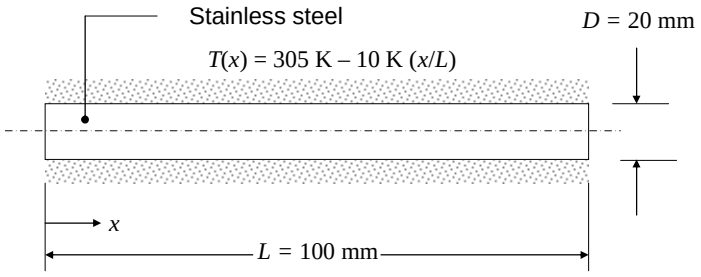
PROBLEM 2.25

KNOWN: Diameter, length, and mass of stainless steel rod, insulated on its exterior surface other than ends. Temperature distribution.

FIND: Heat flux.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional conduction in x-direction, (3) Constant properties.

ANALYSIS: The heat flux can be found from Fourier's law,

$$q''_x = -k\frac{dT}{dx}$$

Table A.1 gives values for the thermal conductivity of stainless steels, however we are not told which type of stainless steel the rod is made of, and the thermal conductivity varies between them. We do know the mass of the rod, and can use this to calculate its density:

$$\rho = \frac{M}{V} = \frac{M}{\pi D^2 L/4} = \frac{0.248\ \text{kg}}{\pi \times (0.02\ \text{m})^2 \times 0.1\ \text{m}/4} = 7894\ \text{kg/m}^3$$

From Table A.1, it appears that the material is AISI 304 stainless steel. The temperature of the rod varies from 295 K to 305 K. Evaluating the thermal conductivity at 300 K, k = 14.9 W/m·K. Thus,

$$q''_x = -k\frac{dT}{dx} = -k(-b/L) = 14.9\ \text{W/m}\cdot\text{K} \times 10\ \text{K}/0.1\ \text{m} = 1490\ \text{W/m}^2 \quad <$$

COMMENTS: If the temperature of the rod varies significantly along its length, the thermal conductivity will vary along the rod as much or more than the variation in thermal conductivities between the different stainless steels.