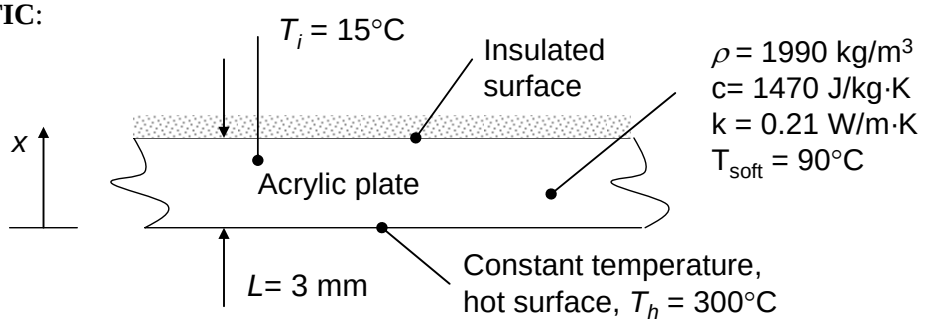
PROBLEM 5.50

KNOWN: Thickness and initial temperature of acrylic sheet.

FIND: Time needed to bring the external surface of the acrylic to its softening temperature.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional conduction, (2) Constant properties, (3) One-term approximate solution is valid.

PROPERTIES: Acrylic (given): ρ = 1990 kg/m^3, c = 1470 J/kg·K and k = 0.21 W/m·K.

ANALYSIS: For the constant temperature boundary condition, the Biot number is $Bi \to \infty$. Hence, from Table 5.1 for the plane wall, ζ_1 = 1.5708, C_1 = 1.2733. The dimensionless external surface temperature at the time of interest is

$$\theta_o^* = \frac{90°C - 300°C}{15°C - 300°C} = 0.737 = C_1 \exp(-\zeta_1^2 Fo) = 1.2733 \exp(-1.5708^2 Fo)$$

From which Fo = 0.222. Hence,

$$t = FoL^2/\alpha = FoL^2\rho c/k = [0.222 \times (0.003\ \text{m})^2 \times 1990\ \text{kg/m}^3 \times 1470\ \text{J/kg·K}]/0.21\ \text{W/m·K} = 27.8\ \text{s} \quad <$$

COMMENTS: (1) Since Fo = 0.222 is greater than 0.2, the one-term approximation is valid. (2) A contact resistance would be present at the interface between the acrylic and the substrate. However, as the acrylic softens and deforms locally to make better contact with the substrate, the thermal contact resistance would decrease in value.