1. SSM *REASONING AND SOLUTION* The difference between these two averages, expressed in Fahrenheit degrees, is

$$98.6\ °\text{F} - 98.2\ °\text{F} = 0.4\ \text{F}°$$

Since 1 C° is equal to $\frac{9}{5}$ F°, we can make the following conversion

$$(0.4\ \text{F}°)\left(\frac{1\ \text{C}°}{(9/5)\ \text{F}°}\right) = \boxed{0.2\ \text{C}°}$$

2. *REASONING AND SOLUTION*
a. The Kelvin temperature and the temperature on the Celsius scale are related by Equation 12.1: $T = T_c + 273.15$, where T is the Kelvin temperature and T_c is the Celsius temperature. Therefore, a temperature of 77 K on the Celsius scale is

$$T_c = T - 273.15 = 77\ \text{K} - 273.15\ \text{K} = \boxed{-196\ °\text{C}}$$

b. The temperature of –196 °C is 196 Celsius degrees *below* the ice point of 0 °C. Since $1\ \text{C}° = \frac{9}{5}\ \text{F}°$, this number of Celsius degrees corresponds to

$$196\ \text{C}°\left(\frac{\frac{9}{5}\ \text{F}°}{1\ \text{C}°}\right) = 353\ \text{F}°$$

Subtracting 353 Fahrenheit degrees from the ice point of 32.0 °F on the Fahrenheit scale gives a Fahrenheit temperature of $\boxed{-321\ °\text{F}}$.

12. *REASONING AND SOLUTION*
a. The radius of the hole will be $\boxed{\text{larger}}$ when the plate is heated, because the hole expands as if it were made of copper.

b. The expansion of the radius is $\Delta r = \alpha r_0 \Delta T$. The fractional change in the radius is

$$\Delta r/r_0 = \alpha\Delta T = (17 \times 10^{-6}\ \text{C}°^{-1})(110\ °\text{C} - 11\ °\text{C}) = \boxed{0.0017}$$

19. SSM WWW ***REASONING AND SOLUTION*** Recall that $\omega = 2\pi / T$, Equation 10.6, where ω is the angular frequency of the pendulum and T is the period. Using this fact and Equation 10.16, we know that the period of the pendulum before the temperature rise is given by $T_1 = 2\pi\sqrt{L_0 / g}$, where L_0 is the length of the pendulum. After the temperature has risen, the period becomes (using Equation 12.2), $T_2 = 2\pi\sqrt{[L_0 + \alpha L_0 \Delta T]/g}$. Dividing these expressions and solving for T_2 we have

$$T_2 = T_1\sqrt{1+\alpha\Delta T} = (2.0000\text{ s})\sqrt{1+(19\times10^{-6}/\text{C°})(140\text{ C°})} = \boxed{2.0027\text{ s}}$$

32. ***REASONING AND SOLUTION*** Both the coffee and beaker expand as the temperature increases. For the expansion of the coffee

$$\Delta V_c = \beta_w V_0 \Delta T$$

and for the expansion of the beaker

$$\Delta V_b = \beta_b V_0 \Delta T$$

The excess expansion of the coffee, hence the amount which spills, is

$$\Delta V = \Delta V_c - \Delta V_b = (\beta_w - \beta_b) V_0 \Delta T$$

$$\Delta V = [207\times10^{-6}\ (\text{C°})^{-1} - 9.9\times10^{-6}\ (\text{C°})^{-1}](0.50\times10^{-3}\text{ m}^3)(92\text{ °C} - 18\text{ °C})$$

$$= \boxed{7.3\times10^{-6}\text{ m}^3}$$

42. ***REASONING*** **Since there is no heat lost or gained by the system, the heat lost by the water in cooling down must be equal to the heat gained by the thermometer in warming up. The heat Q lost or gained by a substance is given by Equation 12.4 as $Q = cm\Delta T$, where c is the specific heat capacity, m is the mass, and ΔT is the change in temperature. Thus, we have that**

$$\underbrace{c_{H_2O}\, m_{H_2O}\, \Delta T_{H_2O}}_{\text{Heat lost by water}} = \underbrace{c_{therm}\, m_{therm}\, \Delta T_{therm}}_{\text{Heat gained by thermometer}}$$

$$\Delta T = \frac{\Delta L_A - \Delta L_B}{\alpha_A L_A + \alpha_B L_B} = \frac{1.3 \times 10^{-3}\ \text{m}}{\left(23 \times 10^{-6}\ \text{C}^{\circ -1}\right)(1.0\ \text{m}) + \left(19 \times 10^{-6}\ \text{C}^{\circ -1}\right)(2.0\ \text{m})} = 21\,\text{C}^\circ$$

The desired temperature is then

$$T = 28\ ^\circ\text{C} + 21\ \text{C}^\circ = \boxed{49\ ^\circ\text{C}}$$

We can use this equation to find the temperature of the water before the insertion of the thermometer.

