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Problem 25.55 (RHK)

(a) *We have to calculate the rate of heat loss through a glass window of area* $1.4\ \text{m}^2$ *and thickness* $3.0\ \text{mm}$ *if the outside temperature is* -20^0F *and the inside temperature is* $+72^0\text{F}$. (b) *A storm window is installed having the same thickness of glass but with an air gap of* $7.5\ \text{cm}$ *between the two windows. We have to calculate the corresponding rate of heat loss presuming that conduction is the only important heat-loss mechanism.*

Solution:

(a)

Inside temperature is $T_1 = +72^0\text{F}$.

Outside temperature is $T_2 = -20^0\text{F}$.

$$T_1 - T_2 = 92\text{F}^0 = 92 \times \frac{5}{9}\text{K} = 51.1\ \text{K}.$$

Thermal conductivity of glass is $k_{glass} = 1.0\ \text{W m}^{-1}\ \text{K}^{-1}$.

Area of the glass window is $A = 1.4\ \text{m}^2$.

Thickness of glass is $L_{glass} = 3.0 \times 10^{-3}$ m.

Therefore, the rate of heat loss through the glass window can be calculated from the heat conduction equation

$$H = kA\frac{T_1 - T_2}{L}.$$

Substituting the numerical values from the data above, we get

$$H_{glass-widow} = 1.4 \times \frac{51.1}{3.0 \times 10^{-3}} \text{ W} = 23.8 \text{ kW}.$$

(b)

We will compute the rate of heat loss from inside of the room to the outside when a storm window of thickness 3 mm but with an air gap of 7.5 cm between the two windows has been installed.

Thermal conductivity of air is $k_{air} = 0.026$ W m^{-1} K^{-1}.

We will use the result that the rate of heat transfer through a compound slab consisting of materials having thicknesses L_1, L_2, L_3 and thermal conductivities k_1, k_2, k_3 is given by the generalisation of the heat conduction given equation

$$H = A \times \frac{T_1 - T_2}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3}}.$$

Substituting the data, we find

$$H_{storm-window} = \frac{1.4 \times 51.1}{3 \times 10^{-3} \times 2 + \frac{7.5 \times 10^{-2}}{0.026}} \text{ W}$$

$$= \frac{1.4 \times 51.1}{0.006 + 2.885} \text{ W} = 24.7 \text{ W}.$$

We notice that the heat flow is determined essentially by the air gap, as air has very low heat conductivity in comparison to that of glass.