Problem 1

(a) Sphere A

Sphere A: $Bi_A = \dfrac{h(D_A/6)}{k_A} = 0.0167$

Sphere B: $Bi_B = \dfrac{h(D_B/6)}{k_B} = 1.67$

(b) $\cancel{A \cdot k_A \dfrac{T_1 - T_2}{\Delta x}} + \cancel{A k_B \dfrac{T_3 - T_2}{\Delta x}} = 0$ $\qquad T_3 = 30$ [℃]

(c) $Re_D = 1173$ Laminar

$Nu_A = 3.66$ $\qquad h = 224$ W/m^2K

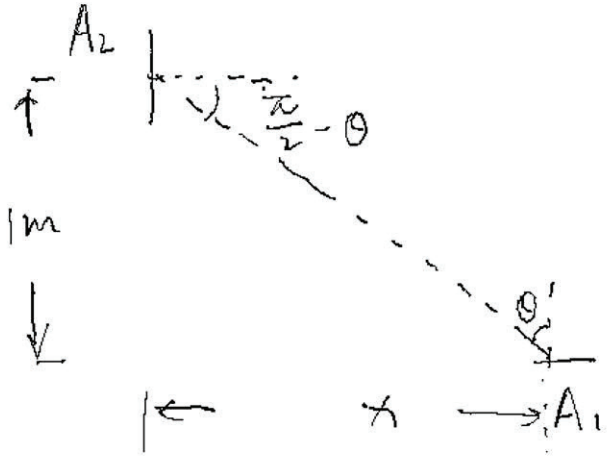
$$\frac{T_s - T_0}{T_s - T_i} = \exp\left[-\frac{\pi \cdot D \cdot L}{\dot{m} c_p} \cdot h\right]$$

$T_0 = 53.5°C$

(d) $x = 1m \cdot \tan(\theta)$

$r = 1m / \cos(\theta)$

$$q_{1-2} = I_{epr} \cdot A_1 \cos\theta \cdot \frac{A_2 \cos\left(\frac{\pi}{2} - \theta\right)}{r^2}$$



Problem 2

(a) free convection on horizontal cylinder

$$\beta = \frac{1}{T_{film}} = \frac{1}{(77+273)\,K} \qquad Ra_D = \frac{g\beta(T_s - T_\infty)D^3}{\nu\alpha} = 2.86 \times 10^8$$

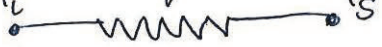
$$\overline{Nu}_D = \frac{\bar{h}D}{k_{air}} = C\,Ra_D^{\,n} = 81.9 \qquad \Leftarrow C = 0.125,\ n = 0.333$$

$$\bar{h} = 6.15\ \frac{W}{m^2 K}$$

(b) Considering conservation of energy

$$\cancel{\dot{E}_{in}}^{\,0} - \dot{E}_{out} + \dot{E}_{gen} = \cancel{\dot{E}_{stored}}^{\,0}$$

$$\Rightarrow \dot{q} \times \frac{\pi}{4}D_i^2 \times L = \bar{h} \times \pi D_o L \times (T_s - T_\infty) \Rightarrow \dot{q} = 24600\ \frac{W}{m^3}$$

(c) thermal resistance 

$$\frac{T_i - T_s}{\frac{\ln(D_o/D_i)}{2\pi k_s L}} = \dot{q} \times \frac{\pi}{4}D_i^2 \times L \Rightarrow T_i = 148.3^\circ C$$

(d) heat generation inside the rod

$$T_o = T_i + \frac{\dot{q} r_i^2}{4k_r} \Rightarrow T_o = 271.3^\circ C$$

Problem 3

(a) $\lambda T = 3\,\mu m \times 400\,K = 1200\,\mu m \cdot K$

$\Rightarrow F(0 \to 3\mu m) = 0.002134$

$\varepsilon_{Total} = 0.002134 \times 0.2 + (1 - 0.002134) \times 0.6 = 0.6$

(b) $\lambda \cdot T = 3\,\mu m \times 1000\,K = 3000\,\mu m \cdot K$

$F(0 \to 3\mu m) = 0.273$

$\alpha_{Total} = F(0 \to 3\mu m) \cdot 0.2 + (1 - F(0 \to 3\mu m)) \cdot 0.6 = 0.49$

(c) $J = \varepsilon_T E_b + \rho_T G = \varepsilon_T E_b + (1 - \alpha_T) G \cong 29{,}800\ [W/m^2]$

(d) $q'' = J - G = 29800 - \sigma T_{1000K}^4 \cong -26{,}900\ [\frac{W}{m^2}]$

Problem 4

(a) $$\frac{E_{b1} - J_1}{1-\varepsilon_1/\varepsilon_1 A_1} = \frac{J_1 - J_2}{1/A_1 F_{12}} + \frac{J_1 - J_3}{1/A_1 F_{13}} + \frac{J_1 - J_4}{1/A_1 F_{14}}$$

$$\frac{E_{b3} - J_3}{1-\varepsilon_3/\varepsilon_3 A_3} = \frac{J_3 - J_1}{1/A_3 F_{31}} + \frac{J_3 - J_2}{1/A_3 F_{32}} + \frac{J_3 - J_4}{1/A_3 F_{34}}$$

(b) $F_{13} = F_{31} = 0.618$ $\quad F_{32} = F_{34} = F_{12} = F_{14} = 0.191$

(c) $J_1 = J_3$

$J_2 = \sigma T_2^4 = 56700 \ w/m^2$

$J_4 = \sigma T_4^4 = 459 \ w/m^2$

$J_1 = 48927 \ w/m^2$

(d) $q_2' = A_2 F_{21} (J_2 - J_1) + A_2 F_{23} (J_2 - J_3) + A_2 F_{24} (J_2 - J_4)$

$= 19211 \ w/m$

$q_{2e}' = q_2' + 1 \times h \cdot (T_2 - T_{air}) = 28211 \ w/m$