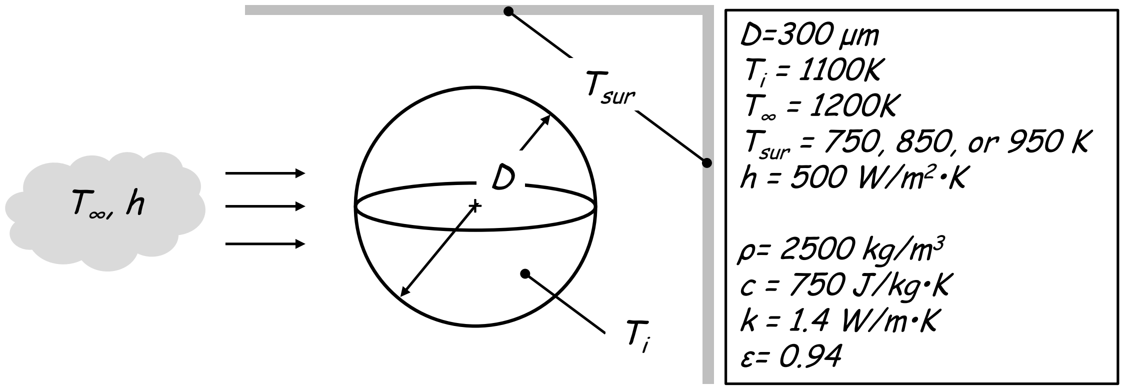
PROBLEM 04

KNOWN: Spherical ceramic particle of known properties, diameter, and initial temperature. Environment temperature and heat transfer coefficient.

FIND: Particle temperature at t = 0.1 s for T_{sur} = 750 K, 850 K, and 950 K. Plot of particle temperature vs. time.

SCHEMATIC:



ASSUMPTIONS: (1) Radiation can be approximated as a small object in large surroundings, (2) Uniform properties, (3) The lumped capacitance approximation is valid.

PROPERTIES: *Given*, ρ = 2500 kg/m^3, c_p =750 J/kg·K, k = 1.4 W/m·K, ε = 0.94.

ANALYSIS: The Biot number is

$$Bi = \frac{hL_c}{k} = \frac{h(V/A_s)}{k} = \frac{1}{3}\frac{hr_o}{k} = \frac{1}{3}\frac{500 \text{ W/m}^2\cdot\text{K} \times 150\times10^{-6} \text{ m}}{1.4 \text{ W/m}^2\cdot\text{K}} = 0.018$$

Hence the lumped capacitance approximation is valid. The temperature of the sphere is governed by Equation 5.15 with q_s'' and $\dot{E}_g$ both zero. Thus,

$$\rho Vc\frac{dT}{dt} = -\left[h(T-T_\infty) + \varepsilon\sigma(T^4 - T_{sur}^4)\right]A_s \tag{1}$$

This differential equation can be solved numerically subject to the initial condition $T(t = 0) = T_i$ = 1100 K. Using the Der function of IHT (see code in Comments section), the particle temperature at t = 0.1 s for the three surroundings temperatures of 750, 850, and 950 K are:

T_{sur} (K)	$T(t = 0.1 \text{ s})$ (K)
750	1092
850	1100
950	1111

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The particle temperature as a function of time is shown below for the three surroundings temperatures.

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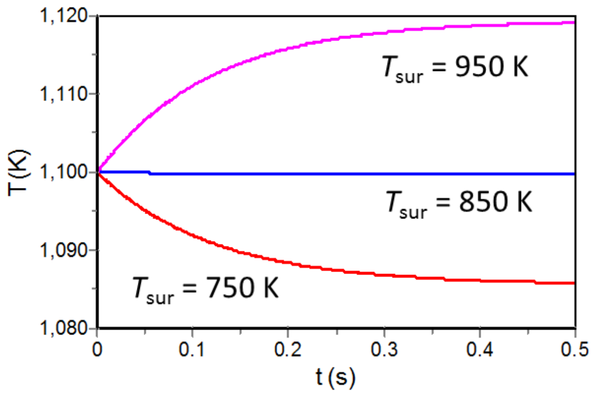
PROBLEM 04 (Cont.)



COMMENTS: (1) The IHT code is given below. (2) Depending on the surroundings temperature, the particle temperature can decrease, stay the same, or increase. (3) The steady-state temperature can be found by setting $dT/dt = 0$ in Eq. (1) and solving for T_{ss}. The results for the three surroundings temperatures are T_{ss} = 1086, 1100, and 1119 K for T_{sur} = 750, 850, and 950 K, respectively.

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D = 300e-6
ro = D/2
k = 1.4
cp = 750
rho = 2500
h = 500
Tinf = 1200
Ti = 1000
eps = 0.94
sigma=5.67e-8

Tsur1 = 750
Tsur2 = 850
Tsur3 = 950

rho*Vol*cp*Der(T1,t) = -Area*(h*(T1 - Tinf) + eps*sigma*(T1^4 - Tsur1^4))
rho*Vol*cp*Der(T2,t) = -Area*(h*(T2 - Tinf) + eps*sigma*(T2^4 - Tsur2^4))
rho*Vol*cp*Der(T3,t) = -Area*(h*(T3 - Tinf) + eps*sigma*(T3^4 - Tsur3^4))

Vol = (4/3)*pi*ro^3
Area = 4*pi*ro^2
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