PQ 3 Heat

Questions

Q and A

PQ1

- A 0.500 kg aluminum pan on a stove is used to heat 0.250 litres of water from 20.0ºC to 80.0ºC . (a) How much heat is required? What percentage of the heat is used to raise the temperature of (b) the pan and (c) the water?
- Because water is in thermal contact with the aluminum, the pan and the water are at the same temperature.
- Calculate the temperature difference:
- $\Delta T = T_f - T_i = 60.0^{\circ}C$.

PQ1 continued

- Calculate the mass of water. Because the density of water is 1000 kg/m3 , one litre of water has a mass of 1 kg, and the mass of 0.250 litres of water is m_w = 0.250 kg.
- Calculate the heat transferred to the water.
- $Q_w = m_w c_w \Delta T$ = (0.250 kg) (4186 J/kg^o C) (60.0^{o}C) =
- 62.8 kJ.

PQ1 continued

- Calculate the heat transferred to the aluminum.

$$Q_{Al} = m_{Al}c_{Al}\Delta T = (0.500\text{ kg})(900\text{ J/kg°C})(60.0\text{°C}) = 27.0 \times 10^4\text{ J} = 27.0\text{ kJ}$$

- Compare the percentage of heat going into the pan versus that going into the water. First, find the total transferred heat:

$$Q_{Total} = Q_W + Q_{Al} = 62.8\text{ kJ} + 27.0\text{ kJ} = 89.8\text{ kJ}.$$

PQ1 continued

- Thus, the amount of heat going into heating the pan is

$$\frac{27.0\ \text{kJ}}{89.8\ \text{kJ}} \times 100\% = 30.1\%.$$

- and the amount going into heating the water is

$$\frac{62.8\ \text{kJ}}{89.8\ \text{kJ}} \times 100\% = 69.9\%.$$

PQ2

Lorry brakes used to control speed on a downhill run do work, converting gravitational potential energy into increased internal energy (higher temperature) of the brake material. This conversion prevents the gravitational potential energy from being converted into kinetic energy of the truck. The problem is that the mass of the truck is large compared with that of the brake material absorbing the energy, and the temperature increase may occur too fast for sufficient heat to transfer from the brakes to the environment.

Calculate the temperature increase of 100 kg of brake material with an average specific heat of 800 J/kg · ºC if the material retains 10% of the energy from a 10,000-kg truck descending 75.0 m (in vertical displacement) at a constant speed.

Calculate the change in gravitational potential energy as the truck goes downhill

$$Mgh = (10{,}000 \text{ kg})(9.80 \text{ m/s}^2)(75.0 \text{ m}) = 7.35\times10^6 \text{ J}.$$

Calculate the temperature from the heat transferred using $Q = Mgh$ and

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

PQ2 continuied

where m is the mass of the brake material. Insert the values $m = 100\ \text{kg}$ and $c = 800\ \text{J/kg} \cdot {}^{\circ}\text{C}$ to find

$$\Delta T = \frac{\left(7.35 \times 10^{6}\ \text{J}\right)}{(100\ \text{kg})(800\ \text{J/kg}^{\circ}\text{C})} = 92^{\circ}\text{C}.$$

PQ3

- How much heat energy is given out when 3 kg of water at 40 ^oC cool to 25 ^oC?
- Heat energy given out = $mC\Delta\theta = 3 \times 4200 \times (40 – 25)$ = 189,000 J= 189 kJ

PQ4

- If 25 kJ is necessary to raise the temperature of a block from 25ºC to 30ºC , how much heat is necessary to heat the block from 45ºC to 50ºC ?
- The heat transfer depends only on the temperature difference. Since the temperature differences are the same in both cases, the same 25 kJ is necessary in the second case.

PQ5

- Three ice cubes are used to chill a soda at 20ºC with mass m_{soda} = 0.25 kg . The ice is at 0ºC and each ice cube has a mass of 6.0 g.
- Assume that the soda is kept in a foam container so that heat loss can be ignored. Assume the soda has the same heat capacity as water. Find the final temperature when all ice has melted.

