PROBLEM 3.67
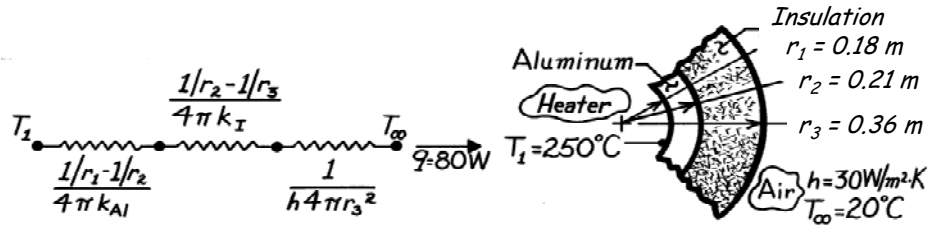
KNOWN: Thickness of hollow aluminum sphere and insulation layer. Heat rate and inner surface temperature. Ambient air temperature and convection coefficient.

FIND: Thermal conductivity of insulation.

SCHEMATIC:

ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional radial conduction, (3) Constant properties, (4) Negligible contact resistance, (5) Negligible radiation exchange at outer surface.

PROPERTIES: *Table A-1*, Aluminum (523K): $k \approx 230$ W/m·K.

ANALYSIS: From the thermal circuit,

$$q = \frac{T_1 - T_\infty}{R_{tot}} = \frac{T_1 - T_\infty}{\dfrac{1/r_1 - 1/r_2}{4\pi\, k_{A1}} + \dfrac{1/r_2 - 1/r_3}{4\pi\, k_I} + \dfrac{1}{h4\pi\, r_3^2}}$$

$$q = \frac{(250 - 20)^\circ C}{\left[\dfrac{1/0.18 - 1/0.21}{4\pi\,(230)} + \dfrac{1/0.21 - 1/0.36}{4\pi\, k_I} + \dfrac{1}{30(4\pi)(0.36)^2}\right]\dfrac{K}{W}} = 80 \text{ W}$$

or

$$2.75 \times 10^{-4} + \frac{0.158}{k_I} + 0.02 = \frac{230}{80} = 2.875.$$

Solving for the unknown thermal conductivity, find

$$k_I = 0.055 \text{ W/m·K.} \qquad <$$

COMMENTS: The dominant contribution to the total thermal resistance is made by the insulation. Hence uncertainties in knowledge of h or k_{A1} have a negligible effect on the accuracy of the k_I measurement.