AESB 2320 Part 2 Exam April 18, 2019

1. a) This is heat transfer through cylindrical wall with T of fluid inside specified, wall T outside specified.

BSL1 Eq. 9.6-31 (BSLK Eq. 10.3-29):

$$U_o = \frac{1}{r_o}\left[\frac{1}{r_o h_o} + \frac{\ln(r_i/r_o)}{k_{plastic}} + \cancel{\frac{1}{r_o h_{out}}}\right]^{-1}$$

↑ outside wall T specified, not a fluid T

Need to determine h_o using method of BSLK ch. 13

$$Re = \frac{D v \rho}{\mu} = \frac{(0.35)(0.2)(1000)}{0.001} = 70{,}000$$

Flow is turbulent. Can use BSLK Eq. 14.3-16 (Re > 70000) *

$$Nu = \frac{hD}{k} = (0.026)\, Re^{0.8} Pr^{1/3} \;;\; Pr = \frac{C_p \mu}{k} = \frac{(4180)(0.001)}{0.6} = 6.97$$

$$= (0.026)(70000)^{0.8}(6.97)^{1/3} = 373.4 = \frac{h(0.35)}{(0.6)}$$

$$\rightarrow h = 640$$

$$U_o = \frac{1}{0.175}\left[\frac{1}{(0.175)640} + \frac{\ln(0.225/0.175)}{0.16}\right]^{-1}$$

$$= \frac{1}{0.175}\left[0.00893 + 1.57\right]^{-1} = 3.62\ W/m^2K$$

↑ Note how much resistance comes from plastic wall

b) For this case, w/ conduction through wall + convection, too

$$\frac{U_o D}{k} = \ln\left(\frac{T_f - T_{b1}}{T_f - T_{b2}}\right) Re\, Pr\, \frac{D}{4L}$$

↑ "T_f" here is wall T, since that is what is given

$$\frac{(3.62)(0.35)}{0.6} = \ln\left(\frac{40 - 80}{40 - T_{b2}}\right)(70000)(6.97)\,\frac{0.35}{4(2000)}$$

$$0.0989 = \ln\left(\frac{40-80}{40-T_{b2}}\right) \rightarrow 1.104 = \frac{40-80}{40-T_{b2}}$$

$$T_{b2} = 76.2\ ^\circ C \quad (349\ K, \text{ if you prefer, but } ^\circ C \text{ OK})$$

* If use BSLK Fig 14.3-2 instead, $0.0028 = \frac{hD}{k} Re^{-1} Pr^{-1/3}$

$\rightarrow \frac{hD}{k} = 374$. Same as above.

If did part b using $U_o = 50$, $\rightarrow T_{b2} = 50.2\ ^\circ C$.

2. a) Use Carslaw + Jaeger Fig 41.

$$\alpha = \frac{K}{\rho c_p} = \frac{2.61}{2270 \cdot 1000} = 1.150 \cdot 10^{-6} \ m^2/s$$

on day 179, $t = 179 \times 24 \times 3600 = 1.55 \cdot 10^7 \ s$

$$\frac{\alpha t}{R_3} = 790,$$

$$r/r_\omega = \frac{1}{0.15} = 6.67 \ ; \ \log r/r_\omega = 0.823$$

From Fig 41, $\frac{T - T_0}{T_\omega - T_0} \cong 0.43 = \frac{T - 10}{40 - 10} \rightarrow T = 22.9°C$

b) Second change is equal in magnitude + opposite in sign to first change. Therefore

$$\frac{T - T_0}{T_\omega - T_0} = \left[\underset{\text{I}}{\text{effect of change 210 days ago}} - \underset{\text{II}}{\text{effect of change 30 days ago}} \right]$$

I: $\frac{\alpha t}{R_3^2} = \frac{(1.15 \cdot 10^{-6})(210 \times 24 \times 3600)}{(0.15)^2} = 927$, $\log \frac{r}{r_\omega} = 0.823$

from Fig 41, $\frac{T - T_0}{T_1 - T_0} \cong 0.46$

II: $\frac{\alpha t}{R_3^2} = \frac{(1.15 \times 10^{-6})(30 \times 24 \times 3600)}{(0.15)^2} = 132.48$ $\log \frac{r}{r_\omega} \cong 0.823$

from Fig 41, $\frac{T - T_0}{T_1 - T_0} \cong 0.33$

$$\frac{T - T_0}{T_1 - T_0} = 0.46 - 0.33 = 0.13 = \frac{T - 10}{40 - 10} = 13.9°C$$

3. From BSL1 Eq. 9.6-15 (BSLK Eq. 10.3-14

a) $$q_0^{(a)} = \frac{T_0 - T_b}{\frac{H_1}{K_1} + \frac{H_2}{K_2}}$$

b) $$q_0^{(b)} = \frac{T_0 - T_b}{\frac{H_1 + H_2}{K_2}}$$

c) $$\frac{q_0^{(a)}}{q_0^{(b)}} = \frac{\left[\frac{H_1}{2K_2} + \frac{H_1}{K_2}\right]^{-1}}{\left[\frac{H_1}{K_2} + \frac{H_1}{K_2}\right]^{-1}}$$ divide top + bottom by H_1 mult. " " " " K_2

$$= \frac{\left[\frac{1}{2} + 1\right]^{-1}}{\left[2\right]^{-1}} = \frac{2}{1.5} = 1.33$$

4. a) A 1D rectangular slab w/ perfectly insulated surface ⟷ finite-width slab.
BSLK Fig. 11.5-1.

b) In reality some resistance to heat transfer arises from convective heat transfer to surface, some from internal conduction.
By interpreting actual heating assuming all the resistance is from conduction, he overestimate the resistance to conduction. Some of the delay in heating is due to imperfect convective heat transfer to the surface. Thus the value of α he calculates is smaller than the true value.