SOLUTION **Solving the equation above for ΔT_{H_2O}, and using the value of c_{H_2O} from Table 12.2, we have**

$$\Delta T_{H_2O} = \frac{c_{therm}\, m_{therm}\, \Delta T_{therm}}{c_{H_2O}\, m_{H_2O}}$$

$$= \frac{[815\ \text{J}/(\text{kg}\cdot\text{C}^\circ)](31.0\ \text{g})(41.5\ ^\circ\text{C} - 12.0\ ^\circ\text{C})}{[4186\ \text{J}/(\text{kg}\cdot\text{C}^\circ)](119\ \text{g})} = 1.50\ \text{C}^\circ$$

The temperature of the water before the insertion of the thermometer was

$$T = 41.5\ ^\circ\text{C} + 1.50\ \text{C}^\circ = \boxed{43.0\ ^\circ\text{C}}$$

43. ***REASONING AND SOLUTION*** From Equation 12.4, $Q = cm\Delta T$, where $\Delta T = T - T_0$. Making this substitution and solving for T gives

$$T = \frac{Q + cmT_0}{cm} = \frac{Q}{cm} + T_0 = \frac{(4.2 \times 10^5\ \text{J/h})(0.50\ \text{h})}{[4186\ \text{J}/(\text{kg}\cdot\text{C}^\circ)](1.0 \times 10^3\ \text{kg})} + 27.00\ ^\circ\text{C} = \boxed{27.05\ ^\circ\text{C}}$$

49. SSM *REASONING AND SOLUTION* According to Equation 12.4, the total heat per kilogram required to raise the temperature of the water is

$$\frac{Q}{m} = c\Delta T = [4186\ \text{J/(kg}\cdot\text{C}^\circ)]\ (32.0\ ^\circ\text{C}) = 1.34\times 10^5\ \text{J/kg}$$

The mass flow rate, $\Delta m/\Delta t$, is given by Equations 11.7 and 11.10 as $\Delta m/\Delta t = \rho A v = \rho Q_V$, where ρ and Q_V are the density and volume flow rate, respectively. We have, therefore,

$$\frac{\Delta m}{\Delta t} = (1.000\times 10^3\ \text{kg/m}^3)(5.0\times 10^{-6}\ \text{m}^3\text{/s}) = 5.0\times 10^{-3}\ \text{kg/s}$$

Therefore, the minimum power rating of the heater must be

$$(1.34\times 10^5\ \text{J/kg})(5.0\times 10^{-3}\ \text{kg/s}) = 6.7\times 10^2\ \text{J/s} = \boxed{6.7\times 10^2\ \text{W}}$$

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54. ***REASONING*** As the body perspires, heat Q must be added to change the water from the liquid to the gaseous state. The amount of heat depends on the mass m of the water and the latent heat of vaporization L_v, $Q = mL_v$ (Equation 12.5).

SOLUTION The mass of water lost to perspiration is

$$m = \frac{Q}{L_v} = \frac{(240\ \text{Calories})\left(\dfrac{4186\ \text{J}}{1\ \text{Calorie}}\right)}{2.42\times 10^6\ \text{J/kg}} = \boxed{0.42\ \text{kg}}$$

61. SSM ***REASONING*** According to the statement of the problem, the initial state of the system is comprised of the ice and the steam. From the principle of energy conservation, the heat lost by the steam equals the heat gained by the ice, or $Q_{\text{steam}} = Q_{\text{ice}}$. When the ice and the steam are brought together, the steam immediately begins losing heat to the ice. An amount $Q_{1(\text{lost})}$ is released as the temperature of the steam drops from 130 °C to 100 °C, the boiling point of water. Then an amount of heat $Q_{2(\text{lost})}$ is released as the steam condenses into liquid water at 100 °C. The remainder of the heat lost by the "steam" $Q_{3(\text{lost})}$ is the heat that is released as the water at 100 °C cools to the equilibrium temperature of $T_{\text{eq}} = 50.0$ °C. According to Equation 12.4, $Q_{1(\text{lost})}$ and $Q_{3(\text{lost})}$ are given by

$$Q_{1(\text{lost})} = c_{\text{steam}} m_{\text{steam}} (T_{\text{steam}} - 100.0\ ^\circ\text{C}) \quad \text{and} \quad Q_{3(\text{lost})} = c_{\text{water}} m_{\text{steam}} (100.0\ ^\circ\text{C} - T_{\text{eq}})$$

