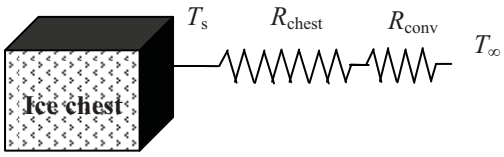
10-151 An ice chest made of 10-cm thick styrofoam is initially filled with 45 kg of ice at 0°C. The length of time it will take for the ice in the chest to melt completely is to be determined.

Assumptions **1** Heat transfer is steady since the specified thermal conditions at the boundaries do not change with time. **2** Heat transfer is one-dimensional. **3** Thermal conductivity is constant. **4** The inner surface temperature of the ice chest can be taken to be 0°C at all times. **5** Heat transfer from the base of the ice chest is negligible.

Properties The thermal conductivity of styrofoam is given to be $k = 0.033$ W/m·°C. The heat of fusion of water at 1 atm is $h_{if} = 333.7$ kJ/kg .



Analysis Disregarding any heat loss through the bottom of the ice chest, the total thermal resistance and the heat transfer rate are determined to be

$$A_i = 2(0.3-0.03)(0.4-0.06)+2(0.3-0.03)(0.5-0.06)+(0.4-0.06)(0.5-0.06) = 0.5708\ \text{m}^2$$

$$A_o = 2(0.3)(0.4)+2(0.3)(0.5)+(0.4)(0.5) = 0.74\ \text{m}^2$$

$$R_{\text{chest}} = \frac{L}{kA_i} = \frac{0.03\ \text{m}}{(0.033\ \text{W/m.°C})(0.5708\ \text{m}^2)} = 1.5927\ \text{°C/W}$$

$$R_{\text{conv}} = \frac{1}{hA_o} = \frac{1}{(18\ \text{W/m}^2\text{.°C})(0.74\ \text{m}^2)} = 0.07508\ \text{°C/W}$$

$$R_{\text{total}} = R_{\text{chest}} + R_{\text{conv}} = 1.5927 + 0.07508 = 1.6678\ \text{°C/W}$$

$$\dot{Q} = \frac{T_s - T_\infty}{R_{\text{total}}} = \frac{(28-0)\text{°C}}{1.6678\ \text{°C/W}} = 16.79\ \text{W}$$

The total amount of heat necessary to melt the ice completely is

$$Q = mh_{if} = (50\ \text{kg})(333.7\ \text{kJ/kg}) = 16{,}685\ \text{kJ}$$

Then the time period to transfer this much heat to the cooler to melt the ice completely becomes

$$\Delta t = \frac{Q}{\dot{Q}} = \frac{16{,}685{,}000\ \text{J}}{16.79\ \text{J/s}} = 9.937\times10^5\ \text{s} = 276\ \text{h} = \mathbf{11.5\ days}$$