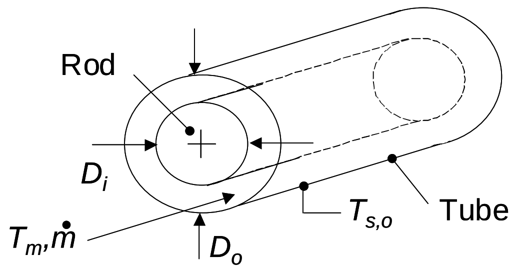
PROBLEM 8.102

KNOWN: Laminar flow within a tube of diameter D_o. Inner rod diameter, D_i. Mean fluid temperature, T_m, and tube wall temperature, $T_{s,o}$.

FIND: Ratio of heat transfer from the fluid to the tube wall for D_i/D_o = 0, 0.10, 0.25 and 0.50.

SCHEMATIC:



ASSUMPTIONS: (1) Fully developed, laminar flow, (2) Constant properties, (3) Negligible conduction in the rod.

ANALYSIS: A control volume analysis about the inner rod reveals that there is no heat transfer to or from the rod. Hence, it acts as an insulated surface. Equation 8.68 may be written for the tube where, from Equation 8.70 $h_o = Nu_o k/D_h = Nu_o k/(D_o - D_i)$. Hence,

$$q''_o = \frac{Nu_o k\left(T_{s,o} - T_m\right)}{D_o(1 - D_i / D_o)} \tag{1}$$

Without the rod, $D_i/D_o = 0$ and $Nu_o = 3.66$, yielding

$$q''_{o,\text{wo}} = \frac{Nu_o k(T_{s,o} - T_m)}{D_o} = \frac{3.66k(T_{s,o} - T_m)}{D_o} \tag{2}$$

Hence,

$$q''_o / q''_{o,\text{wo}} = \frac{Nu_o}{3.66(1 - D_i / D_o)}$$

From Table 8.2,

D_i/D_o	Nu_o	$q''_o / q''_{o,\text{wo}}$
0	3.66	1
0.10	4.11	1.25
0.25	4.23	1.54
0.50	4.43	2.42

<

COMMENTS: (1) The proposed scheme enhances the heat transfer between the fluid and the tube wall, (2) The fluid temperature will change as the fluid flows in the axial direction. If the rod is of relatively high thermal conductivity compared to the fluid, the rod will be at a nearly uniform temperature. Hence, the rod could no longer be considered an insulated surface, since it would cool the fluid in upstream locations, and heat the fluid further downstream for the case where the fluid enters the annular region at a temperature higher than that of the tube wall.