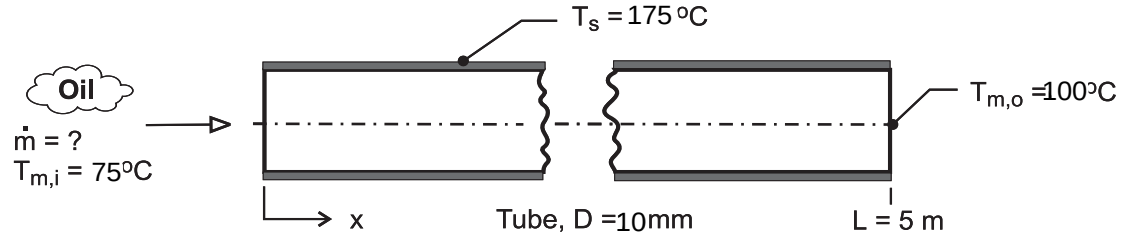
PROBLEM 8.28

KNOWN: Oil at 75°C enters a single-tube preheater of 10-mm diameter and 5-m length; tube surface maintained at 175°C by swirling combustion gases.

FIND: Determine the flow rate and heat transfer rate when the outlet temperature is 100°C.

SCHEMATIC:



ASSUMPTIONS: (1) Laminar flow, (2) Tube wall is isothermal, (3) Incompressible liquid with negligible viscous dissipation, (4) Constant properties.

PROPERTIES: *Table A-5*, Engine oil, new ($T_m = (T_{m,i} + T_{m,o})/2 = 361$ K): $\rho = 847.5$ kg/m^3, $c_p = 2163$ J/kg·K, $\nu = 2.931 \times 10^{-5}$ m^2/s, $k = 0.1379$ W/m·K, Pr = 390.2, $\mu = 0.0245$.

ANALYSIS: The overall energy balance, Eq. 8.34, and rate equation, Eq. 8.41b, are

$$q = \dot{m} c_p \left(T_{m,o} - T_{m,i}\right) \tag{1}$$

$$\frac{T_s - T_{m,o}}{T_s - T_{m,i}} = \exp\left(-\frac{PL\bar{h}}{\dot{m} c_p}\right) \tag{2}$$

Not knowing the flow rate $\dot{m}$, the Reynolds number cannot be calculated. Assume that the flow is laminar. Since Pr > 5, the average convection coefficient can be estimated using the Hausen correlation, Eq. 8.57, with Eq. 8.56 for the Graetz number:

$$\overline{Nu}_D = 3.66 + \frac{0.0668(D/L)\,Re_D\,Pr}{1 + 0.04\left[(D/L)\,Re_D\,Pr\right]^{2/3}} \tag{3}$$

where all properties are evaluated at $T_m = (T_{m,i} + T_{m,o})/2$. The Reynolds number follows from Eq. 8.6,

$$Re_D = 4\dot{m}/\pi D\mu \tag{4}$$

A tedious trial-and-error solution is avoided by using *IHT* to solve the system of equations with the following result:

Re_D	$\overline{Nu}_D$	$\bar{h}_D$ (W/m^2·K)	q(W)	$\dot{m}$(kg/h)
130	7.25	100	1360	90

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Note that the flow is laminar, and evaluating $x_{fd,t}$ using Eq. 8.23, find $x_{fd,t} = 25$ m, so the flow is not thermally fully developed.

COMMENT: Use of the Baehr and Stephan correlation for the combined entry problem yields the identical values. Hence it may also be used.