Measuring Thermal Energy

5 • 4

Science Words

specific heat

Objectives

- Define *specific heat.*
- Calculate changes in thermal energy.

Specific Heat

If you have jumped into a swimming pool or lake on a hot summer day, did you find the water surprisingly cold? Even though lots of radiant energy has been transferred to the water from the sun, the temperature of the water is still cooler than that of the surroundings.

Different materials need different amounts of heat to produce similar changes in their temperatures. The materials have different specific heats. The **specific heat** (*C*) of a material is the amount of energy it takes to raise the temperature of 1 kg of the material 1 kelvin. Specific heat is measured in joules per kilogram per kelvin [J/(kg · K)]. **Table 5-2** shows the specific heats of some familiar materials. How does the specific heat of water compare with the specific heats of the other materials?

Table 5-2

Specific Heat of Some Common Materials (J/(kg · K))	
Water	4184
Alcohol	2450
Aluminum	920
Carbon (graphite)	710
Sand	664
Iron	450
Copper	380
Silver	235

Heat Absorption

When you see how high the specific heat of water is compared to other materials, do you understand why one of the persons in **Figure 5-16** is testing the water before going in? The materials around the water heat up much faster than the water itself, so the water is cold compared with its surroundings.

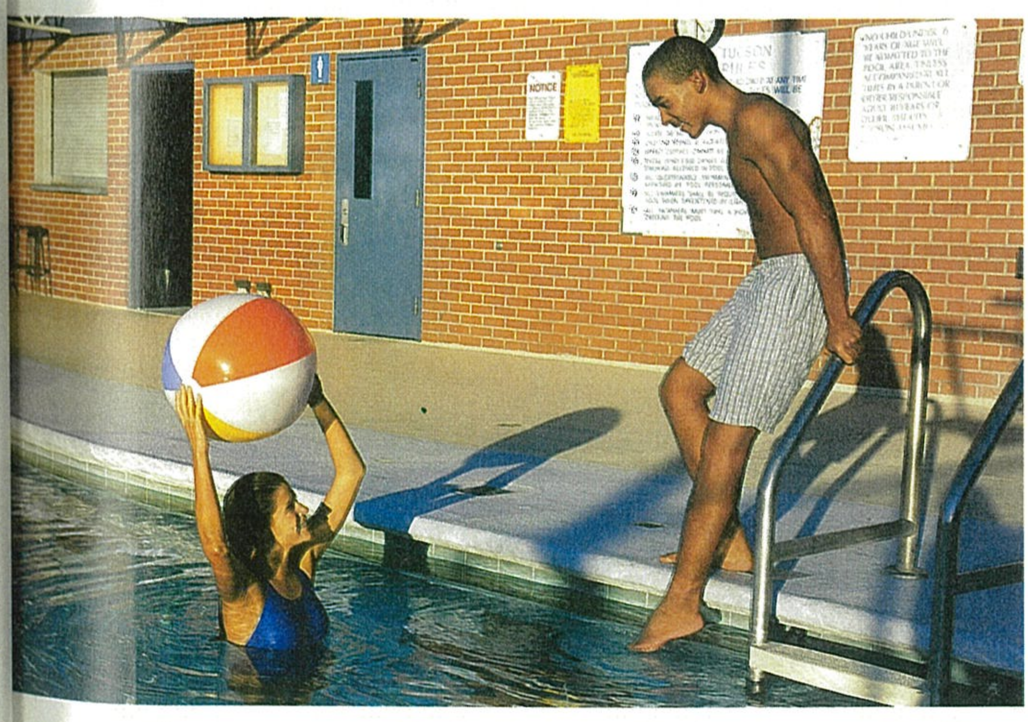


Figure 5-16

Because of its high specific heat, water warms up more slowly than its surroundings.

