AESB2320 Pt 2 Re-Exam July 2017

1. We use eq. from BSL 1 Sect 9.6 to get overall heat-transfer coef. U_o, but first we need h_o at inner surface.

$$Re = \frac{DV\rho}{\mu} = \frac{0.6(2)\,1.1}{3\cdot10^{-5}} = 44{,}000$$

$$Pr = \frac{C_p\,\mu}{K} = \frac{1006\,(3\cdot10^{-5})}{0.025} = 1.207$$

Re is large enough (>20,000) to use BSLK Eq. 14.3-16:

$$Nu = 0.026\,Re^{0.8}Pr^{1/3} = 0.026(44000)^{0.8}(1.207)^{1/3}$$

↑ see note at end of exam

$$= 143.5 = \frac{hD}{K} = \frac{h\,(0.6)}{0.025} \rightarrow h = 5.98$$

BSL1 9.6-31 (BSLK 10.3-31)

$$(r_o U_o)^{-1} = \left[\frac{1}{(0.3)(5.98)} + \frac{\ln(0.35/0.3)}{0.5} + \frac{1}{(0.35)(50)}\right] \quad (\mathrm{I})$$

$$= \left[0.557 + 0.308 + 0.057\right]$$

(resistance from) heat transfer to inner wall; conduction thru wall; heat transfer to air

$$U_o = \frac{1}{0.3}\left[0.922\right]^{-1} = 3.61 \ \ W/m\,K$$

Eq. from class:

$$\frac{U_o D_o}{K} = \ln\left(\frac{T_e - T_{b1}}{T_e - T_{b2}}\right) Re\,Pr\,\frac{D_o}{4L}$$

$$\frac{(3.61)(0.6)}{0.025} = \ln\left(\frac{20-300}{20-T_{b2}}\right)(44000)(1.207)\frac{0.6}{4\times50}$$

$$86.64 = \ln\left(\frac{20-300}{20-T_{b2}}\right)\ 159$$

$$\frac{20-300}{20-T_{b2}} = \exp\left(\frac{86.64}{159}\right) = 1.72$$

$$T_{b2} = 182^\circ C$$

b) Back to Eq. I above. Heat transfer to the air is an insignificant component in this problem; its resistance is small compared to the others. I could be off by 2 or 3 times with almost no effect. (In fact, I think I probably am wrong by more than that!)

Note: ρ and C_p for the smokestack don't matter for this problem.

2. Since T is assumed uniform, we can take a macro energy balance. Assume wire length L. (The value of L doesn't matter)

generation: $\pi R^2 L S$

heat transfer at surface: $-(2\pi R L) A (T-T_0)^4$

(>0 because heat is lost)

accumulation $\pi R^2 L \rho C_p \frac{dT}{dt}$

$$(\pi R^2 L S) - (2\pi R L) A (T-T_0)^4 = \pi R^2 L \rho C_p \frac{dT}{dt}$$

$$RS - 2A(T-T_0)^4 = R\rho C_p \frac{dT}{dt}$$

$$\frac{dT}{dt} = \frac{1}{\rho C_p}\left(S - \frac{2A}{R}(T-T_0)^4\right)$$

initial condition: $T = T_0$ at $t=0$

3. This is unsteady conduction in a semi-infinite solid.

BSLK Eq. 11.5-12: $q_x = \frac{K}{\sqrt{\pi \alpha t}}(T_1 - T_0)$

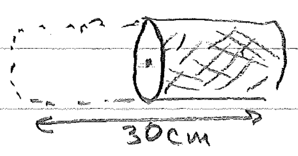
(where in our case conduction is in the x direction)

$$q = \frac{K}{\sqrt{\pi t}\sqrt{K/\rho C_p}}(T_1 - T_0) = \sqrt{\frac{K\rho C_p}{\pi t}}\,(T_1 - T_0)$$

$$-7000 = \sqrt{K}\left(\frac{11000 \cdot 130}{\pi\, 3600}\right)^{1/2}(20-100) = -900\sqrt{K}$$

$$K = 60.5 \ \text{W/m}^2\text{K}$$

4. a) This is a product of a slab + cylinder. The insulated surface makes it equivalent to a slab 30 cm thick. The slowest spot to change is the center of the insulated surface, which is the center of the 30 cm slab.



b) $\alpha = \frac{K}{\rho C_p} = \frac{23}{7820 \cdot 461} = 6.37 \cdot 10^{-6}$

cyl: $(\alpha t / R^2) = 6.37 \cdot 10^{-6} \times 60 \,/ (0.05)^2 = 0.153$

From BSLK Fig 11.5-2, at $r/R = 0$, $\frac{T_1 - T}{T_1 - T_0} = 0.64$

slab: $\alpha t / b^2 = 6.37 \cdot 10^{-6} (60) / (0.15)^2 = 0.02$

from Fig 11.5-1, no effect at insulated edge: $\frac{T_1 - T}{T_1 - T_0} = 1$

For solid, $\frac{T_1 - T}{T_1 - T_0} = 0.64 \times 1 = 0.64 = \frac{100 - T}{100 - 50} \rightarrow T = 68°C$

c) Internal conduction and heat transfer to the surface are in series. The slower process dominates. If the second calculation says the whole solid is at 90°C, then that process is much faster and therefore it is less important. The calculation in part (b) is more accurate.

Note on problem 1: In solving for h_o, one could also use BSLK Fig 14.3-2 (instead of BSLK Eq. 14.3-16).

For Re = 44,000, one gets $0.0032 \approx \frac{h_{m} D}{k} (Re)^{-1} (Pr)^{-1/3}$

$$0.0032 = \frac{h_{m} (0.6)}{0.025} (44000)^{-1} (1.207)^{-1/3}$$

$h_{m} = 6.25 \rightarrow h_o$ in eq. for U_o.

Result is nearly the same as w/ Eq. 14.3-16.