac{720{,}000\ \text{J}}{8{,}370{,}000\ \text{J}} \times 100\% = 8.6\%$$

2.c)

Students should realize that at this rate the athlete is expending about twice the energy he or she consumes. The energy output is greater than the input. This means the athlete will need to eat twice as much.

3.a)

There are many possible ideas students might devise to figure out how much energy is required to keep a 50-kg person at body temperature when they are in a room 17°C cooler than their body temperature. Students should realize that the temperature difference of 17°C indicates that heat energy will be transferred from the person to the room. One might consider that because a person is usually in a room of 20°C (68°F) it is part of the common energy consumption of the 2000-C dietary intake and probably the bulk of energy usage. For a person to maintain body temperature, he or she will need to transform some of their input food energy to thermal energy. To find out how much energy is needed, one could leave the person in a 20°C room and vary the amount of food intake and see how that might affect a person's temperature.

An alternative way might be to put the person in an isolated tank of water (a calorimeter) with an oxygen tank and measure how the water temperature increases over a short time in order to determine the person's specific heat.

However, the easiest method may be to assume humans are basically water (in reality only composed of about 65% water), and have a specific heat equal to water (in reality it is about 15% less than water). The problem then becomes, how much energy is needed to maintain water at a temperature of 37° C in a room of air temperature 17° C. To investigate this, the students may model the human body with a beaker of water. The water should be placed in a container of some sort, maybe a beaker or a metal can—1 kg should be sufficient—on a hot plate. To maintain the water at 37°C, first heat it up to 37°C, then wrap it in a piece of cloth to simulate clothing (or do without to simulate minimal clothing). Place the container on a hot plate of variable settings, and put a thermometer into the water. The room should be at 20°C. Various settings of the hot plate should be tried until the water maintains the temperature of around 37°C. This may require turning the hot plate on for a few minutes on a low setting, then turning it off for a while. When the temperature of the water seems to vary around 37°C fairly consistently, measure the input energy using $E = Pt$ to get the amount of energy required for constant temperature. Scale up from the 1 kg to 50 kg and convert to kilocalories from joules at $1\ \text{C} = 4185\ \text{J}$.

3.b)

To calculate the percentage of the person's 2000 C of food energy input, one should use the following equation, after converting kilocalories (C) into joules.

Percentage of food =

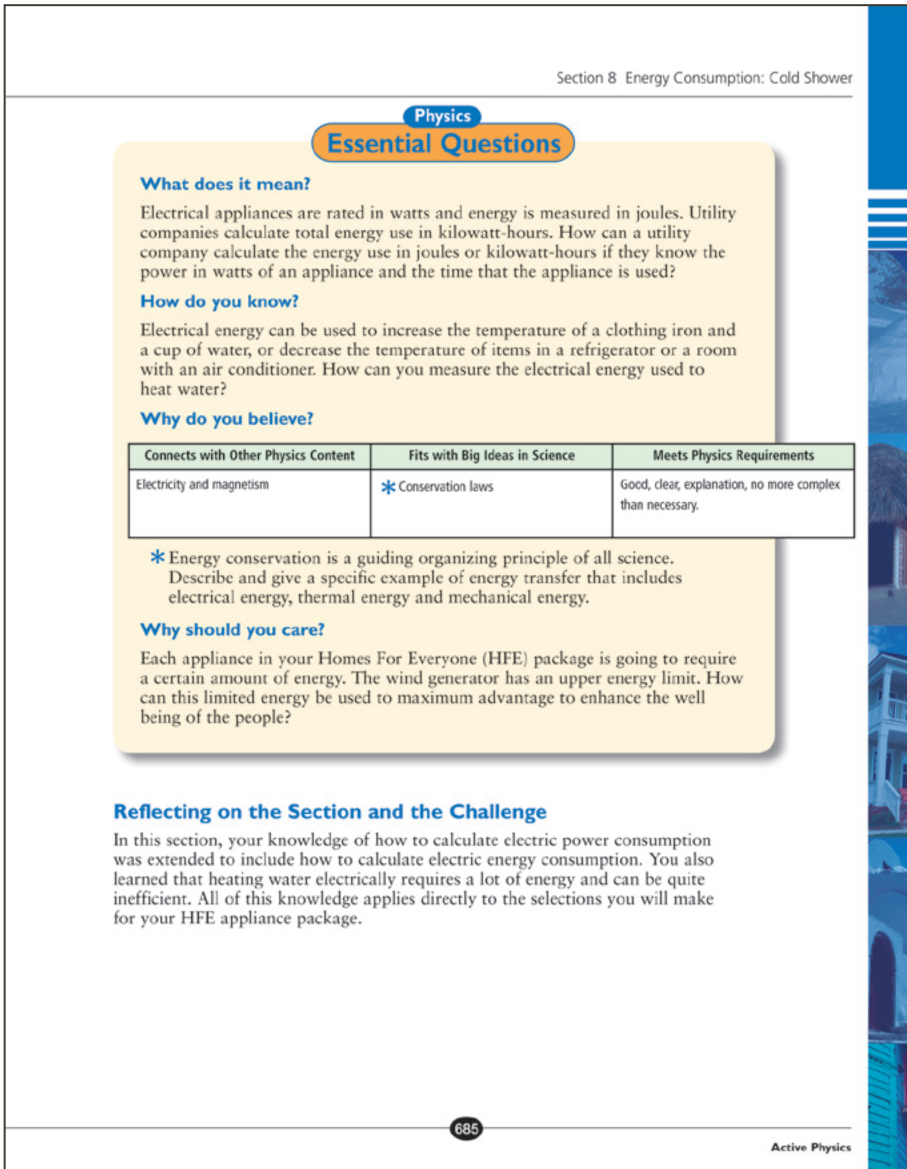
$$\frac{\text{energy output}}{\text{energy input}} \times 100\% =$$

