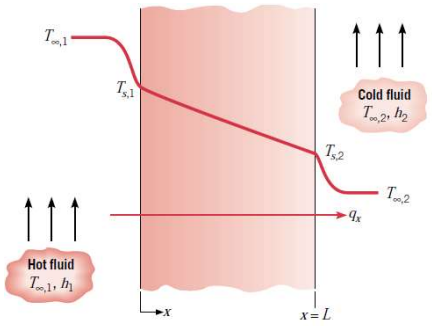
Heat Transfer I, Hw # 3

1. Consider the plane wall of Figure 1, separating hot and cold fluids at temperatures $T_{\infty 1}$ and $T_{\infty 2}$, respectively. Using surface energy balances as boundary conditions at $x = 0$ and $x = L$, obtain the temperature distribution within the wall and the heat flux in terms of $T_{\infty 1}$, $T_{\infty 2}$, h_1, h_2, k, and L.

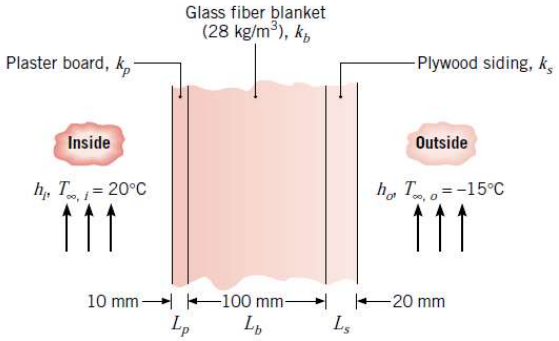


2. The rear window of an automobile is defogged by passing warm air over its inner surface. If the warm air is at $T_{\infty,i}$ = 40°C and the corresponding convection coefficient is h_i = 30 W/m2 .K, what are the inner and outer surface temperatures of 4-mm-thick window glass, if the outside ambient air temperature is $T_{\infty,o}$=-10°C and the associated convection coefficient is h_o = 65 W/m2 .K?

3. The walls of a refrigerator are typically constructed by sandwiching a layer of insulation between sheet metal panels. Consider a wall made from fiberglass insulation of thermal conductivity k_i =0.046 W/m.K and thickness L_i =50 mm and steel panels, each of thermal conductivity k_p = 60 W/m.K and thickness L_p =3 mm. If the wall separates refrigerated air at $T_{\infty,i}$ = 4C from ambient air at $T_{\infty,o}$ = 25C, what is the heat gain per unit surface area? Coefficients associated with natural convection at the inner and outer surfaces may be approximated as $h_i = h_o$=5W/m^2.K.

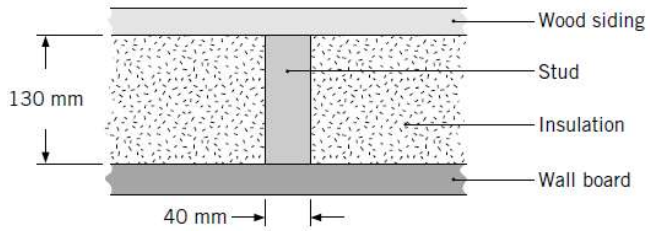
4. The *wind chill*, which is experienced on a cold, windy day, is related to increased heat transfer from exposed human skin to the surrounding atmosphere. Consider a layer of fatty tissue that is 3 mm thick and whose interior surface is maintained at a temperature of 36°C. On a calm day the convection heat transfer coefficient at the outer surface is 25 W/m^2 .K, but with 30 km/h winds it reaches 65 W/m^2.K. In both cases the ambient air temperature is 15°C.
(a) What is the ratio of the heat loss per unit area from the skin for the calm day to that for the windy day?
(b) What will be the skin outer surface temperature for the calm day? For the windy day?
(c) What temperature would the air have to assume on the calm day to produce the same heat loss occurring with the air temperature at 15°C on the windy day?

5. A house has a composite wall of wood, fiberglass insulation, and plaster board, as indicated in the sketch. On a cold winter day the convection heat transfer coefficients are h_o = 60 W/m^2 .K and h_i= 30 W/m^2.K. The total wall surface area is 350 m2.



(a) Determine a symbolic expression for the total thermal resistance of the wall, including inside and outside convection effects for the prescribed conditions.
(b) Determine the total heat loss through the wall.
(c) If the wind were blowing violently, raising h_o to 300 W/m^2.K, determine the percentage increase in the heat loss.
(d) What is the controlling resistance that determines the amount of heat flow through the wall?

6. Consider a composite wall that includes an 8-mm-thick hardwood siding, 40-mm by 130-mm hardwood studs on 0.65-m centers with glass fiber insulation (paper faced, 28 kg/m3), and a 12-mm layer of gypsum (vermiculite) wall board.



What is the thermal resistance associated with a wall that is 2.5 m high by 6.5 m wide (having 10 studs, each 2.5 m high)?