12.5: Thermal Energy (Exercises)

Conceptual Questions

1. How is heat transfer related to temperature?

2. Describe a situation in which heat transfer occurs.

3. When heat transfers into a system, is the energy stored as heat? Explain briefly.

4. The brakes in a car increase in temperature by **ΔT** when bringing the car to rest from a speed v. How much greater would **ΔT** be if the car initially had twice the speed? You may assume the car stops fast enough that no heat transfers out of the brakes.

Problems

5. *(A bit U.S.-centric. Sorry.)* While traveling outside the United States, you feel sick. A companion gets you a thermometer, which says your temperature is 39. What scale is that on? What is your Fahrenheit temperature? Should you seek medical help?

6. What are the following temperatures on the Kelvin scale?

(a) **68.0°F**, an indoor temperature sometimes recommended for energy conservation in winter

(b) **134°F**, one of the highest atmospheric temperatures ever recorded on Earth (Death Valley, California, 1913)

(c) **9890°F**, the temperature of the surface of the Sun

6. (a) Suppose a cold front blows into your locale and drops the temperature by 40.0 Fahrenheit degrees. How many degrees Celsius does the temperature decrease when it decreases by **40.0°F**? (b) Show that any change in temperature in Fahrenheit degrees is nine-fifths the change in Celsius degrees
7. An Associated Press article on climate change said, “Some of the ice shelf’s disappearance was probably during times when the planet was 36 degrees Fahrenheit (2 degrees Celsius) to 37 degrees Fahrenheit (3 degrees Celsius) warmer than it is today.” What mistake did the reporter make?
8. (a) At what temperature do the Fahrenheit and Celsius scales have the same numerical value? (b) At what temperature do the Fahrenheit and Kelvin scales have the same numerical value?
9. A person taking a reading of the temperature in a freezer in Celsius makes two mistakes: first omitting the negative sign and then thinking the temperature is Fahrenheit. That is, the person reads **–x°C** as **x°F**. Oddly enough, the result is the correct Fahrenheit temperature. What is the original Celsius reading? Round your answer to three significant figures.
10. On a hot day, the temperature of an 80,000-L swimming pool increases by **1.50°C**. What is the net heat transfer during this heating? Ignore any complications, such as loss of water by evaporation.
11. To sterilize a 50.0-g glass baby bottle, we must raise its temperature from **22.0°C** to **95.0°C**. How much heat transfer is required?
12. The same heat transfer into identical masses of different substances produces different temperature changes. Calculate the final temperature when 1.00 kcal of heat transfers into 1.00 kg of the following, originally at **20.0°C**:

(a) water;

(b) concrete;

(c) steel; and

(d) mercury.

13. Rubbing your hands together warms them by converting work into thermal energy. If a woman rubs her hands back and forth for a total of 20 rubs, at a distance of 7.50 cm per rub, and with an average frictional force of 40.0 N, what is the temperature increase? The mass of tissues warmed is only 0.100 kg, mostly in the palms and fingers.
14. A **0.250-kg** block of a pure material is heated from **20.0°C** to **65.0°C** by the addition of 4.35 kJ of energy. Calculate its specific heat and identify the substance of which it is most likely composed.
15. Suppose identical amounts of heat transfer into different masses of copper and water, causing identical changes in temperature. What is the ratio of the mass of copper to water?

16. (a) The number of kilocalories in food is determined by calorimetry techniques in which the food is burned and the amount of heat transfer is measured. How many kilocalories per gram are there in a 5.00-g peanut if the energy from burning it is transferred to 0.500 kg of water held in a 0.100-kg aluminum cup, causing a **54.9-°C** temperature increase? Assume the process takes place in an ideal calorimeter, in other words a perfectly insulated container.

17. (b) Compare your answer to the following labeling information found on a package of dry roasted peanuts: a serving of 33 g contains 200 calories. Comment on whether the values are consistent.

