AESB 2320 Physical Transport Phen. Part 2 15 April 2015

1\. a) The water is well-mixed, so we can use a macroscopic balance on the water in the tank.

heat in by convection: $w C_p T_w$

" out " : $w C_p T$

heat lost through tank bottom: $h A (T - T_c)$

accumulation: $V \rho C_p \frac{dT}{dt}$

energy balance: $w C_p (T_w - T) - h A (T - T_c) = V \rho C_p \frac{dT}{dt}$

b) At steady state, $dT/dt = 0$; $w C_p (T_w - T) - h A (T - T_c) = 0$

$$w C_p (T_w - T) = h A (T - T_c)$$

$$w C_p T_w + h A T_c = h A T + w C_p T$$

$$T = \frac{w C_p T_w + h A T_c}{w C_p + h A}$$

2\. a) What is Re? $v = Q / \pi R^2 = \frac{0.05}{\pi (0.05)^2} = 6.37$ m/s

$Re = \frac{D v \rho}{\mu} = \frac{(0.1)\, 6.37 (1008)}{0.00059} = 1.088 \cdot 10^6$ highly turbulent

Eq. 14.3-16 applies $\quad Pr = \frac{C_p \mu}{k} = \frac{(4157)(0.00059)}{0.635} = 3.86$

$$Nu = 0.026\, Re^{0.8} Pr^{1/3} = 0.026 (1.088 \cdot 10^6)^{0.8} (3.86)^{1/3}$$

$= 2754$

Eq. "III": $Nu = \ln\left(\frac{T_0 - T_{b1}}{T_0 - T_{b2}}\right) Re\, Pr \frac{D}{4L} = \ln\left(\frac{30-70}{30-40}\right)(1.088 \cdot 10^6)\, 3.86 \frac{0.1}{4 \cdot L}$

$2754 = (1.386)(1.05 \cdot 10^5)/L$

$L = 52.9$ m (a little more than 8 sec. travel)

b) Now we use the version of the eq. w/ U_o:

$\frac{U_o D_o}{k} = \ln\left(\frac{T_f - T_{b1}}{T_f - T_{b2}}\right) Re\, Pr \frac{D_o}{4L}$ [note D_o cancels on both sides]

$$U_o = \ln\left(\frac{30-70}{30-40}\right)(1.088 \cdot 10^6)(3.86) \frac{0.635}{4 \cdot 3000} = 308 \text{ W/m}^2\text{K}.$$

c) from Eq. 10.6-31, $\frac{1}{r_0 U_0} = \left[\frac{1}{r_0 h_0} + \frac{\ln(0.15/0.05)}{k}\right]$

$$\frac{1}{(0.05)(308)} = \frac{1}{(0.05)(17500)} + \frac{\ln 3}{k}$$

$0.0649 - 0.00114 = \frac{\ln 3}{k} \rightarrow$ $k = 17.2$ W/m K

Oops. We need h_o. From (a), $Nu = \frac{hD}{k} = 2754 = \frac{h(0.1)}{0.635} \rightarrow h = 17500$

3. Radiation + convective heat transfer are "in parallel" in this case. Rocky wants a clean measurement where all the measured heat transfer reflects radiation. More convection → more convective heat transfer, which he would incorrectly ascribe to radiation. In the extreme case, heat transfer might be dominated by convection, giving no information at all on radiation. Therefore he wants to suppress convective heat transfer, by making the air as still as possible.

4. a) It's a solid: no convection.

✓ conduction

✓ generation ("uniform heating")

no accumulation at steady state.

b) 1) at $x = 0$ $q_x = 0$ or $\frac{dT}{dx} = 0$

2) at $x = H$ $q_x = h(T - T_c)$ or $-k\frac{dT}{dx} = h(T - T_c)$

(note $q_x > 0$ if solid $T > T_c$)

5. 1. cylinder $R = 0.05\,m$ or $D = 0.1$

2. finite-width slab $B = 0.2\ m$ or $D = 0.4\,m$

[(effective width doubled by insulated surface)

[No third component]