$$\frac{\text{energy output}}{8{,}370{,}000\ \text{J}} \times 100\%$$

What Do You Think Now?

Now is the time for students to review their previous answers to the question. They will find that their answers need to be updated to accommodate changes in their ideas. Record the factors students think are responsible for the temperature increase of the water. Students should explain how the factors they have identified are responsible for an increase in the temperature of water. Discussing the information in *A Physicist's Response* will help students to support their responses with the physics concepts they have investigated in this chapter.

NOTES



Section 8 Energy Consumption: Cold Shower

Physics

Essential Questions

What does it mean?

Electrical appliances are rated in watts and energy is measured in joules. Utility companies calculate total energy use in kilowatt-hours. How can a utility company calculate the energy use in joules or kilowatt-hours if they know the power in watts of an appliance and the time that the appliance is used?

How do you know?

Electrical energy can be used to increase the temperature of a clothing iron and a cup of water, or decrease the temperature of items in a refrigerator or a room with an air conditioner. How can you measure the electrical energy used to heat water?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Electricity and magnetism	* Conservation laws	Good, clear, explanation, no more complex than necessary.

* Energy conservation is a guiding organizing principle of all science. Describe and give a specific example of energy transfer that includes electrical energy, thermal energy and mechanical energy.

Why should you care?

Each appliance in your Homes For Everyone (HFE) package is going to require a certain amount of energy. The wind generator has an upper energy limit. How can this limited energy be used to maximum advantage to enhance the well being of the people?

Reflecting on the Section and the Challenge

In this section, your knowledge of how to calculate electric power consumption was extended to include how to calculate electric energy consumption. You also learned that heating water electrically requires a lot of energy and can be quite inefficient. All of this knowledge applies directly to the selections you will make for your HFE appliance package.

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Active Physics

Reflecting on the Section and the Challenge

Using the information in the student text, discuss how the students have calculated the energy consumption for heating water by using the power rating and by calculating the heat transferred to water, and from this how they calculated the efficiency of heating water. Emphasize how this information will be important when they consider their appliance design package for the HFE.

Physics Essential Questions

What does it mean?

When hot and cold water are mixed, the cold water will gain energy and become warmer. Assuming no losses, the hot water will lose an equal amount of energy and become cooler. The energy gained can be determined from the power rating of the heating coil using the relationship

Power = Energy/time

Energy = Power × time

How do you know?

The energy can be computed by measuring the voltage, current, and time. $P = VI$, and $E = Pt$.

Why do you believe?

A hand generator uses mechanical energy to produce electrical energy. The electrical energy can light up a bulb, thereby producing light energy and thermal energy.

Why should you care?

The value of each appliance in enhancing the well being of the people must be considered while choosing appliances and the time that they will be used.

CHAPTER 6

Physics to Go

1.

The energy supplied to the water heater was not all transferred to the water. Some other places this energy might have been transferred to are the thermometer, the warming the air above the water, and the cup. Some of the electrical energy may have been transformed to thermal energy in the wiring of the circuit, while some energy may have remained in the heating coil.

2.

Hot-water heaters in homes try to make themselves isolated systems but they are not. Heat transferred to the water may be transferred to connecting copper pipes, which have a low specific heat and transfer heat away rapidly. Heat may be transferred from the water heater through the insulation or through connecting joints to the heater. Making sure insulation is sufficient and insulating pipes as much as possible is also very helpful. Having variable settings for the hot-water heater is also useful; for example, regulating it so that it does not heat the water while members of the home are usually out during the day or on vacation, and keeping the water temperature as low as possible.

3.

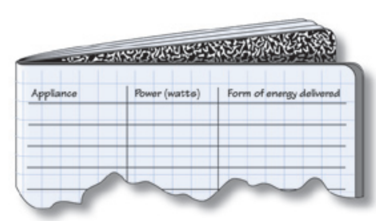
Students' ideas should be supported with reasons. For example, some students might suggest that because it is so energy intensive to heat water, the water should be heated using solar energy. They might even consider designing a solar heating method!

