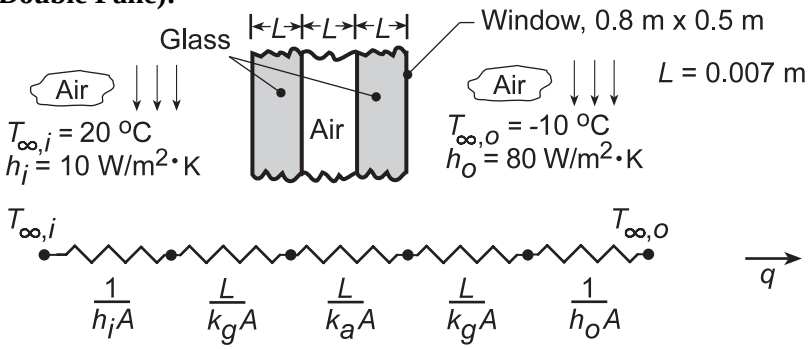
PROBLEM 3.12

KNOWN: Dimensions of a thermopane window. Room and ambient air conditions.

FIND: (a) Heat loss through window, (b) Effect of variation in outside convection coefficient for double and triple pane construction.

SCHEMATIC (Double Pane):



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional heat transfer, (3) Constant properties, (4) Neglect radiation effects, (5) Air between glass is stagnant.

PROPERTIES: *Table A-3*, Glass (300 K): k_g = 1.4 W/m·K; *Table A-4*, Air (T = 278 K): k_a = 0.0245 W/m·K.

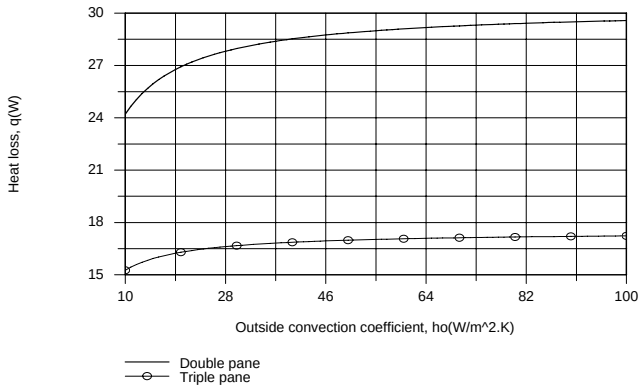
ANALYSIS: (a) From the thermal circuit, the heat loss is

$$q=\frac{T_{\infty,i}-T_{\infty,o}}{\frac{1}{A}\left(\frac{1}{h_i}+\frac{L}{k_g}+\frac{L}{k_a}+\frac{L}{k_g}+\frac{1}{h_o}\right)}$$

$$q=\frac{20^\circ\text{C}-\left(-10^\circ\text{C}\right)}{\left(\frac{1}{0.4\,\text{m}^2}\right)\left(\frac{1}{10\,\text{W/m}^2\cdot\text{K}}+\frac{0.007\,\text{m}}{1.4\,\text{W/m}\cdot\text{K}}+\frac{0.007\,\text{m}}{0.0245\,\text{W/m}\cdot\text{K}}+\frac{0.007\,\text{m}}{1.4\,\text{W/m}\cdot\text{K}}+\frac{1}{80\,\text{W/m}^2\cdot\text{K}}\right)}$$

$$q=\frac{30^\circ\text{C}}{(0.25+0.0125+0.715+0.0125+0.03125)\,\text{K/W}}=\frac{30^\circ\text{C}}{1.021\,\text{K/W}}=29.4\ \text{W} \quad <$$

(b) For the triple pane window, the additional pane and airspace increase the total resistance from 1.021 K/W to 1.749 K/W, thereby reducing the heat loss from 29.4 to 17.2 W. The effect of h_o on the heat loss is plotted as follows.



Continued...

PROBLEM 3.12 (Cont.)

Changes in h_o influence the heat loss at small values of h_o, for which the outside convection resistance is not negligible relative to the total resistance. However, the resistance becomes negligible with increasing h_o, particularly for the triple pane window, and changes in h_o have little effect on the heat loss.

COMMENTS: (1) The largest contribution to the thermal resistance is due to conduction across the enclosed air. Note that this air could be in motion due to free convection currents. If the corresponding convection coefficient exceeded 3.5 $W/m^2 \cdot K$, the thermal resistance would be less than that predicted by assuming conduction across stagnant air, thereby increasing the heat loss.
(2) Determination of the radiation heat loss is complex and will be addressed in Chapters 12 and 13. Radiation would increase the heat loss between the room and outside air, but on a sunny day, solar radiation transmitted through the window would contribute to heating the room.