PHY 130: HW_10 Help

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

(a) Use the conversion 1 Cal = 1 kcal = 4186 J to find the following.

$$E = (59.0\text{ Cal})\left(\frac{4186\text{ J}}{1\text{ Cal}}\right)$$
$$= 2.47 \times 10^5\text{ J}$$

(b) Use the work-energy theorem with $W_{net} = 2.47 \times 10^5$ J and $v_i = 0$ to find the final speed.

$$W_{net} = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$
$$v_f = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{2(2.47 \times 10^5\text{ J})}{1.63\text{ kg}}}$$
$$= 550\text{ m/s}$$

(c) From the definition of specific heat c, adding energy $Q = 2.47 \times 10^5$ J to a mass m of water raises its temperature by the following.

$$\Delta T = \frac{Q}{mc}$$

Here, $m = 3.79$ kg and the specific heat of water is $c = 4186 \frac{\text{J}}{(\text{kg}\cdot{}^\circ\text{C})}$ so that we have the following.

$$\Delta T = \frac{2.47 \times 10^5\text{ J}}{(3.79\text{ kg})\left(4186\,\frac{\text{J}}{(\text{kg}\cdot{}^\circ\text{C})}\right)} = 15.6^\circ\text{C}$$

The water's final temperature is the following.

$$T_f = T_i + \Delta T$$
$$= 23.7^\circ\text{C} + 15.6^\circ\text{C}$$
$$= 39.3^\circ\text{C}$$

Solution or Explanation

(a) $Q = 610\text{ Cal}\left(\frac{10^3\text{ cal}}{1\text{ Cal}}\right)\left(\frac{4.186\text{ J}}{1\text{ cal}}\right) = 2.55 \times 10^6\text{ J}$

(b) The work done lifting her weight mg up one stair of height h is $W_1 = mgh$. Thus, the total work done in climbing N stairs is $W = Nmgh$, and we have $W = Nmgh = Q$ or

$$N = \frac{Q}{mgh} = \frac{2.55 \times 10^6\text{ J}}{(58\text{ kg})(9.80\text{ m/s}^2)(0.15\text{ m})} = 29900\text{ stairs.}$$

(c) If only 26% of the energy from the donut goes into mechanical energy, we have

$$N = 0.26\left(\frac{Q}{mgh}\right) = 0.26(29900\text{ stairs}) = 7790\text{ stairs.}$$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

As mass m of water drops from the top to the bottom of the falls, the gravitational potential energy given up (and hence, the kinetic energy gained) is $Q = mgh$. If all of this goes into raising the temperature, the rise in temperature will be

$$\Delta T = \frac{Q}{mc_{\text{water}}} = \frac{mgh}{mc_{\text{water}}} = \frac{(9.80\text{ m/s}^2)(807\text{ m})}{4{,}186\text{ J/kg}\cdot{}^\circ\text{C}} = 1.89^\circ\text{C}$$

and the final temperature is

$$T_f = T_i + \Delta T = 17.5^\circ\text{C} + 1.89^\circ\text{C} = 19.4^\circ\text{C}.$$

Solution or Explanation

When thermal equilibrium is reached, the water and aluminum will have a common temperature of $T_f = 60.0^\circ\text{C}$. Assuming that the water-aluminum system is thermally isolated from the environment,

$$Q_{\text{cold}} = -Q_{\text{hot}},\text{ so } m_w c_w(T_f - T_{i,w}) = -m_{\text{Al}}c_{\text{Al}}(T_f - T_{i,\text{Al}}),\text{ or}$$

$$m_w = \frac{-m_{\text{Al}}c_{\text{Al}}(T_f - T_{i,\text{Al}})}{c_w(T_f - T_{i,w})} = \frac{-(1.70\text{ kg})(900\text{ J/kg}\cdot{}^\circ\text{C})(60.0^\circ\text{C} - 150^\circ\text{C})}{(4{,}186\text{ J/kg}\cdot{}^\circ\text{C})(60.0^\circ\text{C} - 22.0^\circ\text{C})} = 0.866\text{ kg}.$$

Solution or Explanation

The total energy input required is

$$\begin{aligned} Q &= (\text{energy to melt 71 g of ice}) + (\text{energy to warm 71 g of water to }100^\circ\text{C}) + (\text{energy to vaporize 8.9 g of water}) \\ &= (71\text{ g})L_f + (71\text{ g})c_{\text{water}}(100^\circ\text{C} - 0^\circ\text{C}) + (8.9\text{ g})L_v. \end{aligned}$$

Thus,

$$Q = (0.071\text{ kg})\left(3.33\times10^5\ \frac{\text{J}}{\text{kg}}\right) + (0.071\text{ kg})\left(4{,}186\ \frac{\text{J}}{\text{kg}\cdot{}^\circ\text{C}}\right)(100^\circ\text{C} - 0^\circ\text{C}) + (0.0089\text{ kg})\left(2.26\times10^6\ \frac{\text{J}}{\text{kg}}\right),$$

which gives

$$Q = 73500\text{ J} = 73.5\text{ kJ}.$$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

In one hour, the energy dissipated by the runner is

$$\Delta E = P \cdot t = (355 \text{ J/s})(3{,}600 \text{ s}) = 1.28 \times 10^{6} \text{ J}.$$