Chapter 6 Electricity for Everyone

Physics to Go

1. The calorimeter did not allow the water to trap 100% of the energy delivered to it by the resistor. Some of the heat probably escaped from the water. Identify and explain ways in which you think heat may have escaped from the water, reducing the efficiency of the calorimeter.
2. The calorimeter used in this investigation can be thought of as a scaled-down, crude version of a household hot-water heater. The efficiencies of hot-water heaters used in homes range from about 80% for older models to as much as 92% for new, energy-efficient models. Identify and explain ways in which you think heat escapes from household hot-water heaters, and how you could improve the efficiency of the heater.
3. From what you have learned so far, discuss the possibilities for providing electrically heated water for Homes For Everyone (HFE). Is a standard water heater of the kind used in American homes desirable, or possible, for HFE? What other electrical options exist for accomplishing part or all of the task of heating water for HFE?
4. For most Americans, the second biggest energy user in the home, next to the heating/air-conditioning system, is the water heater. A family of four that heats water electrically (some use gas or oil to heat water) typically spends about $35 per month using a 4500-W heater to keep a 160-L (40 gallon) tank of water hot at all times. The water is raised from an average inlet temperature of 10°C (50°F) to a temperature of 60°C (140°F), and the average family uses about 250 L (60 gallons) of hot water per day for bathing and washing clothes and dishes.

   In the above description, explain what each of the following numbers represents: 35, 4500, 160, 40, 10, 50, 60, 140, 250, 60.
5. Electrical appliances are designed to convert electrical energy into some other form of energy. Choose five appliances from the list of Home Electrical Appliances beginning on the next page that have a wide range of power. In your log, make a list like the one shown.



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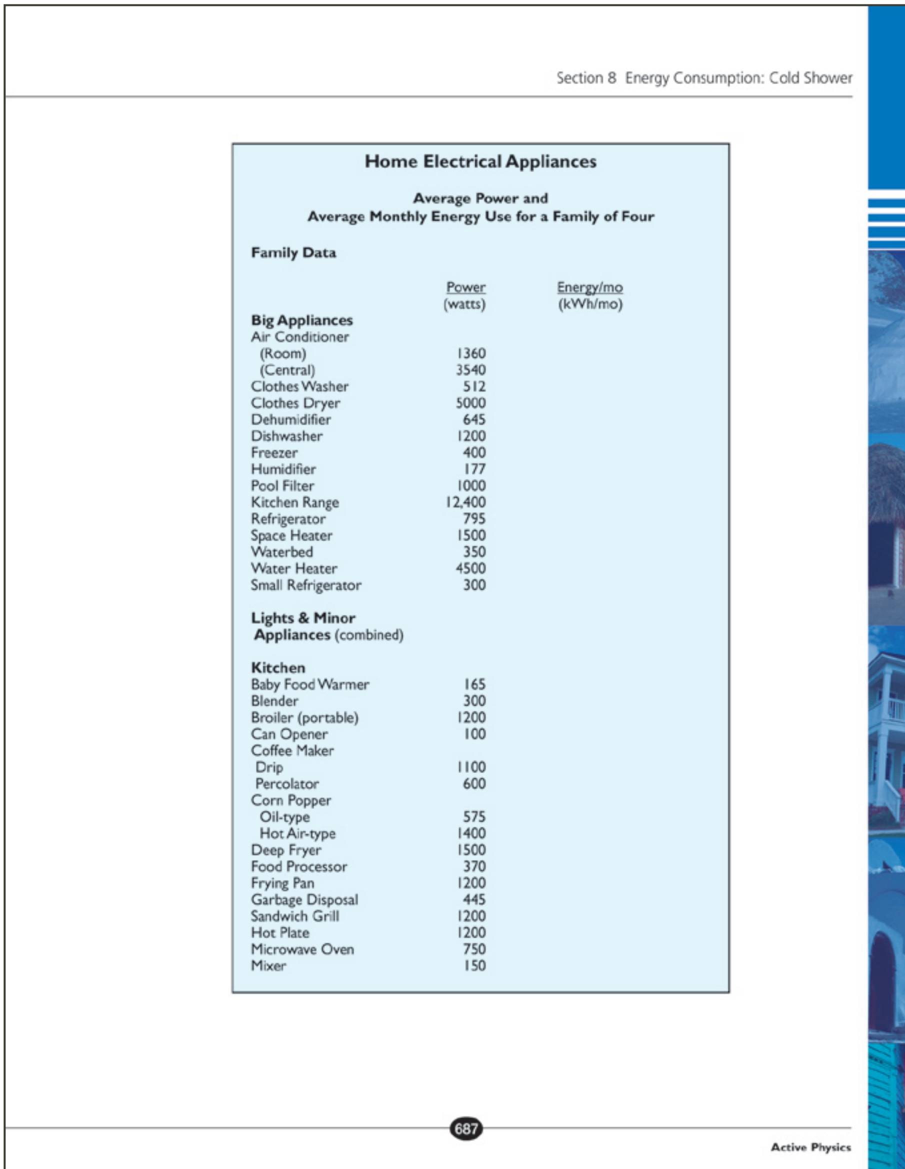
Active Physics

4.

