Problems

13–1 Atomic Theory

1. (I) How many atoms are there in a 3.4-gram copper penny?
2. (I) How does the number of atoms in a 26.5-gram gold ring compare to the number in a silver ring of the same mass?

13–2 Temperature and Thermometers

3. (I) (*a*) "Room temperature" is often taken to be 68°F. What is this on the Celsius scale? (*b*) The temperature of the filament in a lightbulb is about 1800°C. What is this on the Fahrenheit scale?
4. (I) Among the highest and lowest temperatures recorded are 136°F in the Libyan desert and −129°F in Antarctica. What are these temperatures on the Celsius scale?
5. (I) (*a*) 15° below zero on the Celsius scale is what Fahrenheit temperature? (*b*) 15° below zero on the Fahrenheit scale is what Celsius temperature?
6. (II) In an alcohol-in-glass thermometer, the alcohol column has length 11.82 cm at 0.0°C and length 22.85 cm at 100.0°C. What is the temperature if the column has length (*a*) 16.70 cm, and (*b*) 20.50 cm?

13–4 Thermal Expansion

7. (I) A concrete highway is built of slabs 12 m long (20°C). How wide should the expansion cracks between the slabs be (at 20°C) to prevent buckling if the range of temperature is −30°C to +50°C?
8. (I) Super Invar™, an alloy of iron and nickel, is a strong material with a very low coefficient of linear expansion $[0.2 \times 10^{-6}\,(\text{C}^\circ)^{-1}]$. A 2.0-m-long tabletop made of this alloy is used for sensitive laser measurements where extremely high tolerances are required. How much will this table expand along its length if the temperature increases 5.0 C°? Compare to tabletops made of steel.
9. (I) The Eiffel Tower (Fig. 13–29) is built of wrought iron approximately 300 m tall. Estimate how much its height changes between July (average temperature of 25°C) and January (average temperature of 2°C). Ignore the angles of the iron beams, and treat the tower as a vertical beam.

FIGURE 13–29
Problem 9.
The Eiffel Tower in Paris.

10. (II) To make a secure fit, rivets that are larger than the rivet hole are often used and the rivet is cooled (usually in dry ice) before it is placed in the hole. A steel rivet 1.871 cm in diameter is to be placed in a hole 1.869 cm in diameter at 20°C. To what temperature must the rivet be cooled if it is to fit in the hole?
11. (II) The density of water at 4°C is $1.00 \times 10^3\,\text{kg/m}^3$. What is water's density at 94°C?
12. (II) A quartz sphere is 8.75 cm in diameter. What will be its change in volume if it is heated from 30°C to 200°C?
13. (II) An ordinary glass is filled to the brim with 350.0 mL of water at 100.0°C. If the temperature decreased to 20.0°C, how much water could be added to the glass?
14. (II) It is observed that 55.50 mL of water at 20°C completely fills a container to the brim. When the container and the water are heated to 60°C, 0.35 g of water is lost. (*a*) What is the coefficient of volume expansion of the container? (*b*) What is the most likely material of the container? The density of water at 60°C is 0.98324 g/mL.
15. (II) (*a*) A brass plug is to be placed in a ring made of iron. At 20°C, the diameter of the plug is 8.753 cm and that of the inside of the ring is 8.743 cm. They must both be brought to what common temperature in order to fit? (*b*) What if the plug were iron and the ring brass?
16. (II) If a fluid is contained in a long, narrow vessel so it can expand in essentially one direction only, show that the effective coefficient of linear expansion α is approximately equal to the coefficient of volume expansion β.
17. (II) (*a*) Show that the change in the density ρ of a substance, when the temperature changes by ΔT, is given by $\Delta\rho = -\beta\rho\,\Delta T$. (*b*) What is the fractional change in density of a lead sphere whose temperature decreases from 25°C to −40°C?
18. (II) A uniform rectangular plate of length l and width w has coefficient of linear expansion α. Show that, if we neglect very small quantities, the change in area of the plate due to a temperature change ΔT is $\Delta A = 2\alpha l w\,\Delta T$. See Fig. 13–30.

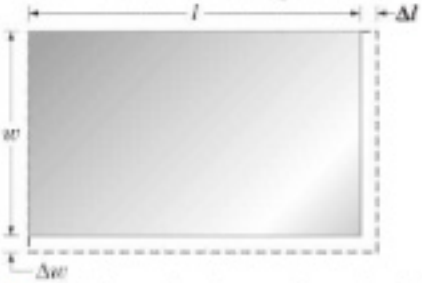

FIGURE 13–30
Problem 18.
A rectangular plate is heated.

19. (III) Show that for an isotropic solid, $\beta = 3\alpha$, if the amount of expansion is small. β and α are the coefficients of volume and linear expansion, respectively. [*Hint*: Consider a cubical solid, and neglect very small quantities. See also Problem 18 and Fig. 13–30.]
20. (III) The pendulum in a grandfather clock is made of brass and keeps perfect time at 17°C. How much time is gained or lost in a year if the clock is kept at 25°C? (Assume the frequency dependence on length for a simple pendulum applies.)
21. (III) (*a*) The tube of a mercury thermometer has an inside diameter of 0.140 mm. The bulb has a volume of 0.255 cm^3. How far will the thread of mercury move when the temperature changes from 11.5°C to 33.0°C? Take into account expansion of the Pyrex glass. (*b*) Determine a formula for the change in length of the mercury column in terms of relevant variables. Ignore tube volume compared to bulb volume.
22. (III) A 23.4-kg solid aluminum cylindrical wheel of radius 0.41 m is rotating about its axle on frictionless bearings with angular velocity $\omega = 32.8$ rad/s. If its temperature is now raised from 20.0°C to 75.0°C, what is the fractional change in ω?