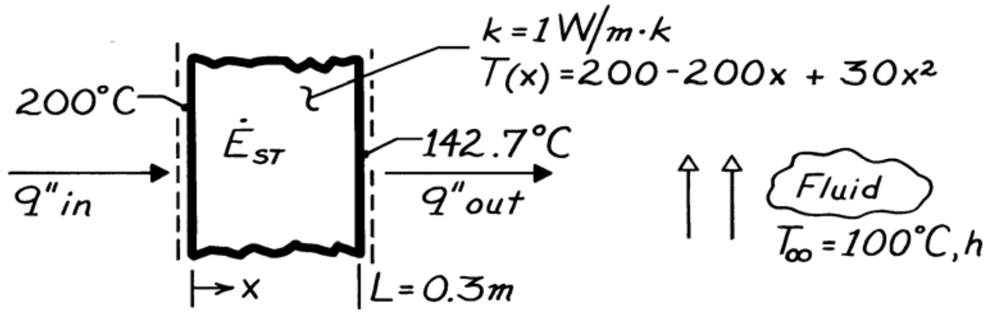
PROBLEM 2.31

KNOWN: Wall thickness, thermal conductivity, temperature distribution, and fluid temperature.

FIND: (a) Surface heat rates and rate of change of wall energy storage per unit area, and (b) Convection coefficient.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional conduction in x, (2) Constant k.

ANALYSIS: (a) From Fourier's law,

$$q''_x = -k\frac{\partial T}{\partial x} = (200 - 60x)\cdot k$$

$$q''_{in} = q''_{x=0} = 200\frac{^\circ C}{m}\times 1\frac{W}{m\cdot K} = 200\ W/m^2$$ <

$$q''_{out} = q''_{x=L} = (200 - 60\times 0.3)^\circ\ C/m\ \times\ 1\ W/m\cdot K = 182\ W/m^2.$$ <

Applying an energy balance to a control volume about the wall, Eq. 1.12c,

$$\dot{E}''_{in} - \dot{E}''_{out} = \dot{E}''_{st}$$

$$\dot{E}''_{st} = q''_{in} - q''_{out} = 18\ W/m^2.$$ <

(b) Applying a surface energy balance at x = L,

$$q''_{out} = h\left[T(L) - T_\infty\right]$$

$$h = \frac{q''_{out}}{T(L) - T_\infty} = \frac{182\ W/m^2}{(142.7\text{-}100)^\circ\ C}$$

$$h = 4.3\ W/m^2\cdot K.$$ <

COMMENTS: (1) From the heat equation,

$$(\partial T/\partial t) = (k/\rho c_p)\ \partial^2 T/\partial x^2 = 60(k/\rho c_p),$$

it follows that the temperature is increasing with time at every point in the wall.

(2) The value of h is small and is typical of free convection in a gas.