PQ5 continued

The heat transferred to the ice is $Q_{\text{ice}} = m_{\text{ice}} L_{\text{f}} + m_{\text{ice}} c_{\text{W}} (T_{\text{f}} - 0°\text{C})$.

The heat given off by the soda is $Q_{\text{soda}} = m_{\text{soda}} c_{\text{W}} (T_{\text{f}} - 20°\text{C})$

Since no heat is lost, $Q_{\text{ice}} = -Q_{\text{soda}}$, so that

$$m_{\text{ice}} L_{\text{f}} + m_{\text{ice}} c_{\text{W}} (T_{\text{f}} - 0°\text{C}) = - m_{\text{soda}} c_{\text{W}} (T_{\text{f}} - 20°\text{C})$$

Bring all terms involving T_{f} on the left-hand-side and all other terms on the right-hand-side.

Solve for the unknown quantity T_{f} :

$$T_{\text{f}} = \frac{m_{\text{soda}} c_{\text{W}} (20°\text{C}) - m_{\text{ice}} L_{\text{f}}}{(m_{\text{soda}} + m_{\text{ice}}) c_{\text{W}}}.$$

$$-M_{soda} C_w (T_f - 20°C)$$

$$\Downarrow$$

$$-M_{soda} C_w T_f + M_{soda} C_w 20°C$$

$$M_{ice} L_f + M_{ice} C_w (T_f - 0°C)$$

$$M_{ice} L_f + M_{ice} C_w T_f - 0$$

$$M_{ice} L_f + M_{ice} C_w T_f = -M_{soda} C_w T_f + M_{soda} C_w 20°C$$

$$M_{ice} C_w T_f = -M_{soda} C_w T_f + M_{soda} C_w 20°C - M_{ice} L_f$$

$$M_{ice} C_w T_f + M_{soda} C_w T_f = M_{soda} C_w 20°C - M_{ice} L_f$$

$$T_f (M_{ice} C_w + M_{soda} C_w) = M_{soda} C_w 20°C - M_{ice} L_f$$

$$T_f = \frac{M_{soda} C_w 20°C - M_{ice} L_f}{(M_{ice} C_w + M_{soda} C_w)}$$

PQ5 continued

Identify the known quantities. The mass of ice is $m_{\text{ice}} = 3{\times}6.0\text{ g} = 0.018\text{ kg}$ and the mass of soda is $m_{\text{soda}} = 0.25\text{ kg}$

Calculate the terms in the numerator:

$$m_{\text{soda}}\,c_{\text{W}}\,(20^{\circ}\text{C}) = (0.25\text{ kg})(4186\text{ J/kg}\cdot{}^{\circ}\text{C})(20^{\circ}\text{C}) = 20{,}930\text{ J}$$

and

$$m_{\text{ice}}\,L_{\text{f}} = (0.018\text{ kg})(334{,}000\text{ J/kg}) = 6012\text{ J}.$$

Calculate the denominator:

$$(m_{\text{soda}} + m_{\text{ice}})c_{\text{W}} = (0.25\text{ kg} + 0.018\text{ kg})(4186\text{ K/(kg}\cdot{}^{\circ}\text{C}) = 1122\text{ J/}^{\circ}\text{C}.$$

Calculate the final temperature:

$$T_{\text{f}} = \frac{20{,}930\text{ J} - 6012\text{ J}}{1122\text{ J/}^{\circ}\text{C}} = 13^{\circ}\text{C}.$$

PQ6

- Why does snow remain on mountain slopes even when daytime temperatures are higher than the freezing temperature?
- Snow is formed from ice crystals and thus is the solid phase of water. Because enormous heat is necessary for phase changes, it takes a certain amount of time for this heat to be accumulated from the air, even if the air is above 0ºC . The warmer the air is, the faster this heat exchange occurs and the faster the snow melts.