Chapter 19 Hint for Exercise 2

Use

$$T = T_3 \frac{p}{p_3}\,,$$

where T is the temperature at the boiling point and T_3 is the temperature at the triple point of water (273.16 K). Solve for p/p_3.

Chapter 19 Hint for Exercise 6

(a) Evaluate $T_F = (9/5)T_C + 32°$.

(b) Solve $T_F = (9/5)T_C + 32°$ for T_C.

CHAPTER 19 HINT FOR PROBLEM 9

Assume a linear relationship between the Kelvin and X scales. Then

$$T_X = A + BT \,,$$

where T_X is the temperature on the X scale, T is the temperature on the Kelvin scale, and A and B are constants. Since water boils at 373.15 K and freezes at 273.15 K,

$$-53.5 = A + 373.15B$$

and

$$-170 = A + 273.15B \,.$$

Solve these equations simultaneously for A and B, then use $T_X = A + BT$, with $T = 340\,\mathrm{K}$, to find T_X for the last temperature.

[ans: $-92.1^\circ\,\mathrm{X}$]

(a) First find the coefficient of linear expansion. The change in temperature from 20.000° C to the boiling point of water is $\Delta T = 100.000°\,\mathrm{C} - 20.000°\,\mathrm{C} = 80.000°\,\mathrm{C}$ and the change in length is $\Delta L = 10.015\,\mathrm{cm} - 10.000\,\mathrm{cm} = 0.015\,\mathrm{cm}$. Solve

$$\Delta L = L\alpha\,\Delta T$$

for α. You should get $1.875 \times 10^{-5}\,\mathrm{K}^{-1}$. The change in temperature from 20.000° C to the freezing point of water is $-20.000°\,\mathrm{C}$. Use $\Delta L = L\alpha\,\Delta T$ to find the change in length and $L + \Delta L$ to find the new length.

(b) The change in length from its length at 20.000° C is $\Delta L = +0.009\,\mathrm{cm}$. Solve $\Delta L = L\alpha\,\Delta T$, with $L = 10.000\,\mathrm{cm}$, for ΔT, then use $T + \Delta T$, with $T = 20.000°\,\mathrm{C}$, to calculate the new temperature.

Chapter 19 Hint for Exercise 13

The change in the diameter of the hole is given by

$$\Delta D = D_0 \alpha \, \Delta T \, ,$$

where D_0 is the original diameter, ΔT is the change in temperature, and α is the coefficient of linear expansion for aluminum ($23 \times 10^{-6}\,\mathrm{K}^{-1}$). The new diameter is $D = D_0 + \Delta D$.

$\left[\text{ans:} \qquad 2.731\,\mathrm{cm}\right]$

Chapter 19 Hint for Problem 18

The change in the length of the rod is given by

$$\Delta L = L_0 \alpha \, \Delta T$$

where L_0 is its original length and α is its coefficient of linear expansion. The new length is $L = L_0 + \Delta L$. This is the value that would be measured by the ruler if the ruler had not also expanded. Because the ruler expands the reading is less by the factor $1 - \alpha_s \, \Delta T$, where α_s is the coefficient of linear expansion for steel. Thus, the reading on the expanded ruler is

$$L' = L(1 - \alpha_s \, \Delta T) = (L_0 + L_0 \alpha \, \Delta T)(1 - \alpha_s \, \Delta T) \approx L_0 + L_0(\alpha - \alpha_s) \, \Delta T \, .$$

Solve for α.

(a) The new diameter of the penny is given by $D = D_0(1+0.0018)$. The increase in the area is given by $\Delta A = \pi(D^2 - D_0^2)/4$. To two significant figures, this is $2(0.0018)\pi D_0^2/4$ and the fractional change is

$$\frac{\Delta A}{A} = \frac{2(0.0018)\pi D_0^2}{\pi D_0^2} = 2(0.0018)\,.$$

(b) The fractional change in the thickness is the same as the fractional change in the diameter.

(c) The change in the volume is $\Delta V = (A + \Delta A)(L + \Delta L) - AL$, where L is the thickness. To two significant figures, this is $\Delta V = 3(0.0018)AL$.

(d) The mass of the penny does not depend on the temperature.

(e) The fractional change in a linear dimension like the diameter is given by

$$\frac{\Delta D}{D} = \alpha\,\Delta T\,,$$

where α is the coefficient of linear expansion. Solve for α.

Chapter 19 Hint for Exercise 28

When mass m of a liquid freezes the energy Q that is extracted as heat is given by

$$Q = mL_F \,,$$

where L_F is the heat of fusion ($333 \times 10^3\,\mathrm{J/kg}$ for water). Solve for m and subtract the result from $260\,\mathrm{g}$.

(a) The temperature of the water is brought from $T_i = 20°$ C to $T_f = 100°$ C. The energy Q_w that is enters the water as heat during this process is

$$Q_w = m_w c_w (T_f - T_i)\,,$$

where m_w is the mass of the water and c_w is the specific heat of water (1.00×10^3 J/kg). Mass m_s is converted to steam. The energy that enters as heat during this process is

$$Q_s = m_s L_V\,,$$

where L_V is heat of vaporization of water (2256×10^3 J/kg). The total energy that enters the water is the sum of these two energies. You will need to convert the heat of vaporization to calories per kilogram. Use 1 J = 0.2389 cal.

(b) The temperature of the copper bowl also changes from $T_i = 20°$ C to $T_f = 100°$ C. The energy that enters it is

$$Q_b = m_b c_c (T_f - T_i)\,,$$

where m_b is the mass of the bowl and c_c is the specific heat of copper.

