

63. (a) We use

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

with the conductivity of glass given in Table 19-6 as  $1.0 \text{ W/m}\cdot\text{K}$ . We choose to use the Celsius scale for the temperature: a temperature difference of

$$T_H - T_C = 72^\circ\text{F} - (-20^\circ\text{F}) = 92^\circ\text{F}$$

is equivalent to  $\frac{5}{9}(92) = 51.1^\circ\text{C}$ . This, in turn, is equal to  $51.1 \text{ K}$  since a change in Kelvin temperature is entirely equivalent to a Celsius change. Thus,

$$\frac{P_{\text{cond}}}{A} = k \frac{T_H - T_C}{L} = (1.0 \text{ W/m}\cdot\text{K}) \left( \frac{51.1^\circ\text{C}}{3.0 \times 10^{-3} \text{ m}} \right) = 1.7 \times 10^4 \text{ W/m}^2 .$$

(b) The energy now passes in succession through 3 layers, one of air and two of glass. The heat transfer rate  $P$  is the same in each layer and is given by

$$P_{\text{cond}} = \frac{A(T_H - T_C)}{\sum L/k}$$

where the sum in the denominator is over the layers. If  $L_g$  is the thickness of a glass layer,  $L_a$  is the thickness of the air layer,  $k_g$  is the thermal conductivity of glass, and  $k_a$  is the thermal conductivity of air, then the denominator is

$$\sum \frac{L}{k} = \frac{2L_g}{k_g} + \frac{L_a}{k_a} = \frac{2L_g k_a + L_a k_g}{k_a k_g} .$$

Therefore, the heat conducted per unit area occurs at the following rate:

$$\begin{aligned} \frac{P_{\text{cond}}}{A} &= \frac{(T_H - T_C)k_a k_g}{2L_g k_a + L_a k_g} \\ &= \frac{(51.1^\circ\text{C})(0.026 \text{ W/m}\cdot\text{K})(1.0 \text{ W/m}\cdot\text{K})}{2(3.0 \times 10^{-3} \text{ m})(0.026 \text{ W/m}\cdot\text{K}) + (0.075 \text{ m})(1.0 \text{ W/m}\cdot\text{K})} \\ &= 18 \text{ W/m}^2 . \end{aligned}$$