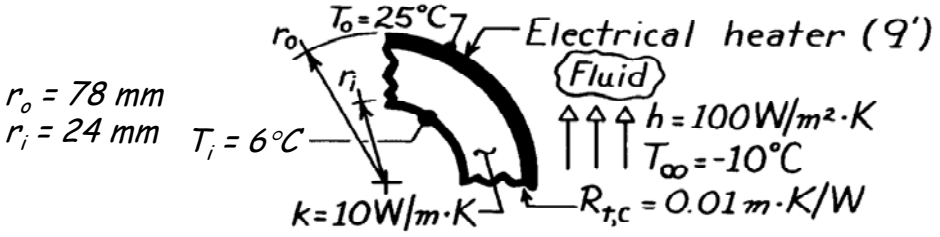
PROBLEM 3.48

KNOWN: Inner and outer radii of a tube wall which is heated electrically at its outer surface and is exposed to a fluid of prescribed h and T_∞. Thermal contact resistance between heater and tube wall and wall inner surface temperature.

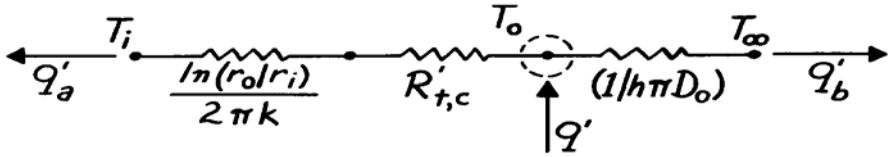
FIND: Heater power per unit length required to maintain a heater temperature of 25°C.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional conduction, (3) Constant properties, (4) Negligible temperature drop across heater.

ANALYSIS: The thermal circuit has the form



Applying an energy balance to a control surface about the heater,

$$q' = q'_a + q'_b$$

$$q' = \frac{T_o - T_i}{\frac{\ln(r_o/r_i)}{2\pi k} + R'_{t,c}} + \frac{T_o - T_\infty}{(1/h\pi D_o)}$$

$$q' = \frac{(25\text{-}6)^\circ\text{C}}{\frac{\ln(78\text{mm}/24\text{mm})}{2\pi \times 10\ \text{W/m}\cdot\text{K}} + 0.01\frac{\text{m}\cdot\text{K}}{\text{W}}} + \frac{\left[25-(-10)\right]^\circ\text{C}}{\left[1/\left(100\ \text{W/m}^2\cdot\text{K}\times\pi\times 0.156\text{m}\right)\right]}$$

$$q' = (661 + 1715)\ \text{W/m}$$

$$q' = 2376\ \text{W/m}. \quad <$$

COMMENTS: The conduction, contact and convection resistances are 0.0188, 0.01 and 0.02 m ·K/W, respectively,