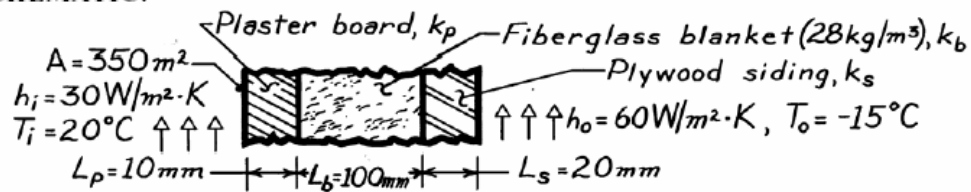


PROBLEM 3.13

KNOWN: Composite wall of a house with prescribed convection processes at inner and outer surfaces.

FIND: (a) Expression for thermal resistance of house wall, R_{tot} ; (b) Total heat loss, $q(W)$; (c) Effect on heat loss due to increase in outside heat transfer convection coefficient, h_o ; and (d) Controlling resistance for heat loss from house.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional conduction, (2) Steady-state conditions, (3) Negligible contact resistance.

PROPERTIES: Table A-3, $\left(\bar{T} = (T_i + T_o)/2 = (20 - 15)^\circ\text{C}/2 = 2.5^\circ\text{C} \approx 300\text{K}\right)$: Fiberglass blanket, 28 kg/m^3 , $k_b = 0.038 \text{ W/m}\cdot\text{K}$; Plywood siding, $k_s = 0.12 \text{ W/m}\cdot\text{K}$; Plasterboard, $k_p = 0.17 \text{ W/m}\cdot\text{K}$.

ANALYSIS: (a) The expression for the total thermal resistance of the house wall follows from Eq. 3.18.

$$R_{\text{tot}} = \frac{1}{h_i A} + \frac{L_p}{k_p A} + \frac{L_b}{k_b A} + \frac{L_s}{k_s A} + \frac{1}{h_o A} \quad <$$

(b) The total heat loss through the house wall is

$$q = \Delta T / R_{\text{tot}} = (T_i - T_o) / R_{\text{tot}}.$$

Substituting numerical values, find

$$R_{\text{tot}} = \frac{1}{30 \text{ W/m}^2 \cdot \text{K} \times 350 \text{ m}^2} + \frac{0.01 \text{ m}}{0.17 \text{ W/m} \cdot \text{K} \times 350 \text{ m}^2} + \frac{0.10 \text{ m}}{0.038 \text{ W/m} \cdot \text{K} \times 350 \text{ m}^2} + \frac{0.02 \text{ m}}{0.12 \text{ W/m} \cdot \text{K} \times 350 \text{ m}^2} + \frac{1}{60 \text{ W/m}^2 \cdot \text{K} \times 350 \text{ m}^2}$$

$$R_{\text{tot}} = [9.52 + 16.8 + 752 + 47.6 + 4.76] \times 10^{-5} \text{ }^\circ\text{C/W} = 831 \times 10^{-5} \text{ }^\circ\text{C/W}$$

The heat loss is then,

$$q = [20 - (-15)]^\circ\text{C} / 831 \times 10^{-5} \text{ }^\circ\text{C/W} = 4.21 \text{ kW}. \quad <$$

(c) If h_o changes from 60 to $300 \text{ W/m}^2\cdot\text{K}$, $R_o = 1/h_o A$ changes from $4.76 \times 10^{-5} \text{ }^\circ\text{C/W}$ to $0.95 \times 10^{-5} \text{ }^\circ\text{C/W}$. This reduces R_{tot} to $826 \times 10^{-5} \text{ }^\circ\text{C/W}$, which is a 0.6% decrease and hence a 0.6% increase in q .

(d) From the expression for R_{tot} in part (b), note that the insulation resistance, $L_b/k_b A$, is $752/830 \approx 90\%$ of the total resistance. Hence, this material layer controls the resistance of the wall. From part (c) note that a 5-fold decrease in the outer convection resistance due to an increase in the wind velocity has a negligible effect on the heat loss.