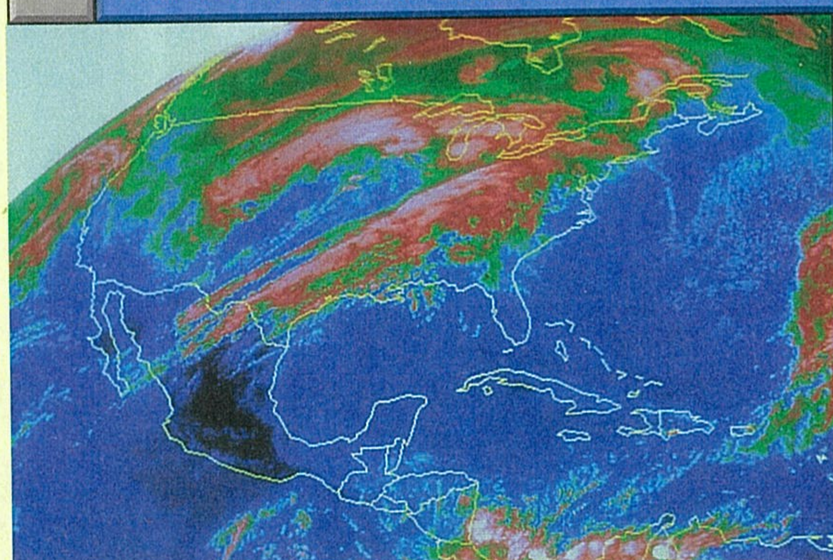
USING TECHNOLOGY

Infrared Weather Eyes

The satellite picture you see on your TV weather show is usually an infrared image captured by a GOES (**G**eostationary **O**perational **E**nvironmental **S**atellite). A GOES remains in orbit directly above the same point on Earth's surface. Each satellite monitors a circular region of the surface 10 000 km across. Within this circle, clouds appear white and Earth's surface appears gray. A meteorologist can point out a line of clouds that indicates a weather front and run a sequence of images to demonstrate how that front is moving.

Warm objects give off more infrared radiation than cool objects. The satellite's sensors measure many bands of infrared radiation. One band indicates moisture in the air. Dry air appears black and moist air appears in varying shades of gray. Because bad weather often breaks out when dry air intrudes into moist air, these water-vapor images can be used to predict storms. Other bands of radiation reveal information about wind speed and direction, rainfall, fog, snow, and ice. Newer satellites may one day provide data for making accurate global weather forecasts 30 to 90 days in advance.

Infrared Photograph of Weather Systems



Think Critically:

In addition to weather information, what other kinds of data could an infrared-measuring satellite provide?

Water, alcohol, and other materials with a high specific heat can absorb a lot of energy with little change in temperature. The specific heats of different substances depend on the chemical makeup of the substances.

Calculating Thermal Changes

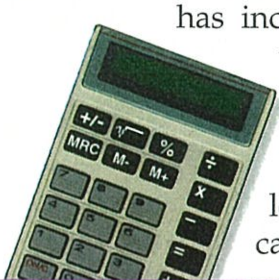
Changes in thermal energy cannot be measured directly, but they can be calculated. Specific heat can be used to determine changes in thermal energy. For example, you can place a heated mass or object in a calorimeter such as the one shown in **Figure 5-17.** By measuring the temperature increase in the water in the calorimeter, you can determine the change in thermal energy. Now, suppose you take a 32-g silver spoon from a pot of water at a temperature of 60°C and allow it to cool to room temperature, which is 20°C. You have enough information to find out the change in the thermal energy of the spoon using the equation below.

$$\text{Change in thermal energy} = \text{mass} \times \text{Change in temperature} \times \text{specific heat}$$

$$Q = m \times \Delta T \times C$$

The symbol Δ (delta) means "change," so ΔT is the change in temperature. "Change" is included in Q, which is the variable for energy change.

$$\Delta T = T_{final} - T_{initial}$$



When ΔT is positive, Q is also positive; the object has increased in temperature and gained thermal energy. When ΔT is negative, Q is also negative; the object has lost thermal energy and decreased in temperature. The problems below will give you practice in calculating changes in thermal energy.

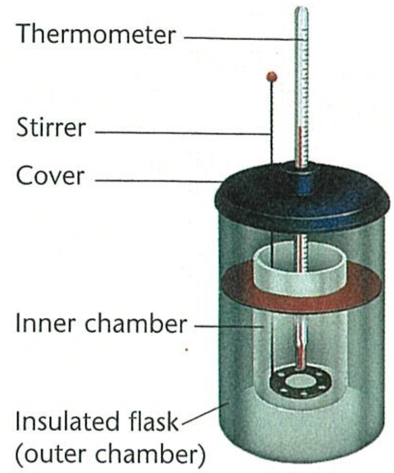


Figure 5-17

Devices like this simple calorimeter are used to measure thermal energy transfer.

USING MATH

Calculating Changes in Thermal Energy

Example Problem:

A 32-g silver spoon cools from 60°C to 20°C. What is the change in its thermal energy?

Problem-Solving Steps:

1. What is known?
   Mass of spoon, $m = 32.0\ \text{g} = 0.0320\ \text{kg}$
   The spoon is made of silver.
   The specific heat, C, of silver is 235 J/(kg · K).
   Initial temperature, $T_{initial} = 60.0°\text{C}$
   Final temperature, $T_{final} = 20.0°\text{C}$
2. What is unknown?
   Change in thermal energy, Q
3. Use the equation $Q = m \times \Delta T \times C$.
4. **Solution:** $Q = m \times (T_{final} - T_{initial}) \times C$
   $= 0.0320\ \text{kg} \times (20.0°\text{C} - 60.0°\text{C}) \times 235\ \text{J/(kg} \cdot \text{K)}$
   $= -301\ \text{J}$
   The spoon loses 301 J of thermal energy as it cools.

Practice Problems

1. Calculate the change in thermal energy when 230 g of water warms from 12°C to 90°C.

Strategy Hint: Will your answer be a positive or negative number?

2. A 45-kg brass sculpture gains 180 480 J of thermal energy as its temperature increases from 28°C to 40°C. What is the approximate specific heat of brass?

Strategy Hint: What is the unknown information?