$Q_{2(\text{lost})}$ is given by $Q_{2(\text{lost})} = m_{\text{steam}} L_{\text{v}}$, where L_{v} is the latent heat of vaporization of water. The total heat lost by the steam has three effects on the ice. First, a portion of this heat $Q_{1(\text{gained})}$ is used to raise the temperature of the ice to its melting point at 0.00 °C. Then, an amount of heat $Q_{2(\text{gained})}$ is used to melt the ice completely (we know this because the problem states that after thermal equilibrium is reached the liquid phase is present at 50.0 °C). The remainder of the heat $Q_{3(\text{gained})}$ gained by the "ice" is used to raise the temperature of the resulting liquid at 0.0 °C to the final equilibrium temperature. According to Equation 12.4, $Q_{1(\text{gained})}$ and $Q_{3(\text{gained})}$ are given by

$$Q_{1(\text{gained})} = c_{\text{ice}} m_{\text{ice}} (0.00\ ^\circ\text{C} - T_{\text{ice}}) \quad \text{and} \quad Q_{3(\text{gained})} = c_{\text{water}} m_{\text{ice}} (T_{\text{eq}} - 0.00\ ^\circ\text{C})$$

$Q_{2(\text{gained})}$ is given by $Q_{2(\text{gained})} = m_{\text{ice}} L_{\text{f}}$, where L_{f} is the latent heat of fusion of ice.

SOLUTION

$$Q_{\text{steam}} = Q_{\text{ice}}$$

$$Q_{1(\text{lost})} + Q_{2(\text{lost})} + Q_{3(\text{lost})} = Q_{1(\text{gained})} + Q_{2(\text{gained})} + Q_{3(\text{gained})}$$

or

$$c_{\text{steam}} m_{\text{steam}} (T_{\text{steam}} - 100.0\ ^\circ\text{C}) + m_{\text{steam}} L_{\text{v}} + c_{\text{water}} m_{\text{steam}} (100.0\ ^\circ\text{C} - T_{\text{eq}})$$

$$= c_{\text{ice}} m_{\text{ice}} (0.00\ ^\circ\text{C} - T_{\text{ice}}) + m_{\text{ice}} L_{\text{f}} + c_{\text{water}} m_{\text{ice}} (T_{\text{eq}} - 0.00\ ^\circ\text{C})$$

Solving for the ratio of the masses gives

$$\frac{m_{\text{steam}}}{m_{\text{ice}}} = \frac{c_{\text{ice}} (0.00\ ^\circ\text{C} - T_{\text{ice}}) + L_{\text{f}} + c_{\text{water}} (T_{\text{eq}} - 0.00\ ^\circ\text{C})}{c_{\text{steam}} (T_{\text{steam}} - 100.0\ ^\circ\text{C}) + L_{\text{v}} + c_{\text{water}} (100.0\ ^\circ\text{C} - T_{\text{eq}})}$$

$$= \frac{[2.00 \times 10^3\ \text{J/(kg} \cdot \text{C}^\circ)][0.0\ ^\circ\text{C} - (-10.0^\circ\text{C})] + 33.5 \times 10^4\ \text{J/kg} + [4186\ \text{J/(kg} \cdot \text{C}^\circ)](50.0\ ^\circ\text{C} - 0.0\ ^\circ\text{C})}{[2020\ \text{J/(kg} \cdot \text{C}^\circ)](130\ ^\circ\text{C} - 100.0\ ^\circ\text{C}) + 22.6 \times 10^5\ \text{J/kg} + [4186\ \text{J/(kg} \cdot \text{C}^\circ)](100.0\ ^\circ\text{C} - 50.0\ ^\circ\text{C})}$$

or

$$\frac{m_{\text{steam}}}{m_{\text{ice}}} = \boxed{0.223}$$