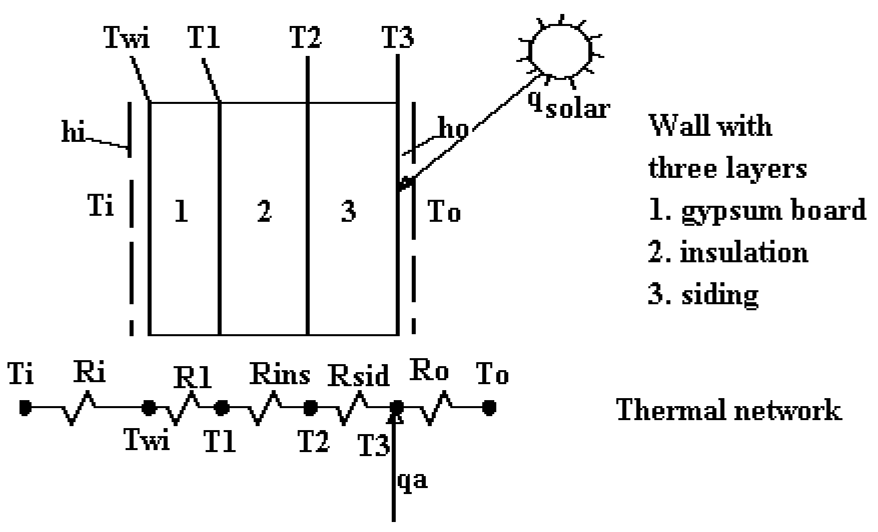
CHAPTER 1 STEADY-STATE HEAT CONDUCTION

1.5 Effect of Solar Radiation on Exterior Walls

In this example, we consider the effect of absorbed solar radiation on an exterior insulated wall. Consider the wall shown below which consists of the following three layers: gypsum board (thickness L1), insulation of thermal resistance R_{ins} and siding of resistance R_{sid}. Determine the net heat flow through the wall and the temperature T1 at the back surface of the gypsum board (front surface of the insulation).



$A := 1\ m^2$ consider unit wall surface area

$L1 := 0.013\ m$

$k1 := 0.16\ \dfrac{W}{m \cdot \Delta°C}$ gypsum board thermal conductivity

$R_{ins} := 2.2\ m^2 \cdot \dfrac{\Delta°C}{W}$ $R_{sid} := 0.3\ m^2 \cdot \dfrac{\Delta°C}{W}$

$\alpha_s := 0.9$ wall solar absorptance

$q_s := 300\ \dfrac{W}{m^2}$ solar radiation incident on wall

$q_a := \alpha_s \cdot q_s$ absorbed radiation

$h_i := 9 \dfrac{W}{m^2 \cdot \Delta°C}$

$h_o := 14 \dfrac{W}{m^2 \cdot \Delta°C}$

interior and exterior film coefficients

$T_i := 20\ \Delta°C$

$T_o := -10\ \Delta°C$

exterior and interior temperatures

Calculation of total thermal resistance Rtot:

$R1 := \dfrac{L1}{k1}$ $\quad R_i := \dfrac{1}{h_i}$ $\quad R_o := \dfrac{1}{h_o}$

$$R_{tot} := \frac{R_i + R1 + R_{ins} + R_{sid} + R_o}{A} = 2.764\ \frac{\Delta°C}{W}$$

Let

$$R_a := \frac{R_i + R1 + R_{ins} + R_{sid}}{A} \quad \text{and} \quad R_b := \frac{R_o}{A}$$

Energy balance at node 3 yields

$$\left(\frac{T_i - T_3}{R_a}\right) + q_a \cdot A = \frac{T3 - T_o}{R_b}$$

Therefore

$$T3 := \frac{T_i \cdot R_b + R_a \cdot T_o + q_a \cdot A \cdot R_a \cdot R_b}{R_a + R_b} = 9.563\ \Delta°C$$

If qa is set to 0, we obtain

$$T3_{\_nosolar} := \frac{T_i \cdot R_b + R_a \cdot T_o}{R_a + R_b} = -9.225\ \Delta°C$$

Therefore, the effect of solar radiation on T3 is to raise it by

$$T3 - T3_{\_nosolar} = 18.787\ \Delta°C$$