Therefore, 89%, or $Q = 0.890(1.28 \times 10^{6} \text{ J}) = 1.14 \times 10^{6}$ J, of this is used to evaporate bodily fluids. The mass of fluid evaporated is

$$m = \frac{Q}{L_v} = \frac{1.14 \times 10^{6} \text{ J}}{2.41 \times 10^{6} \text{ J/kg}} = 0.472 \text{ kg}.$$

Assuming the fluid is primarily water, the volume of fluid evaporated in one hour is

$$V = \frac{m}{\rho} = \frac{0.472 \text{ kg}}{1000 \text{ kg/m}^3} = (4.72 \times 10^{-4} \text{ m}^3)\left(\frac{10^{6} \text{ cm}^3}{1 \text{ m}^3}\right) = 472 \text{ cm}^3.$$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

The mass of 2.2 liters of water is

$$m_w = \rho V = (10^3 \text{ kg/m}^3)(2.20 \times 10^{-3} \text{ m}^3) = 2.2 \text{ kg}.$$

The energy required to raise the temperature of the water (and pot) up to the boiling point of water is

$$Q_{boil} = (m_w c_w + m_{Al} c_{Al})(\Delta T)$$
$$= \left[(2.2 \text{ kg})\left(4{,}186 \frac{\text{J}}{\text{kg}}\right) + (0.47 \text{ kg})\left(900 \frac{\text{J}}{\text{kg}}\right)\right](100°\text{C} - 20°\text{C}) = 7.71 \times 10^{5} \text{ J}.$$

The time required for the 14,000 Btu/h burner to produce this much energy is

$$t_{boil} = \frac{Q_{boil}}{14000 \text{ Btu/h}} = \frac{7.71 \times 10^{5} \text{ J}}{14{,}000 \text{ Btu/h}}\left(\frac{1 \text{ Btu}}{1050 \text{ J}}\right) = 0.0522 \text{ h} = 3.13 \text{ min}.$$

(b) Once the boiling temperature is reached, the additional energy required to evaporate all of the water is

$$Q_{evaporate} = m_w L_v = (2.2 \text{ kg})(2.26 \times 10^{6} \text{ J/kg}) = 4.97 \times 10^{6} \text{ J}$$

and the time required for the burner to produce this energy is

$$t_{evaporate} = \frac{Q_{evaporate}}{14{,}000 \text{ Btu/h}} = \frac{4.97 \times 10^{6} \text{ J}}{14{,}000 \text{ Btu/h}}\left(\frac{1 \text{ Btu}}{1050 \text{ J}}\right) = 0.337 \text{ h} = 20.2 \text{ min}.$$

Solution or Explanation

(a) The rate of energy transfer by conduction through a material of area A, thickness L, with thermal conductivity k, and temperatures $T_h > T_c$ on opposite sides is $P = kA(T_h - T_c)/L$. For the given windowpane, this is

$$P = \left(0.8 \frac{\text{J}}{\text{s} \cdot \text{m} \cdot {}^\circ\text{C}}\right)[(1.1 \text{ m})(1.9 \text{ m})]\frac{(26^\circ\text{C} - 0^\circ\text{C})}{0.62 \times 10^{-2} \text{ m}} = 7010 \text{ J/s} = 7010 \text{ W}.$$

(b) The total energy lost per day is

$$E = P \cdot \Delta t = (7010 \text{ J/s})(8.64 \times 10^4 \text{ s}) = 6.06 \times 10^8 \text{ J}.$$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

(a) Use the conversion $T = T_C + 273$ to find $T = 113^\circ\text{C} + 273 = 386$ K.

(b) The ball has the surface area of a sphere: $A = 4\pi R^2 = 4\pi(2.32 \text{ m})^2 = 67.6 \text{ m}^2$.

(c) Stefan's law for the net radiated power is $P_{net} = \sigma A e(T^4 - T_0{}^4)$ where $T_0 = 22.0^\circ\text{C} = 295$ K is the temperature of the surrounding environment. Substitute values to find the following.

$$\begin{aligned} P_{net} &= \sigma A e(T^4 - T_0{}^4) \\ &= \left(5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4}\right)(67.6 \text{ m}^2)(0.900)\left[(386 \text{ K})^4 - (295 \text{ K})^4\right] \\ &= 5.05 \times 10^4 \text{ W} \end{aligned}$$

A class of 13 students taking an exam has a power output per student of about 200 W. Assume the initial temperature of the room is 20°C and that its dimensions are 6.7 m by 16.4 m by 3.0 m. What is the temperature of the room at the end of 1.0 h if all the energy remains in the air in the room and none is added by an outside source? The specific heat of air is 1.01×10^3 J/kg · °C, and its density is about 1.2×10^{-3} g/cm^3.

[ ] 43.4 °C

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

The energy added to the air in one hour is

$$Q = (P_{total})t = [(13)(200 \text{ W})](3{,}600 \text{ s}) = 9.36 \times 10^6 \text{ J}$$

and the mass of air in the room is

$$m = \rho V = (1.2 \text{ kg/m}^3)[(6.7 \text{ m})(16.4 \text{ m})(3.0 \text{ m})] = 396 \text{ kg}.$$

The change in temperature is

$$\Delta T = \frac{Q}{mc} = \frac{9.36 \times 10^6 \text{ J}}{(396 \text{ kg})(1.01 \times 10^3 \text{ J/kg} \cdot {}^\circ\text{C})} = 23.4^\circ\text{C}$$

giving

$$T = T_0 + \Delta T = 20^\circ\text{C} + 23.4^\circ\text{C}$$
$$= 43.4^\circ\text{C}.$$