- 35 is the number of dollars that a family of four typically spends in a month for heating water.
- 4500 is the power rating (4500 watts) of the typical water heater.
- 160 is the volume of water in the water heater measured in liters.
- 40 is the volume of water in the water heater measured in gallons.
- 10 is the initial temperature in ˚C of the water entering the hot-water tank.
- 60 is the final temperature in ˚C of the warmed water in the hot-water tank.
- 50 is the initial temperature in ˚F of the water entering the hot-water tank.
- 140 is the final temperature in ˚F of the warmed water in the hot-water tank.



Home Electrical Appliances

Average Power and
Average Monthly Energy Use for a Family of Four

Family Data

	Power (watts)	Energy/mo (kWh/mo)
Big Appliances		
Air Conditioner		
(Room)	1360	
(Central)	3540	
Clothes Washer	512	
Clothes Dryer	5000	
Dehumidifier	645	
Dishwasher	1200	
Freezer	400	
Humidifier	177	
Pool Filter	1000	
Kitchen Range	12,400	
Refrigerator	795	
Space Heater	1500	
Waterbed	350	
Water Heater	4500	
Small Refrigerator	300	
Lights & Minor Appliances (combined)		
Kitchen		
Baby Food Warmer	165	
Blender	300	
Broiler (portable)	1200	
Can Opener	100	
Coffee Maker		
Drip	1100	
Percolator	600	
Corn Popper		
Oil-type	575	
Hot Air-type	1400	
Deep Fryer	1500	
Food Processor	370	
Frying Pan	1200	
Garbage Disposal	445	
Sandwich Grill	1200	
Hot Plate	1200	
Microwave Oven	750	
Mixer	150	

5.

Students record at least five different appliances from the list of Home Electrical Appliances with their power ratings and what form of energy they deliver. Students should describe the relationships between power and form of usable energy delivered, and discuss any patterns they may find in this information. For example, appliances used for heating have higher power rating then those designed to produce sound. A few examples representative of the students' answers are listed in the table below.

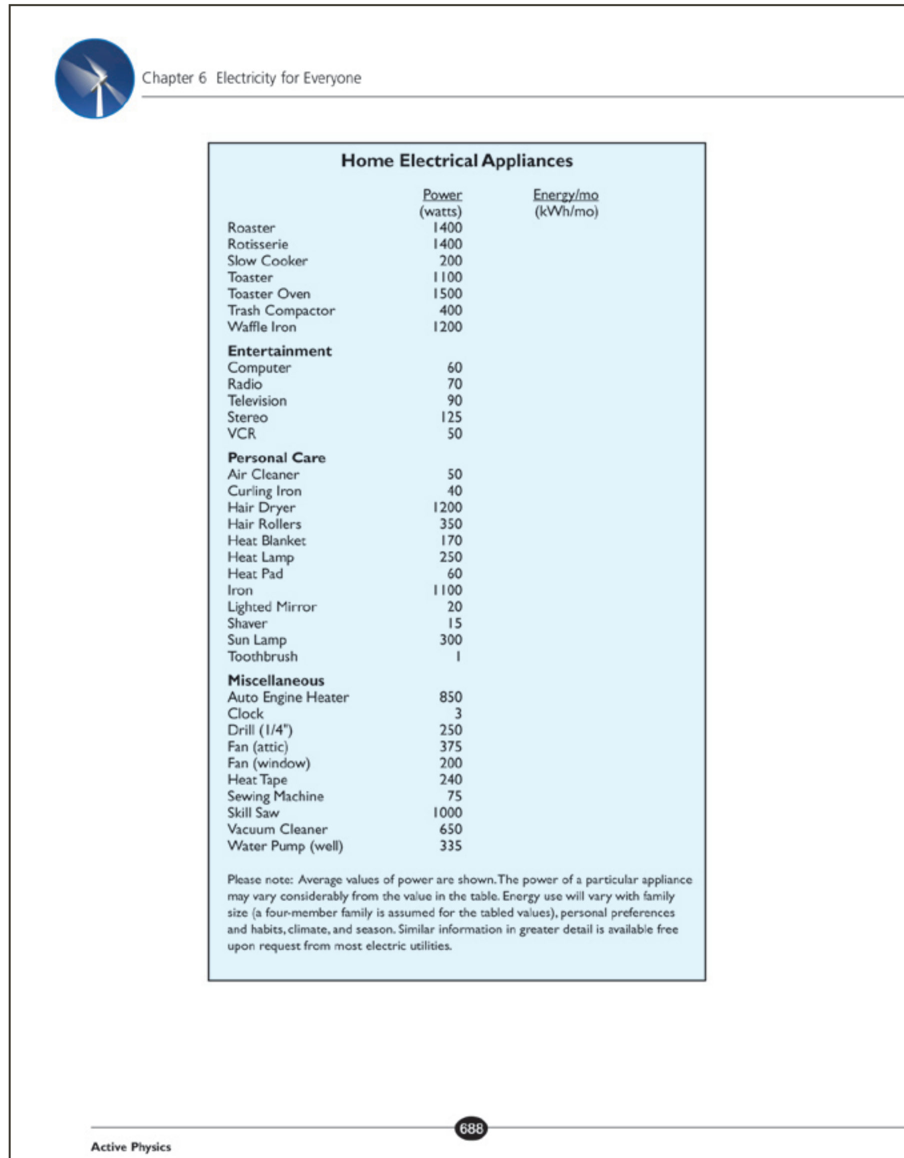
- 250 is the volume of hot water measured in liters that the average family of four uses in a day.
- 60 is the volume of hot water measured in gallons that the average family of four uses in a day.