18. Following vigorous exercise, the body temperature of an 80.0 kg person is **40.0°C.** At what rate in watts must the person transfer thermal energy to reduce the body temperature to **37.0°C** in 30.0 min, assuming the body continues to produce energy at the rate of 150 W? **(1watt=1joule/secondor1W=1J/s)**

19. In a study of healthy young men^1, doing 20 push-ups in 1 minute burned an amount of energy per kg that for a 70.0-kg man corresponds to 8.06 calories (kcal). How much would a 70.0-kg man's temperature rise if he did not lose any heat during that time?

20. A 1.28-kg sample of water at **10.0°C** is in a calorimeter. You drop a piece of steel with a mass of 0.385 kg at **215°C** into it. After the sizzling subsides, what is the final equilibrium temperature? (Make the reasonable assumptions that any steam produced condenses into liquid water during the process of equilibration and that the evaporation and condensation don't affect the outcome, as we'll see in the next section.)

21. Repeat the preceding problem, assuming the water is in a glass beaker with a mass of 0.200 kg, which in turn is in a calorimeter. The beaker is initially at the same temperature as the water. Before doing the problem, should the answer be higher or lower than the preceding answer? Comparing the mass and specific heat of the beaker to those of the water, do you think the beaker will make much difference?

22. Even when shut down after a period of normal use, a large commercial nuclear reactor transfers thermal energy at the rate of 150 MW by the radioactive decay of fission products. This heat transfer causes a rapid increase in temperature if the cooling system fails (**1watt=1joule/second** or **1W=1J/s** and **1MW=1megawatt**).

    (a) Calculate the rate of temperature increase in degrees Celsius per second (**°C/s**) if the mass of the reactor core is $1.60 \times 10^5 kg$and it has an average specific heat of **0.3349kJ/kg·°C**.

    (b) How long would it take to obtain a temperature increase of **2000°C**, which could cause some metals holding the radioactive materials to melt? (The initial rate of temperature increase would be greater than that calculated here because the heat transfer is concentrated in a smaller mass. Later, however, the temperature increase would slow down because the 500,000-kg steel containment vessel would also begin to heat up.)

23. You leave a pastry in the refrigerator on a plate and ask your roommate to take it out before you get home so you can eat it at room temperature, the way you like it. Instead, your roommate plays video games for hours. When you return, you notice that the pastry is still cold, but the game console has become hot. Annoyed, and knowing that the pastry will not be good if it is microwaved, you warm up the pastry by unplugging the console and putting it in a clean trash bag (which acts as a perfect calorimeter) with the pastry on the plate. After a while, you find that the equilibrium temperature is a nice, warm **38.3°C**. You know that the game console has a mass of 2.1 kg. Approximate it as having a uniform initial temperature of **45°C**. The pastry has a mass of 0.16 kg and a specific heat of **3.0kJ/(kg·°C),** and is at a uniform initial temperature of **4.0°C**. The plate is at the same temperature and has a mass of 0.24 kg and a specific heat of **0.90J/(kg·°C)**. What is the specific heat of the console?

24. Two solid spheres, A and B, made of the same material, are at temperatures of **0°C** and **100°C**, respectively. The spheres are placed in thermal contact in an ideal calorimeter, and they reach an equilibrium temperature of **20°C**. Which is the bigger sphere? What is the ratio of their diameters?

25. In some countries, liquid nitrogen is used on dairy trucks instead of mechanical refrigerators. A 3.00-hour delivery trip requires 200 L of liquid nitrogen, which has a density of $808 kg/m^3$..

    (a) Calculate the heat transfer necessary to evaporate this amount of liquid nitrogen and raise its temperature to **3.00°C**. (Use c_P and assume it is constant over the temperature range.) This value is the amount of cooling the liquid nitrogen supplies.

    (b) What is this heat transfer rate in kilowatt-hours?

    (c) Compare the amount of cooling obtained from melting an identical mass of **0-°C** ice with that from evaporating the liquid nitrogen.

26. Some gun fanciers make their own bullets, which involves melting lead and casting it into lead slugs. How much heat transfer is needed to raise the temperature and melt 0.500 kg of lead, starting from **25.0°C**?

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