Solutions

2.1

- $L_c = r/3 = 10/3 = \mathbf{3.33}$ mm.
- $Bi = hL_c/k = 300 \times 0.00333/43 = \mathbf{0.0233}$, below 0.1: lumped is valid.

2.2

- $\tau = \rho c L_c/h = 7850 \times 475 \times 0.00333/300 = \mathbf{41.4}$ s.
- $t = \tau \ln(\theta_i/\theta) = 41.4 \ln(760/60) = \mathbf{105}$ s.

2.3

- $T = T_\infty + \theta_i e^{-t/\tau} = 40 + 760 e^{-60/41.4} = \mathbf{219}$ °C.

3.1

- $Bi = hr_o/k = 2000 \times 0.020/43 = \mathbf{0.93}$, far above 0.1: the centre lags the surface.
- $\theta_0/\theta_i = 270/820 = 0.329$; $Fo = \ln(C_1/0.329)/\zeta_1^2 = \ln(1.195/0.329)/1.221^2 = 0.865$.
- $\alpha = k/(\rho c) = 1.153 \times 10^{-5}$ m^2/s; $t = Fo\, r_o^2/\alpha = 0.865 \times 0.02^2/(1.153 \times 10^{-5}) = \mathbf{30.0}$ s.
- Lumped: $\tau = \rho c (r/2)/h = 18.6$ s and $t = 18.6 \ln(820/270) = \mathbf{20.7}$ s, a third too short.

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