Appliance	Power (watts)	Form of Energy Delivered
Air conditioner (room/central)	1360/3540	kinetic energy, heat – transfer of heat energy out of room, (sound)
Clothes washer	512	kinetic, heat, (sound)
Clothes dryer	5000	heat, kinetic energy, (sound)
Kitchen range	12,400	heat
Refrigerator	795	kinetic energy, heat, light, (sound)
Microwave oven	750	light – microwaves and visible, kinetic energy, (sound, heat)

CHAPTER 6

6.

Students should construct a table in their log similar to the one below and record the name and power rating of appliances from the list provided. They also record the approximate time each appliance is used per day and calculate the time used for a month (assuming 30 days/month). To calculate the energy consumption in units of kilowatt-hours, they should use $E = Pt$.



Chapter 6 Electricity for Everyone

Home Electrical Appliances

	Power (watts)	Energy/mo (kWh/mo)
Roaster	1400	
Rotisserie	1400	
Slow Cooker	200	
Toaster	1100	
Toaster Oven	1500	
Trash Compactor	400	
Waffle Iron	1200	
Entertainment		
Computer	60	
Radio	70	
Television	90	
Stereo	125	
VCR	50	
Personal Care		
Air Cleaner	50	
Curling Iron	40	
Hair Dryer	1200	
Hair Rollers	350	
Heat Blanket	170	
Heat Lamp	250	
Heat Pad	60	
Iron	1100	
Lighted Mirror	20	
Shaver	15	
Sun Lamp	300	
Toothbrush	1	
Miscellaneous		
Auto Engine Heater	850	
Clock	3	
Drill (1/4")	250	
Fan (attic)	375	
Fan (window)	200	
Heat Tape	240	
Sewing Machine	75	
Skill Saw	1000	
Vacuum Cleaner	650	
Water Pump (well)	335	

Please note: Average values of power are shown. The power of a particular appliance may vary considerably from the value in the table. Energy use will vary with family size (a four-member family is assumed for the tabled values), personal preferences and habits, climate, and season. Similar information in greater detail is available free upon request from most electric utilities.

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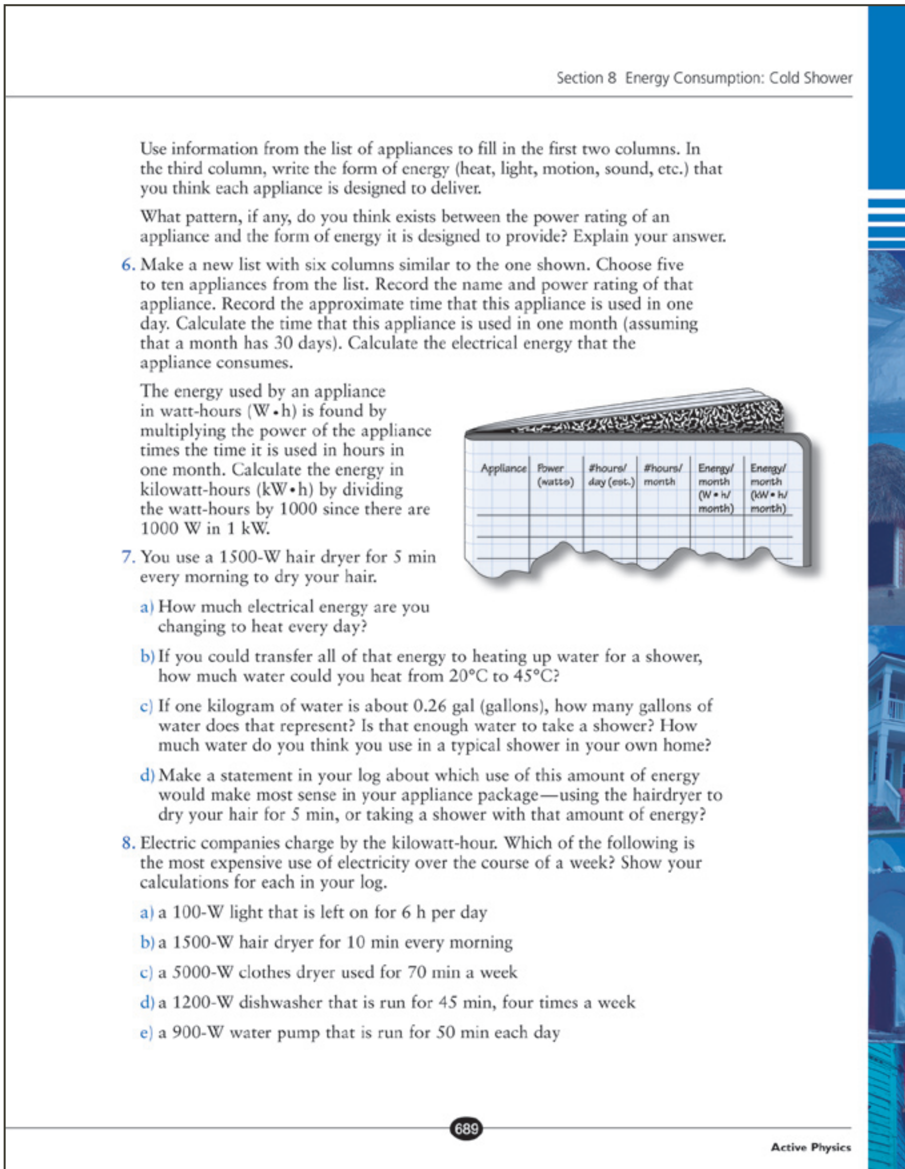
Appliance	Power (watts)	# hours/ day	# hours/ month	Energy/month (W·h/month)	Energy/month (kW·h/month)
Clothes washer	512	1	30	(30 h/month) (512 W) = 15,360	15.3
Clothes dryer	5000	1	30	(30 h/month) (5000 W) = 150,000	150
Coffee maker	1100	0.5	30	(15 h/month) (1100 W) = 16,500	16.5



