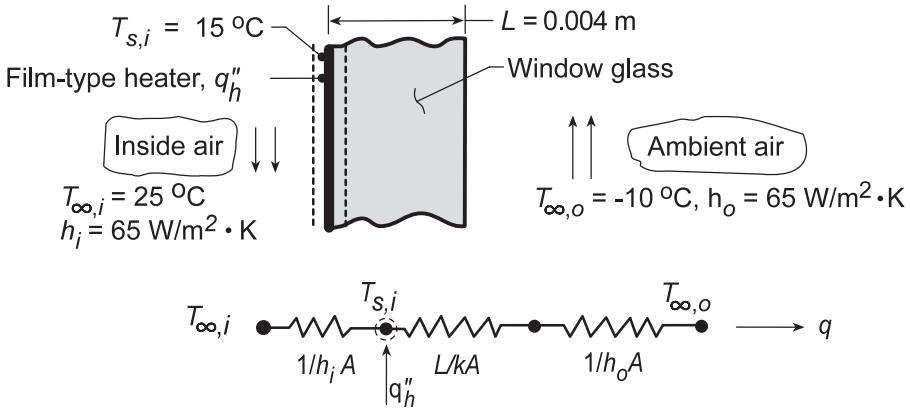
PROBLEM 3.4

KNOWN: Desired inner surface temperature of rear window with prescribed inside and outside air conditions.

FIND: (a) Heater power per unit area required to maintain the desired temperature, and (b) Compute and plot the electrical power requirement as a function of $T_{\infty,o}$ for the range $-30 \le T_{\infty,o} \le 0°C$ with h_o of 2, 20, 65 and 100 W/m^2·K. Comment on heater operation needs for low h_o. If $h \sim V^n$, where V is the vehicle speed and n is a positive exponent, how does the vehicle speed affect the need for heater operation?

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional heat transfer, (3) Uniform heater flux, q''_h, (4) Constant properties, (5) Negligible radiation effects, (6) Negligible film resistance.

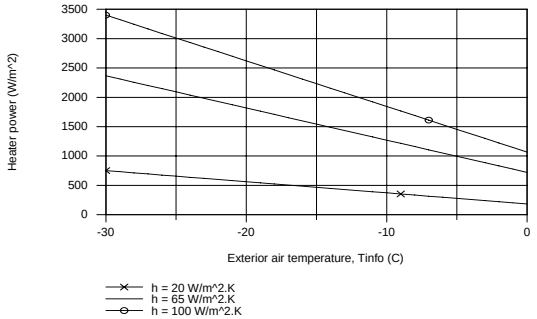
PROPERTIES: *Table A-3*, Glass (300 K): k = 1.4 W/m·K.

ANALYSIS: (a) From an energy balance at the inner surface and the thermal circuit, it follows that for a unit surface area,

$$\frac{T_{\infty,i} - T_{s,i}}{1/h_i} + q''_h = \frac{T_{s,i} - T_{\infty,o}}{L/k + 1/h_o} \quad \text{and that} \quad q''_h = \frac{T_{s,i} - T_{\infty,o}}{L/k + 1/h_o} - \frac{T_{\infty,i} - T_{s,i}}{1/h_i}$$

$$q''_h = \frac{15^\circ C - \left(-10^\circ C\right)}{\frac{0.004\,m}{1.4\,W/m\cdot K} + \frac{1}{65\,W/m^2\cdot K}} - \frac{25^oC\text{-}15^oC}{\frac{1}{10\,W/m^2\cdot K}} = \left(1370 - 100\right) W/m^2 = 1270\,W/m^2 \quad <$$

(b) The heater electrical power requirement as a function of the exterior air temperature for different exterior convection coefficients is shown in the plot. When h_o = 2 W/m^2·K, the heater is unecessary, since the glass is maintained at 15°C by the interior air. If $h \sim V^n$, we conclude that, with higher vehicle speeds, the exterior convection will increase, requiring increased heat power to maintain the 15°C condition.



COMMENTS: With q''_h = 0, the inner surface temperature with $T_{\infty,o}$ = -10°C would be given by

$$\frac{T_{\infty,i} - T_{s,i}}{T_{\infty,i} - T_{\infty,o}} = \frac{1/h_i}{1/h_i + L/k + 1/h_o} = \frac{0.10}{0.118} = 0.846, \qquad \text{or} \qquad T_{s,i} = 25^\circ C - 0.846\left(35^\circ C\right) = -4.6^\circ C\,.$$