10-92 An electric wire is tightly wrapped with a 1-mm thick plastic cover. The interface temperature and the effect of doubling the thickness of the plastic cover on the interface temperature are to be determined.

Assumptions **1** Heat transfer is steady since there is no indication of any change with time. **2** Heat transfer is one-dimensional since there is thermal symmetry about the centerline and no variation in the axial direction. **3** Thermal properties are constant. **4** The thermal contact resistance at the interface is negligible. **5** Heat transfer coefficient accounts for the radiation effects, if any.

Properties The thermal conductivity of plastic cover is given to be $k = 0.15$ W/m·°C.

Analysis In steady operation, the rate of heat transfer from the wire is equal to the heat generated within the wire,

$$\dot{Q} = \dot{W}_e = \mathbf{V}I = (8 \text{ V})(13 \text{ A}) = 104 \text{ W}$$

The total thermal resistance is
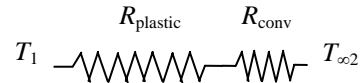
$$R_{conv} = \frac{1}{h_o A_o} = \frac{1}{(24 \text{ W/m}^2 \cdot °C)[\pi(0.0042 \text{ m})(10 \text{ m})]} = 0.3158 \text{ °C/W}$$

$$R_{plastic} = \frac{\ln(r_2 / r_1)}{2\pi kL} = \frac{\ln(2.1/1.1)}{2\pi(0.15 \text{ W/m.°C})(10 \text{ m})} = 0.0686 \text{ °C/W}$$

$$R_{total} = R_{conv} + R_{plastic} = 0.3158 + 0.0686 = 0.3844 \text{ °C/W}$$

Then the interface temperature becomes

$$\dot{Q} = \frac{T_1 - T_{\infty 2}}{R_{total}} \longrightarrow T_1 = T_\infty + \dot{Q}R_{total} = 30°C + (104 \text{ W})(0.3844 \text{ °C/W}) = \mathbf{70.0°C}$$

The critical radius of plastic insulation is

$$r_{cr} = \frac{k}{h} = \frac{0.15 \text{ W/m.°C}}{24 \text{ W/m}^2 \cdot °C} = 0.00625 \text{ m} = 6.25 \text{ mm}$$

Doubling the thickness of the plastic cover will increase the outer radius of the wire to 3 mm, which is less than the critical radius of insulation. Therefore, doubling the thickness of plastic cover will increase the rate of heat loss and decrease the interface temperature.