Section 8 Energy Consumption: Cold Shower

Use information from the list of appliances to fill in the first two columns. In the third column, write the form of energy (heat, light, motion, sound, etc.) that you think each appliance is designed to deliver.

What pattern, if any, do you think exists between the power rating of an appliance and the form of energy it is designed to provide? Explain your answer.

6. Make a new list with six columns similar to the one shown. Choose five to ten appliances from the list. Record the name and power rating of that appliance. Record the approximate time that this appliance is used in one day. Calculate the time that this appliance is used in one month (assuming that a month has 30 days). Calculate the electrical energy that the appliance consumes.

The energy used by an appliance in watt-hours (W•h) is found by multiplying the power of the appliance times the time it is used in hours in one month. Calculate the energy in kilowatt-hours (kW•h) by dividing the watt-hours by 1000 since there are 1000 W in 1 kW.

7. You use a 1500-W hair dryer for 5 min every morning to dry your hair.

a) How much electrical energy are you changing to heat every day?

b) If you could transfer all of that energy to heating up water for a shower, how much water could you heat from 20°C to 45°C?

c) If one kilogram of water is about 0.26 gal (gallons), how many gallons of water does that represent? Is that enough water to take a shower? How much water do you think you use in a typical shower in your own home?

d) Make a statement in your log about which use of this amount of energy would make most sense in your appliance package—using the hairdryer to dry your hair for 5 min, or taking a shower with that amount of energy?

8. Electric companies charge by the kilowatt-hour. Which of the following is the most expensive use of electricity over the course of a week? Show your calculations for each in your log.

a) a 100-W light that is left on for 6 h per day

b) a 1500-W hair dryer for 10 min every morning

c) a 5000-W clothes dryer used for 70 min a week

d) a 1200-W dishwasher that is run for 45 min, four times a week

e) a 900-W water pump that is run for 50 min each day

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7.a)

Students may solve this problem giving the energy value in joules, kilojoules, watt-hours, or kilowatt-hours. Assuming all the electrical energy is transformed to heat energy,

Given:

$P = 1500\ \text{W};\ t = 5\ \text{min}$

$E = Pt =$

$(1500\ \text{W})(5\ \text{min})\left(\dfrac{60\ \text{s}}{1\ \text{min}}\right)$

$E = 450{,}000\ \text{J} = 450\ \text{kJ}$

$E = Pt =$

$(1500\ \text{W})(5\ \text{min})\left(\dfrac{1\ \text{h}}{60\ \text{min}}\right)$

$E = 125\ \text{W}\cdot\text{h} = 0.125\ \text{kW}\cdot\text{h}$

7.b)

Assuming all the energy gets transferred to warming the water, the amount of water that could be warmed from 20°C to 45°C is

$\Delta Q = mc\Delta T$

$m = \dfrac{\Delta Q}{c\Delta T} =$

$\dfrac{450{,}000\ \text{J}}{\left(4.18\dfrac{\text{J}}{\text{g°C}}\right)(45°\text{C} - 20°\text{C})} =$

$4306\ \text{g}$

7.c)

Using 1 kg of water = 0.26 gal, and the result from *7.b)*, you have

$m = 4306\ \text{g} = 4.306\ \text{kg}$

$m = (4.306\ \text{kg})\left(\dfrac{0.26\ \text{gal}}{1\ \text{kg}}\right) =$

$1.12\ \text{gal}$

This is not enough to take a shower, but it is enough to clean oneself. Most modern showerheads are designed to save water and allow 2 to 4 gallons to flow per minute. A two-minute shower would use 4 to 8 gallons of water.

7.d)

Students should record their ideas in their log. Most students should realize that warm water to clean oneself is more important than drying hair, which can air-dry.

8.a)

Students should show their calculations for energy usage over a week's time for each appliance.

