3.102 A long, circular aluminum rod is attached at one end to a heated wall and transfers heat by convection to a cold fluid.

(a) If the diameter of the rod is doubled, by how much would the rate of heat removal change?

(b) If a copper rod of the same diameter is used in place of the aluminum, by how much would the rate of heat removal change?

$$K_a = 237 \frac{W}{mK}$$

$$K_c = 401 \frac{W}{mK}$$

$$A_c = \frac{\pi d^2}{4}$$

$$M = \sqrt{hPKA_c}\,\theta_b = q_f$$

$$\sqrt{hPK\frac{\pi d^2}{4}}\,\theta_b = \frac{d}{2}\sqrt{hPK\pi}\,\theta_b$$

$$q_{f_c} = a\,q_{f_a}$$

$$\sqrt{\cancel{hP}K_c\cancel{A_c}}\,\cancel{\theta_b} = a\sqrt{\cancel{hP}K_a\cancel{A_c}}\,\cancel{\theta_b}$$

$$\sqrt{K_c} = a\sqrt{K_a}$$

$$a = \sqrt{\frac{K_c}{K_a}}$$

5.10 A steel sphere (AISI 1010), 100 mm in diameter, is coated with a dielectric material layer of thickness 2 mm and thermal conductivity 0.04 W/m · K. The coated sphere is initially at a uniform temperature of 500°C and is suddenly quenched in a large oil bath for which $T_\infty = 100°C$ and $h = 3000\ W/m^2 \cdot K$. Estimate the time required for the coated sphere temperature to reach 150°C. *Hint:* Neglect the effect of energy storage in the dielectric material, since its thermal capacitance $(\rho c V)$ is small compared to that of the steel sphere.

$$k = 63.9 \frac{W}{mK}$$

$$\rho = 7832 \frac{kg}{m^3}$$

$$c = 434 \frac{J}{kg\,K}$$

$$Bi = \frac{hL_c}{k} = \frac{3000 \frac{W}{m^2K} 0.05\ m}{63.9 \frac{W}{mK}}$$

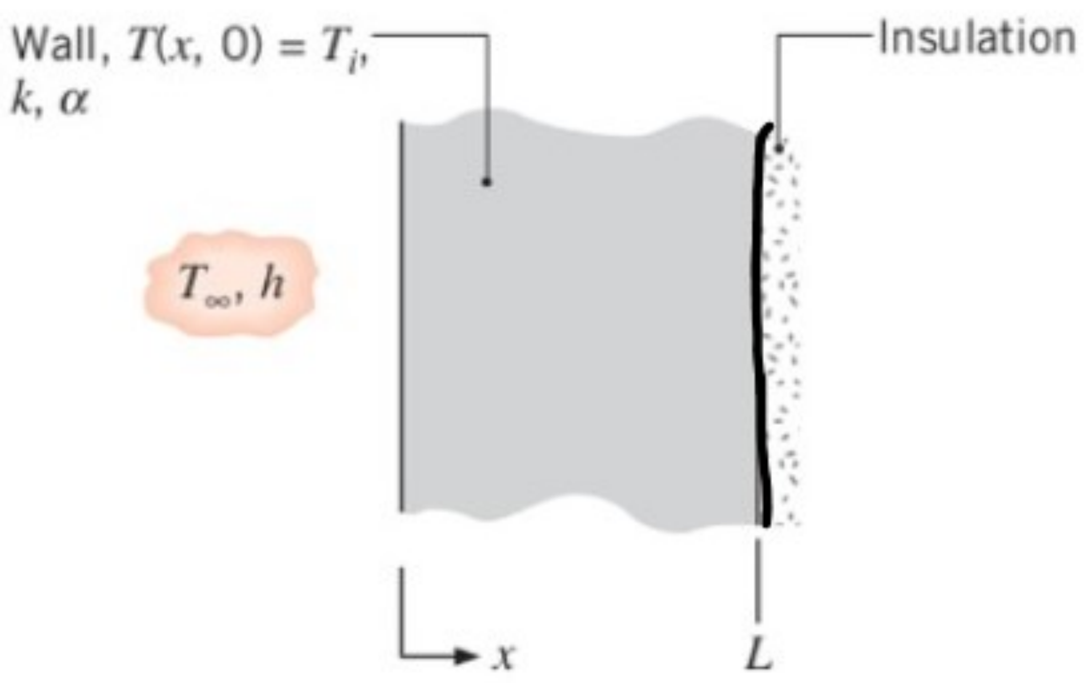
$$\theta = T - T_\infty = 150°C - 100°C = 50\ K$$

$$\theta_i = 500°C - 100°C = 400\ K$$

$$\frac{\theta}{\theta_i} = \exp\left(-\frac{hA_s}{\rho V c} t\right)$$

$$= 0.0068$$

5.36 Consider the one-dimensional wall shown in the sketch, which is initially at a uniform temperature T_i and is suddenly subjected to the convection boundary condition with a fluid at T_∞.



For a particular wall, case 1, the temperature at $x = L_1$ after $t_1 = 100$ s is $T_1(L_1, t_1) = 315°C$. Another wall, case 2, has different thickness and thermal conditions as shown.

Case	L (m)	α (m^2/s)	k ($W/m \cdot K$)	T_i (°C)	T_∞ (°C)	h ($W/m^2 \cdot K$)
1	0.10	15×10^{-6}	50	300	400	200
2	0.40	25×10^{-6}	100	30	20	100

How long will it take for the second wall to reach 28.5°C at the position $x = L_2$? Use as the basis for analysis, the dimensionless functional dependence for the transient temperature distribution expressed in Equation 5.41.

$$\theta^* = C_1 \exp(-\zeta_1^2 Fo) \cos(\zeta_1 x^*)$$

$$\theta^* = \frac{T - T_\infty}{T_i - T_\infty} \qquad Fo = \frac{\alpha t}{L^2} \qquad x^* = \frac{x}{L} = 1$$