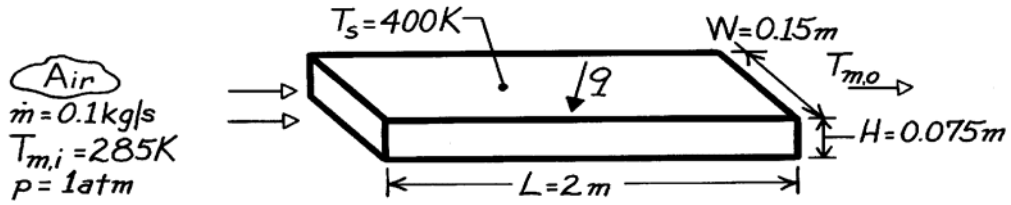
PROBLEM 8.85

KNOWN: Temperature, pressure and flow rate of air entering a rectangular duct of prescribed dimensions and surface temperature.

FIND: Air outlet temperature and duct heat transfer rate.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Constant properties, (3) Uniform surface temperature, (4) Fully developed flow throughout, (5) Ideal gas with negligible viscous dissipation and pressure variation.

PROPERTIES: *Table A-4*, Air (assume $T_m \approx 325$K, 1 atm): $c_p = 1008$ J/kg·K, $\mu = 196.4 \times 10^{-7}$ N·s/m^2, k = 0.0282 W/m·K, Pr = 0.707.

ANALYSIS: From Eqs. 8.66 and 8.1,

$$D_h = \frac{4\,A_c}{P} = \frac{4\times(0.15\times 0.075)\,m^2}{2(0.15+0.075)\,m} = 0.10\ m$$

$$Re_D = \frac{\rho\, u_m D_h}{\mu} = \frac{\dot{m}\, D_h}{A_c \mu} = \frac{0.1\ kg/s\,(0.1m)}{(0.15m\times 0.075m)196.4\times 10^{-7}\ N\cdot s/m^2} = 45,260.$$

Hence the flow is turbulent, and from Eq. 8.60

$$h = \frac{k}{D_h} 0.023\, Re_D^{4/5}\, Pr^{0.4} = \frac{0.0282\ W/m\cdot K}{0.10\ m} 0.023(45,260)^{4/5}(0.707)^{0.4} = 30\ W/m^2\cdot K.$$

From Eq. 8.41b, with P = 2(W + H),

$$T_{m,o} = T_s - (T_s - T_{m,i}) \exp\left(-\frac{PL}{\dot{m}\, c_p}\bar{h}\right)$$

$$T_{m,o} = 400\ K - (400-285)K \exp\left[-\frac{2(0.15m+0.075m)\,2m\left(30W/m^2\cdot K\right)}{0.1\ kg/s\times 1008\ J/kg\cdot K}\right]$$

$$T_{m,o} = 312\ K \qquad <$$

and from Eq. 8.34

$$q = \dot{m}\, c_p (T_{m,o} - T_{m,i}) = 0.1\ kg/s\times 1008\ J/kg\cdot K\,(312-285)K = 2724\ W. \qquad <$$

COMMENTS: (1) The calculations may be checked by determining q from Eqs. 8.43 and 8.44. We obtain $\Delta T_{\ell m} = 101^\circ C$ and q = 2724 W.

(2) $\bar{T}_m$ has been over-estimated. The calculations should be repeated with properties evaluated at $\bar{T}_m$ = 299 K.