$E = Pt =$

$(100\ \text{W})\left(\dfrac{6\ \text{h}}{1\ \text{day}}\right)\left(\dfrac{7\ \text{day}}{1\ \text{week}}\right) =$

$\dfrac{4200\ \text{W}\cdot\text{h}}{\text{week}} = \dfrac{4.2\ \text{kW}\cdot\text{h}}{\text{week}}$

8.b)

$$E = Pt =$$

$$(1500\ \text{W})\left(\frac{10\ \text{min}}{1\ \text{day}}\right)\times$$

$$\left(\frac{1\ \text{h}}{60\ \text{min}}\right)\left(\frac{7\ \text{day}}{1\ \text{week}}\right)=$$

$$\frac{1750\ \text{W}\cdot\text{h}}{\text{week}}=\frac{1.75\ \text{kW}\cdot\text{h}}{\text{week}}$$

8.c)

$$E = Pt =$$

$$(5000\ \text{W})\left(\frac{70\ \text{min}}{1\ \text{week}}\right)\left(\frac{1\ \text{h}}{60\ \text{min}}\right)$$

$$E=\frac{5833\ \text{W}\cdot\text{h}}{\text{week}}=\frac{5.83\ \text{kW}\cdot\text{h}}{\text{week}}$$

8.d)

$$E = Pt =$$

$$(1200\ \text{W})\left(4\times\frac{45\ \text{min}}{1\ \text{week}}\right)\left(\frac{1\ \text{h}}{60\ \text{min}}\right)$$

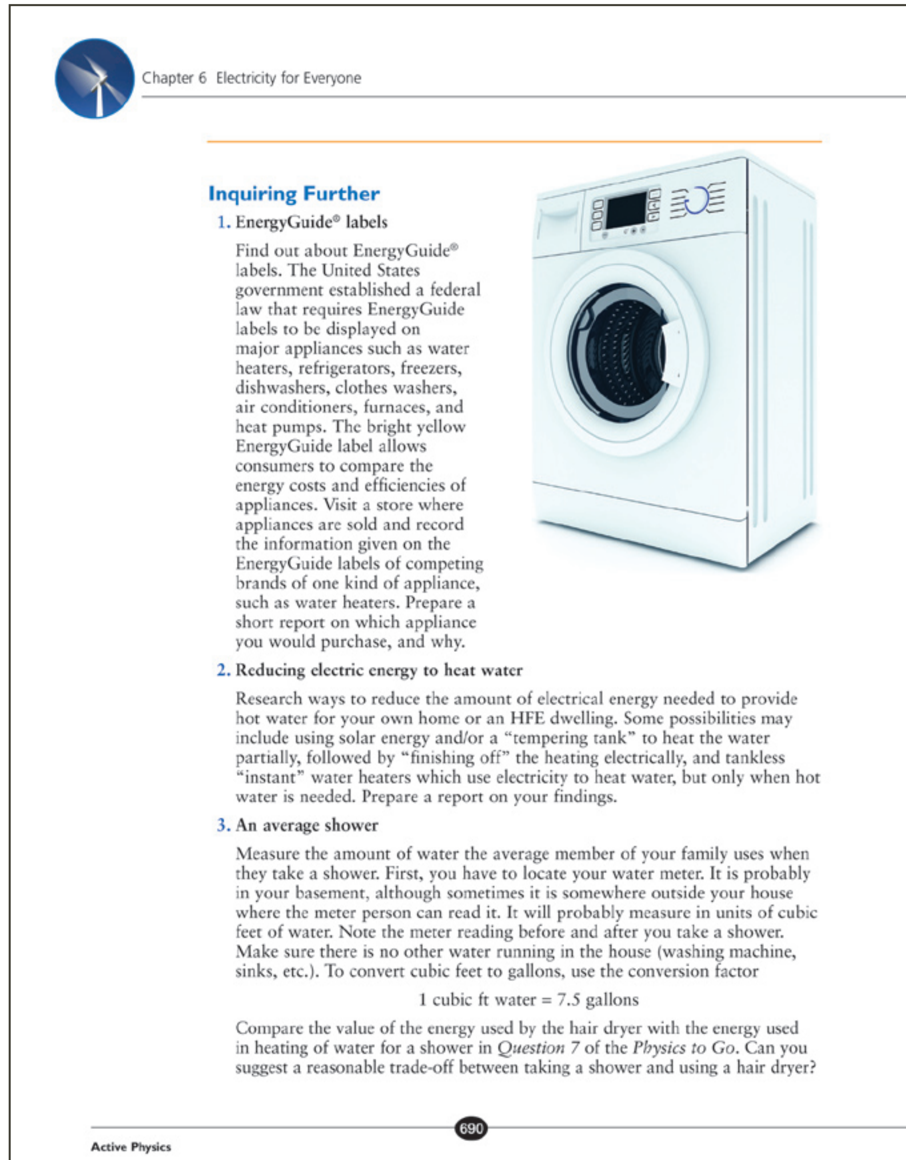
$$E=\frac{3600\ \text{W}\cdot\text{h}}{\text{week}}=\frac{3.6\ \text{kW}\cdot\text{h}}{\text{week}}$$

