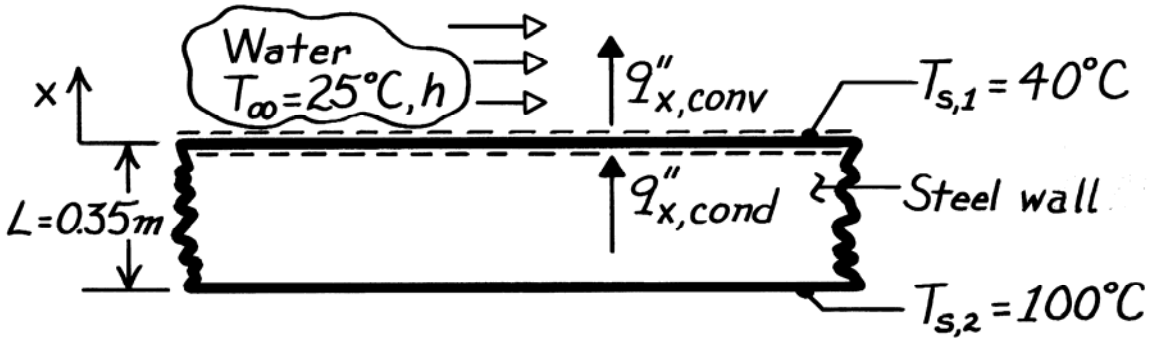
PROBLEM 6.4

KNOWN: Surface temperatures of a steel wall and temperature of water flowing over the wall.

FIND: (a) Convection coefficient, (b) Temperature gradient in wall and in water at wall surface.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional heat transfer in x, (3) Constant properties.

PROPERTIES: *Table A-1*, Steel Type AISI 1010 (70°C = 343K), k_s = 61.7 W/m·K; *Table A-6*, Water (32.5°C = 305K), k_f = 0.62 W/m·K.

ANALYSIS: (a) Applying an energy balance to the control surface at x = 0, it follows that

$$q''_{x,cond} - q''_{x,conv} = 0$$

and using the appropriate rate equations,

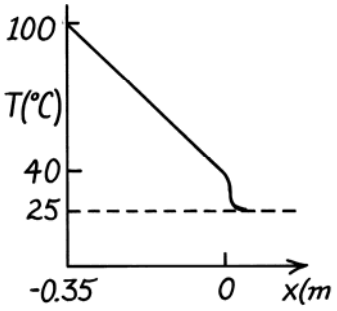
$$k_s \frac{T_{s,2} - T_{s,1}}{L} = h\left(T_{s,1} - T_\infty\right).$$

Hence,

$$h = \frac{k_s}{L}\frac{T_{s,2} - T_{s,1}}{T_{s,1} - T_\infty} = \frac{61.7\ \text{W/m}\cdot\text{K}}{0.35\text{m}}\frac{60^\circ\text{C}}{15^\circ\text{C}} = 705\ \text{W/m}^2\cdot\text{K}. \quad <$$

(b) The gradient in the wall at the surface is

$$\left(dT/dx\right)_s = -\frac{T_{s,2} - T_{s,1}}{L} = -\frac{60^\circ\text{C}}{0.35\text{m}} = -171.4^\circ\text{C/m}.$$



In the water at x = 0, the definition of h gives

$$\left(dT/dx\right)_{f,x=0} = -\frac{h}{k_f}\left(T_{s,1} - T_\infty\right)$$

$$\left(dT/dx\right)_{f,x=0} = -\frac{705\ \text{W/m}^2\cdot\text{K}}{0.62\ \text{W/m}\cdot\text{K}}\left(15^\circ\text{C}\right) = -17,056^\circ\text{C/m}. \quad <$$

COMMENTS: Note the relative magnitudes of the gradients. Why is there such a large difference?