Learning Objectives

- To define energy and heat.

Energy is the ability to do work. You can understand what this means by thinking about yourself when you feel “energetic.” You feel ready to go—to jump up and get something done. When you have a lot of energy, you can perform a lot of work. By contrast, if you do not feel energetic, you have very little desire to do much of anything. This description is not only applicable to you but also to all physical and chemical processes. The quantity of work that can be done is related to the quantity of energy available to do it.

Energy can be transferred from one object to another if the objects have different temperatures. The transfer of energy due to temperature differences is called heat. For example, if you hold an ice cube in your hand, the ice cube slowly melts as energy in the form of heat is transferred from your hand to the ice. As your hand loses energy, it starts to feel cold.

Because of their interrelationships, energy, work, and heat have the same units. The SI unit of energy, work, and heat is the joule (J). A joule is a tiny amount of energy. For example, it takes about 4 J to warm 1 mL of H₂O by 1°C. Many processes occur with energy changes in thousands of joules, so the kilojoule (kJ) is also common. Another unit of energy, used widely in the health professions and everyday life, is the calorie (cal). The calorie was initially defined as the amount of energy needed to warm 1 g of H₂O by 1°C, but in modern times, the calorie is related directly to the joule, as follows:

\[ 1\; \text{cal} = 4.184\; \text{J} \]

We can use this relationship to convert quantities of energy, work, or heat from one unit to another.

Although the joule is the proper SI unit for energy, we will use the calorie or the kilocalorie (or Calorie) in this chapter because they are widely used by health professionals.

The calorie is used in nutrition to express the energy content of foods. However, because a calorie is a rather small quantity, nutritional energies are usually expressed in kilocalories (kcal), also called Calories (capitalized; Cal). For example, a candy bar may provide 120 Cal (nutritional calories) of energy, which is equal to 120,000 cal. Figure \ref{PageIndex{1}} shows an example. Proteins and carbohydrates supply 4 kcal/g, while fat supplies 9 kcal/g.
Example \((\PageIndex{1})\)

The energy content of a single serving of bread is 70.0 Cal. What is the energy content in calories? In joules?

**SOLUTION**

This is a simple conversion-factor problem. Using the relationship 1 Cal = 1,000 cal, we can answer the first question with a one-step conversion:

\[
\text{Cal} \times \dfrac{1,000 \text{ cal}}{1 \text{ Cal}} = 70,000 \text{ cal}
\]

Then we convert calories into joules

\[
70,000 \text{ cal} \times \dfrac{4.184 \text{ J}}{1 \text{ cal}} = 293,000 \text{ J}
\]

and then kilojoules

\[
293,000 \text{ J} \times \dfrac{1 \text{ kJ}}{1,000 \text{ J}} = 293 \text{ kJ}
\]

The energy content of bread comes mostly from carbohydrates.

Exercise \((\PageIndex{1})\)

The energy content of one cup of honey is 1,030 Cal. What is its energy content in calories and joules?
**To Your Health: Energy Expenditures**

Most health professionals agree that exercise is a valuable component of a healthy lifestyle. Exercise not only strengthens the body and develops muscle tone but also expends energy. After obtaining energy from the foods we eat, we need to expend that energy somehow, or our bodies will store it in unhealthy ways (e.g., fat). Like the energy content in food, the energy expenditures of exercise are also reported in kilocalories, usually kilocalories per hour of exercise. These expenditures vary widely, from about 440 kcal/h for walking at a speed of 4 mph to 1,870 kcal/h for mountain biking at 20 mph. Table \( \PageIndex{1} \) lists the energy expenditure for a variety of exercises. Table \( \PageIndex{1} \): Energy Expenditure of a 180-Pound Person during Selected Exercises

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Energy Expended (kcal/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aerobics, low-level</td>
<td>325</td>
</tr>
<tr>
<td>basketball</td>
<td>940</td>
</tr>
<tr>
<td>bike riding, 20 mph</td>
<td>830</td>
</tr>
<tr>
<td>golfing, with cart</td>
<td>220</td>
</tr>
<tr>
<td>golfing, carrying clubs</td>
<td>425</td>
</tr>
<tr>
<td>jogging, 7.5 mph</td>
<td>950</td>
</tr>
<tr>
<td>racquetball</td>
<td>740</td>
</tr>
<tr>
<td>skiing, downhill</td>
<td>520</td>
</tr>
<tr>
<td>soccer</td>
<td>680</td>
</tr>
</tbody>
</table>
Because some forms of exercise use more energy than others, anyone considering a specific exercise regimen should consult with his or her physician first.

### Summary

Energy is the ability to do work. Heat is the transfer of energy due to temperature differences. Energy and heat are expressed in units of joules.

### Concept Review Exercises

1. What is the relationship between energy and heat?
2. What units are used to express energy and heat?

### Answers

1. Heat is the exchange of energy from one part of the universe to another. Heat and energy have the same units.
2. Joules and calories are the units of energy and heat.

### Exercises

1. Define energy.
2. What is heat?
3. What is the relationship between a calorie and a joule? Which unit is larger?
4. What is the relationship between a calorie and a kilocalorie? Which unit is larger?
5. Express 1,265 cal in kilocalories and in joules.
6. Express 9,043.3 J in calories and in kilocalories.

7. One kilocalorie equals how many kilojoules?

8. One kilojoule equals how many kilocalories?

9. Many nutrition experts say that an average person needs 2,000 Cal per day from his or her diet. How many joules is this?

10. Baby formula typically has 20.0 Cal per ounce. How many ounces of formula should a baby drink per day if the RDI is 850 Cal?

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**Answers**

1. Energy is the ability to do work.

3. 1 cal = 4.184 J; the calorie is larger.

5. 1.265 kcal; 5,293 J

7. 1 kcal = 4.184 kJ

9. $8.4 \times 10^6$ J