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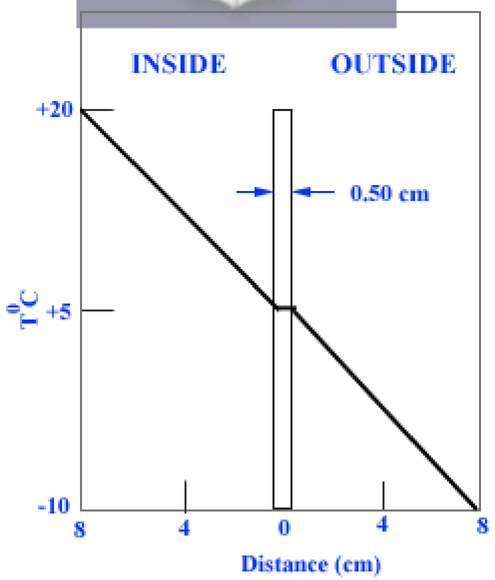
Problem 25.57 (RHK)

An idealised representation of the air temperature as a function of distance from a single-pane window on a calm, winter day is as shown in the figure. The window dimensions are $60\text{ cm}\times 60\text{ cm}\times 0.50\text{ cm}$. (a) *We have to calculate the rate at which heat is flowing out through the window.* (b) *We have to estimate the difference in temperature between the inner and outer glass surfaces. We can use that the temperature drop across the glass is very small.*



Solution:

We note data from the diagram. The heat flow across the glass will be the same as the heat flow across air corridor of thickness 8 cm, when the temperature across the corridor is

$$T_1 - T_2 = \left(20.0 - 5.0\right)\,^0\text{C} = 15.0^0\text{C}.$$

The thermal conductivity of air, $k_{air} = 0.026$ W m^{-1} K^{-1}.

Area of the glass window, $$\begin{aligned} A &= 60 \times 60 \times 10^{-4}\ \text{m}^2 \\ &= 3.6 \times 10^{-1}\ \text{m}^2. \end{aligned}$$

From the heat conduction formula, we calculate the heat flow from the inside to the outside across the glass window. It will be

$$\begin{aligned} H &= 2.6 \times 10^{-2} \times 3.6 \times 10^{-1} \times \frac{15}{8 \times 10^{-2}}\ \text{W} \\ &= 1.75\ \text{W}. \end{aligned}$$

We will next estimate the temperature difference between the inner and the outer surface of the glass-pane by using the result that 1.75 W of heat energy is flowing through it.

The thermal conductivity of glass is

$k_{glass} = 1.0$ W m^{-1} K^{-1}.

Let ΔT be the temperature difference.

We use the relation

$$\Delta T = \frac{H \times \Delta x}{k_{glass} \times A}$$

$$= \frac{1.755 \times 5.0 \times 10^{-3}}{3.6 \times 10^{-1}} \, {}^{0}\mathrm{C} = 0.024^{0}\,\mathrm{C}.$$