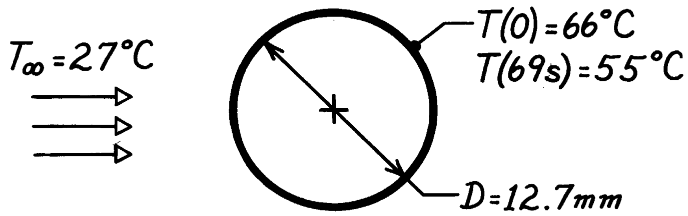
PROBLEM 5.8

KNOWN: The temperature-time history of a pure copper sphere in an air stream.

FIND: The heat transfer coefficient between the sphere and the air stream.

SCHEMATIC:



ASSUMPTIONS: (1) Temperature of sphere is spatially uniform, (2) Negligible radiation exchange, (3) Constant properties.

PROPERTIES: *Table A-1*, Pure copper (333K): ρ = 8933 kg/m^3, c_p = 389 J/kg·K, k = 398 W/m·K.

ANALYSIS: The time-temperature history is given by Eq. 5.6 with Eq. 5.7.

$$\frac{\theta(t)}{\theta_i} = \exp\left(-\frac{t}{R_t C_t}\right) \qquad \text{where} \qquad R_t = \frac{1}{hA_s} \qquad A_s = \pi D^2$$

$$C_t = \rho V c_p \qquad V = \frac{\pi D^3}{6}$$

$$\theta = T - T_\infty.$$

Recognize that when t = 69s,

$$\frac{\theta(t)}{\theta_i} = \frac{(55-27)^\circ C}{(66-27)^\circ C} = 0.718 = \exp\left(-\frac{t}{\tau_t}\right) = \exp\left(-\frac{69s}{\tau_t}\right)$$

and solving for τ_t find

$$\tau_t = 208s.$$

Hence,

$$h = \frac{\rho V c_p}{A_s \tau_t} = \frac{8933\ kg/m^3 \left(\pi 0.0127^3\ m^3/6\right) 389 J/kg\cdot K}{\pi 0.0127^2 m^2 \times 208s}$$

$$h = 35.3\ W/m^2\cdot K.$$ <

COMMENTS: Note that with $L_c = D_o/6$,

$$Bi = \frac{hL_c}{k} = 35.3\ W/m^2\cdot K \times \frac{0.0127}{6} m/398\ W/m\cdot K = 1.88\times10^{-4}.$$

Hence, Bi < 0.1 and the spatially isothermal assumption is reasonable.