15.2

$e = 0.75 \quad Q = 75(W) \quad A = 4\pi\left(\frac{0.055}{2}\right)^2 = 9.5\times10^{-3}(m^2)$

$T_{air} = 25°C \quad T_{surface} = ?$

$$q_{tot} = \frac{Q}{A} = q_{rad} + q_{conv}$$

* radiation

$$q_{rad} = e\sigma T_s^4 = 0.75(5.67\times10^{-8})\,T_s^4$$

* convection

Assume T_s for evaluation of physical properties.

$T_s = 200°C \quad T_f = \frac{1}{2}(200+20) = 110°C$.

$\gamma = 4\times10^7 (m^{-3}K^{-1}) \quad Pr = 0.7 \quad \mu = 2.1\times10^{-5} \quad \rho = 0.84 \quad k_T = 0.03$

$\nu = 2.5\times10^{-5} (m^2/s)$

$$Gr = \frac{g\beta L^3 \Delta T}{\nu^2} = \frac{9.8\times\left(\frac{1}{383}\right)(0.055/2)^3 (T_s-293)}{(2.5\times10^{-5})^2} = 851(T_s-293)$$

$$Ra = Gr\cdot Pr = 851(T_s-293)\times0.7 = 596(T_s-293)$$

$$Nu = 0.53\,Ra^{0.25} = \frac{h_{conv}}{k_T}\cdot L.$$

$$\Rightarrow h_{conv} = \frac{k_T}{L}Nu = \frac{0.03}{0.055/2}\times(0.53)\times(596)^{0.25}(T_s-293)^{0.25} = 2.8(T_s-293)^{0.25}$$

$$q_{total} = q_{rad} + q_{conv} = 0.75(5.67\times10^{-8})T_s^4 + 2.8(T_s-293)^{0.25}(T_s-293) = \frac{75}{9.5\times10^{-3}}$$

$$= 7895$$

Through a rough trial & error calculation,

we can get $T_s = 575(K) = 302°C$.

※ For $T_f = \frac{1}{2}(302+20) = 161°C$,

$\gamma = 2\times10^7 \quad \mu = 2.3\times10^{-5} \quad \rho = 0.74 \quad Pr = 0.7 \quad k_T = 0.034 \quad \nu = 3.1\times10^{-5}$

$$Gr = \frac{(9.8)(1/434)}{(3.1\times10^{-5})^2}\left(\frac{0.055}{2}\right)^3(T_s-293) = 517(T_s-293)$$

$$Ra = 517(T_s-293)\times0.7 = 362(T_s-293)$$

$$h_{conv} = \frac{0.034}{0.028}(0.53)(362)^{0.25}(T_s-293)^{0.25} = 2.8(T_s-293)^{0.25} \Rightarrow$$

T_s is changed from 200 °C to 302°C, but h_{conv} is unchanged !!

15.4.

$e = 0.03$

$h = 2\times10^5 (J/kg)$

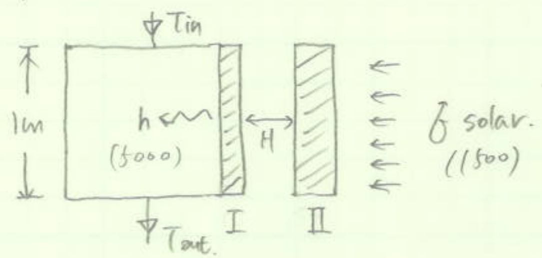
$$q_{12} = \frac{\sigma(T_1^4 - T_2^4)}{1 + (\frac{1}{e} - 1) + \frac{1}{4}(\frac{1}{e} - 1)} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1.25}{e} - 0.25}$$

$$= \frac{5.67\times10^{-8}(90^4 - 270^4)}{\frac{1.25}{0.03} - 0.25} = 7.2\ (W/m^2)$$

$$q_{12} = \frac{Q_{12}}{A} \Rightarrow Q_{12} = q_{12}\cdot A = q_{12}\cdot 4\pi(r_1)^2 = 7.2 \times 4\pi\times0.25^2 = 5.65\ (W)$$

$$\dot{m} = \frac{Q}{2\times10^5} = \frac{5.65}{2\times10^5} = 2.825\times10^{-5}\ (kg/s)$$

15.7.



