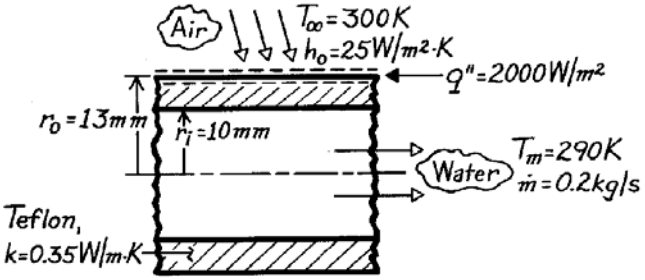
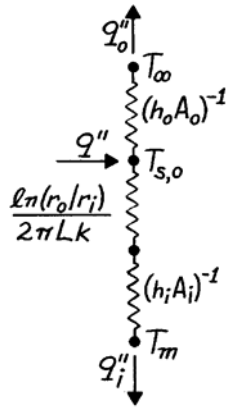
## PROBLEM 8.74

**KNOWN:** Inner and outer radii and thermal conductivity of a Teflon tube. Flowrate and temperature of confined water. Heat flux at outer surface and temperature and convection coefficient of ambient air.

**FIND:** Fraction of heat transfer to water and temperature of tube outer surface.

**SCHEMATIC:**




**ASSUMPTIONS:** (1) Steady-state conditions, (2) Fully-developed flow, (3) One-dimensional conduction, (4) Negligible tape contact and conduction resistances.

**PROPERTIES:** *Table A-6*, Water ($T_m$ = 290K): $\mu = 1080 \times 10^{-6}$ kg/s·m, k = 0.598 W/m·K, Pr = 7.56.

**ANALYSIS:** The outer surface temperature follows from a surface energy balance

$$(2\pi\, r_o L)q'' = \frac{T_{s,o} - T_\infty}{(h_o 2\pi\, r_o L)^{-1}} + \frac{T_{s,o} - T_m}{\left(\ln(r_o/r_i)/2\pi\, Lk\right) + \left(1/2\pi\, r_i L h_i\right)}$$

$$q'' = h_o\left(T_{s,o} - T_\infty\right) + \frac{T_{s,o} - T_m}{(r_o/k)\ln(r_o/r_i) + (r_o/r_i)/h_i}.$$

With $\mathrm{Re_D} = 4\,\dot{m}/(\pi\, D\mu) = 4(0.2\text{kg/s})/\left[\pi(0.02\text{ m})1080\times10^{-6}\text{ kg/s}\cdot\text{m}\right] = 11,789$

the flow is turbulent and Eq. 8.60 yields

$$h_i = (k/D_i)\,0.023\mathrm{Re}_D^{4/5}\,\mathrm{Pr}^{0.4} = (0.598\text{ W/m}\cdot\text{K}/0.02\text{ m})(0.023)(11,789)^{4/5}(7.56)^{0.4} = 2792\text{ W/m}^2\cdot\text{K}.$$

Hence

$$2000\text{ W/m}^2 = 25\text{ W/m}^2\cdot\text{K}\left(T_{s,o} - 300\text{K}\right) + \frac{T_{s,o} - 290\text{ K}}{(0.013\text{ m}/0.35\text{ W/m}\cdot\text{K})\ln(1.3) + (1.3)/\left(2792\text{ W/m}^2\cdot\text{K}\right)}$$

and solving for $T_{s,o}$, $T_{s,o} = 308.3$ K. <

The heat flux to the air is

$$q''_o = h_o\left(T_{s,o} - T_\infty\right) = 25\text{ W/m}^2\cdot\text{K}(308.3 - 300)\text{K} = 207.5\text{ W/m}^2.$$

Hence, $q''_i/q'' = (2000 - 207.5)\text{W/m}^2/2000\text{ W/m}^2 = 0.90.$ <

**COMMENTS:** The resistance to heat transfer by convection to the air substantially exceeds that due to conduction in the teflon and convection in the water. Hence, most of the heat is transferred to the water.