8.e)

$$E = Pt = (900\ \text{W})\left(\frac{50\ \text{min}}{1\ \text{day}}\right)\times$$

$$\left(\frac{1\ \text{h}}{60\ \text{min}}\right)\left(\frac{7\ \text{day}}{1\ \text{week}}\right)$$

$$E=\frac{5250\ \text{W}\cdot\text{h}}{\text{week}}=\frac{5.25\ \text{kW}\cdot\text{h}}{\text{week}}$$



Chapter 6 Electricity for Everyone

Inquiring Further

1. **EnergyGuide® labels**

   Find out about EnergyGuide® labels. The United States government established a federal law that requires EnergyGuide labels to be displayed on major appliances such as water heaters, refrigerators, freezers, dishwashers, clothes washers, air conditioners, furnaces, and heat pumps. The bright yellow EnergyGuide label allows consumers to compare the energy costs and efficiencies of appliances. Visit a store where appliances are sold and record the information given on the EnergyGuide labels of competing brands of one kind of appliance, such as water heaters. Prepare a short report on which appliance you would purchase, and why.

2. **Reducing electric energy to heat water**

   Research ways to reduce the amount of electrical energy needed to provide hot water for your own home or an HFE dwelling. Some possibilities may include using solar energy and/or a "tempering tank" to heat the water partially, followed by "finishing off" the heating electrically, and tankless "instant" water heaters which use electricity to heat water, but only when hot water is needed. Prepare a report on your findings.

3. **An average shower**

   Measure the amount of water the average member of your family uses when they take a shower. First, you have to locate your water meter. It is probably in your basement, although sometimes it is somewhere outside your house where the meter person can read it. It will probably measure in units of cubic feet of water. Note the meter reading before and after you take a shower. Make sure there is no other water running in the house (washing machine, sinks, etc.). To convert cubic feet to gallons, use the conversion factor

   1 cubic ft water = 7.5 gallons

   Compare the value of the energy used by the hair dryer with the energy used in heating of water for a shower in *Question 7* of the *Physics to Go*. Can you suggest a reasonable trade-off between taking a shower and using a hair dryer?

Active Physics 690

Inquiring Further

1.

Students should research an appliance, such as a water heater, dishwasher, refrigerator, washing machine, dryer, air conditioner, furnace, or heat pump. They should compare the energy consumption and discuss the EnergyGuide labels used to describe these products. Students should then write a report comparing the devices and state which one they would purchase and why.

2.

Students should write a report containing research on how to reduce the amount of electrical energy needed to provide hot water for their home or the HFE dwelling. They could include solar energy and/or a tempering tank to heat the water partially, followed by finishing off the heating electrically and tankless instant water heaters (also called flash heaters) which use electricity to heat water at the faucet when it is needed.

3.

Students should estimate the amount of water their family uses for a shower by reading their water meter before and after someone takes a shower. They should then compare the value of the energy used by the hair dryer with the energy used in heating the water for a shower as in the *Physics to Go*, *Question 7*.

NOTES

SECTION 8 QUIZ

6-8c **Blackline Master**

1. Students in a class are doing an experiment to measure the efficiency of a heating coil when heating water. The energy gained by the water is 4000 J when heated by a 300-W heater for 20 s. How much energy would the coil provide to the water during the 20 s if all the energy were transferred to the water?

   a) 4000 J b) 6000 J

   c) 8000 J d) 15,000 J

2. In *Question 1*, what is the efficiency of the water-heating process?

   a) 67% b) 75%

   c) 80% d) 90%

3. A wind generator for a home generates an average of 0.50 A of current at 48 V. If the generator runs for an average time of 6 h each day, how much energy does it generate per day?

   a) 4 W·h b) 16 W·h

   c) 64 W·h d) 144 W·h

4. A 60-W light bulb runs on 120 V and draws 0.50 A of current when running for 10 minutes (600 seconds). How much energy does the light bulb use up in this time?

   a) 600 J b) 6000 J

   c) 36,000 J d) 72,000 J

5. A student wishes to heat the water in the school swimming pool by circulating water through an immersion heater in a separate tank. The pool contains 100,000 kg of water. Each kilogram of water needs 4000 J of energy to increase its temperature by 1°C. How long must a 10,000-W heater run to raise the pools temperature one degree?

   a) 1000 s b) 2000 s

   c) 4000 s d) 8000 s

SECTION 8 QUIZ ANSWERS

1. b) $E = Pt = (300 \text{ W})(20 \text{ s}) = 6000 \text{ J}$

2. a) $\text{Efficiency} = \dfrac{\text{useful energy}}{\text{total energy input}} = \dfrac{4000 \text{ J}}{6000 \text{ J}} \times 100\% = 67\%$

3. d) $E = Pt = VIt = (48 \text{ V})(0.50 \text{ A})(6 \text{ h}) = 144 \text{ W} \cdot \text{h}$

4. c) $E = Pt = VIt = (120 \text{ V})(0.50 \text{ A})(600 \text{ s}) = 36{,}000 \text{ J}$

5. c) $E = Pt$, therefore $t = \dfrac{E}{P} = \dfrac{(100{,}000 \text{ kg})(4000 \text{ J/kg})}{10{,}000 \text{ W}} = 4000 \text{ s}$