(c) The total energy ($Q_w + Q_s + Q_b$) that enters the water and bowl has been extracted from the copper cylinder. Its temperature decreases from some initial temperature T to $T_f = 100°$ C. Thus

$$Q_w + Q_s + Q_b = m_c c_c (T_i - T_f)\,,$$

where m_c is the mass of the cylinder. Solve for T_i.

Chapter 19 Hint for Problem 41

Since the specific heat depends on temperature you must evaluate the integral

$$Q = \int_{T_i}^{T_f} mc \, \mathrm{d}T \,,$$

where T_i is the initial temperature and T_f is the final temperature. You should obtain

$$Q = m[0.20(T_f - T_i) + 0.07(T_f^2 - T_i^2) + (0.023/3)(T_f^3 - T_i^3)] \,.$$

[ans: 82 cal]

Chapter 19 Hint for Problem 46

Let L_F be the heat of fusion of water (333 kJ/kg) and let m_i be the original mass of the ice. The ice absorbs heat $m_i L_F$. If T is the final temperature of the water (and coffee), then the water from the ice absorbs an additional heat $m_i cT$, where c is the specific heat of water (4190 J/kg · K). Let m_c be the mass of coffee originally in the thermos. Then, the coffee gives up heat $m_c c(T - T_c)$, where T_c is the initial temperature of the coffee. Since no energy escapes the thermos,

$$m_i L_F + m_i cT + m_w c(T - T_c) = 0\,.$$

Solve for T, then calculate $\Delta T = T_c - T$. The density of water is $0.998 \times 10^3\,\mathrm{kg/m^3}$ so $130\,\mathrm{cm^3}$ has a mass of $(130\,\mathrm{cm^3})(1 \times 10^{-6}\,\mathrm{m^3/cm^3})(0.998 \times 10^3\,\mathrm{kg/m^3}) = 0.130\,\mathrm{kg}$.

CHAPTER 19 HINT FOR EXERCISE 48

In the sense of the first law, W is the work done *by* the system. It is positive if the system does positive work and negative if the environment does positive work. Heat Q is positive if it represents energy entering the system and negative if it represents energy leaving the system. Use $1\,\mathrm{cal} = 4.186\,\mathrm{J}$ to convert to joules. Use

$$\Delta E_{\mathrm{int}} = Q - W$$

to calculate the change in the internal energy.

(a) Over the path A $\rightarrow$ B the work done by the system is positive (the volume increases). Since $\Delta E_{\text{int}} = Q - W$ and ΔE_{int} is positive, Q must be positive.

Over the path B $\rightarrow$ C the work done by the system is 0, so $\Delta E_{\text{int}} = Q$.

Over the path C $\rightarrow$ A the work done by the system is negative (the volume decreases). Over the entire cycle the change in the internal energy is 0. Since it is positive over the other two portions of the cycle, it must be negative over this portion.

Over the entire cycle $Q = W$. Now, the area under the curve A $\rightarrow$ B is smaller than the area under the curve C $\rightarrow$ A so the total work done by the system over the cycle is negative.

(b) The work done is the negative of the area of the triangle, or $\frac{1}{2}\,\Delta V\,\Delta p$.

Chapter 19 Hint for Exercise 54

Use

$$P_{\text{cond}} = kA\frac{T_H - T_C}{L}\,,$$

with $P_{\text{cond}}/A = 54\,\text{mW/m}^2$, $T_C = 10\,^\circ\text{C}$, $k = 2.50\,\text{W/m}\cdot\text{K}$, and $L = 35.0\,\text{km}$. Solve for T_H.

Chapter 19 Hint for Problem 61

Let L be the length of each rod, let A be cross-sectional area of each rod, and let ΔT be the temperature difference from one end of the combination to the other. For the arrangement of Fig. 19–40a the heat conducted in time Δt_1 is

$$Q = P_{\text{cond}}\Delta t_1 = kA\frac{\Delta T}{2L}\,\Delta t_1\,,$$

since the total length is $2L$.

For the arrangement of Fig. 19–40b the heat conducted in time Δt_2 is

$$Q = P_{\text{cond}}\Delta t_2 = k2A\frac{\Delta T}{L}\,\Delta t_2\,,$$

since the cross-sectional area is $2A$. The heat is the same so

$$kA\frac{\Delta T}{2L}\,\Delta t_1 = k2A\frac{\Delta T}{L}\,\Delta t_2\,.$$

Solve for Δt_2.

$\Big[$ ans: $\quad 0.50\,\text{min}\Big]$

Let x be the ice thickness and L be the total depth. Then, the depth of the water under the ice is $L - x$. If T_1 is the temperature of the top surface of ice, T_2 is the temperature of the water-ice interface, and T_3 is the temperature at the pond bottom, then the rate of heat flow through the ice is

$$P_{\text{cond } i} = k_i A \frac{T_2 - T_1}{x}$$

and the rate of heat flow through the water is

$$P_{\text{cond } w} = k_w A \frac{T_3 - T_2}{L - x}\,.$$

Here k_i is the thermal conductivity of ice and k_w is the thermal conductivity of water. At steady state the two rates of heat flow are equal, so

$$k_i \frac{T_2 - T_1}{x} = k_w \frac{T_3 - T_2}{L - x}\,.$$

Take $T_2 = 0.0\,^\circ\text{C}$ and solve for x.