$e_2 = 0.1$

$e_1 = 0.2$

i) Plate I : $q_{solar}\cdot a = q_{2\to1} + e_2\sigma T_2^4$

$$1500(0.1) = q_{21} + 0.1\times(5.67\times10^{-8})\, T_2^4$$

$$\Rightarrow 150 = q_{21} + 5.7\times10^{-9}\, T_2^4$$

ii) Plate II : $q_{21} = h(T_1 - T_{out})$ (The heat transfer fluid is well-mixed and at the uniform temperature Tout)

$$q_{21} = 5000(T_1 - T_{out})$$

iii) Fluid : $\omega C_p(T_{out} - T_{in}) = q_{21}\cdot A_1$ (Assume $T_{in} = 300 (K)$)

$$\frac{100(4000)}{3600}(T_{out} - 300) = \frac{\pi}{4} q_{21}$$

$$\Rightarrow q_{21} = 141(T_{out} - 300)$$

iV) Eq 15.2.57 : $q_{21} = \dfrac{\sigma(T_2^4 - T_1^4)}{1/e_1 + 1/e_2 - 2 + \frac{2}{1+F_{12}}} = \dfrac{5.67\times10^{-8}(T_2^4 - T_1^4)}{13 + \frac{2}{1+F_{12}}} \simeq 3.9\times10^{-7}(T_2^4 - T_1^4)$

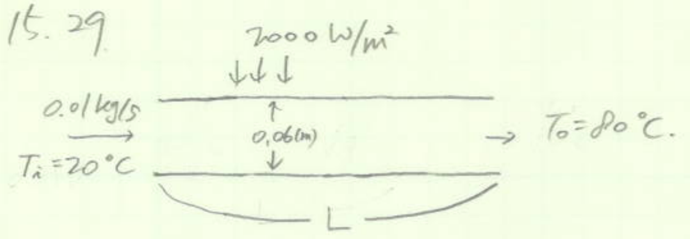
* From Fig 15.2.5 $\begin{cases}(F_{12})_{max} = 0.72 & D/H = 6.5 \text{ for disks} \\ (F_{12})_{min} = 0.07 & D/H = 0.5 \text{ for disks}\end{cases}$

Changes in H (or D/H) has no significant effect on q_{21} and results.

From 4 equations (plate I, II, Fluid, eq, 15.2.37), we can get q_{21}, T_1, T_2, T_{out}.

$q_{21} = 43 (W/m^2)$ $T_1 = 300.3 (K)$ $T_2 = 370.5 (K)$ $T_{out} = 300.3 (K)$

15.29



$(C_p)_{water} = 4180$ (J

(a) $\dot{m} C_p \Delta T = \pi D L \, q_{abs}$

$$L = \frac{\dot{m} C_p \Delta T}{\pi \cdot D \cdot q_{abs}} = \frac{0.01(4180)\cdot 60}{\pi(0.06)\,2000} = 6.65(m)$$

(b). At the end of the tube

$q = h(T_s - T_o)$ To find h, begin with $Re = \frac{4\dot{m}}{\pi \cdot D \cdot \mu}$

For the evaluation of properties, guess $T_s = 100°C$.

$T_f = \frac{1}{2}(100+80) = 90°C. \Rightarrow \mu = 0.3\times10^{-3}$ $k_f = 0.7$ $P_r = 2.$

$$Re = \frac{4\times 0.01}{\pi(0.06)(0.3\times10^{-3})} = 707$$

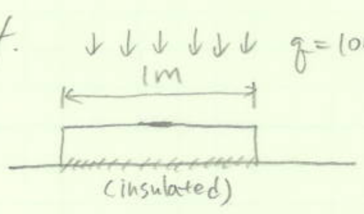
$$\frac{L}{D\cdot Re\cdot Pr} = \frac{6.65}{0.06(707)^2} = 0.08 \Rightarrow \frac{2L}{D\, Re\cdot Pr} = 0.16.$$

From Fig 12.5.5 $Nu_D \simeq 4.4$

$$h = \frac{k_f \cdot Nu}{D} = \frac{0.7(4.4)}{0.06} = 51\ (W/m^2\cdot K)$$

$$T_s - T_o = \frac{q}{h} = \frac{2000}{51} \Rightarrow T_s = 80 + 39 = 119°C$$

15.34.



$T_{air} = 25°C$. $T_s = ?$

Assume black body behavior.

$q_{solar} = \sigma T_s^4 + h_{conv}(T_s - T_a)$

guess $T_s = 100°C$ $T_f = \frac{1}{2}(100+25) = 62.5°C$

$\Rightarrow \gamma = 8\times10^7 (m^{-3}K^{-1})$ $P_r = 0.72$

$Ra = \gamma \cdot Pr \cdot L^3 \cdot \Delta T = 8\times10^7 (0.72)(1)^3(100-25) \simeq 3.1\times10^9$

From Table 14.4.1, $Nu_L = 0.15(Ra)^{0.33} = 204$

$$h = Nu \frac{k_{air}}{L} = 204 \frac{(0.028)}{0.9} = 6.3 \ (W/m^2 \cdot K).$$

$$h \cdot \Delta T = 6.3(75) = 477.$$

$$q = 1000 = 5.67 \times 10^{-8} \cdot T_s^4 + 477 \Rightarrow T_s = 310 \ (K) = 37^\circ C.$$

change to $T_f = \frac{1}{2}(37+25) = 31^\circ C$. and continue by trial & error

$T_s = 67^\circ C$