AESB 2320 Part 2 Exam 13 April 2018

1. What is Re? $D v \rho/\mu = \frac{(0.016) V (1000)}{0.001} = 795$

{What is v? $v = Q/A = 10^{-5}/(\pi (0.008)^2) = 0.0497$ ]

Laminar flow. How close to equil.? (How long is tube?)

$Re\, Pr\, D/L = 795 \left(\frac{130 (0.001)}{35}\right)(0.016)/(0.3) = 0.157 \ll 10$

Must use Fig 14.2-1.* Axis is $(Re\, Pr\, D/L)^{-1} = 6.35$

$Nu = 3.657 = \frac{hD}{k} = \frac{h (0.016)}{35} \rightarrow h = 8000\ W/m^2K$

* curve for "constant wall temperature (tube)"

[Note Eq. 14.2-7 is for turbulent flow of liquid metals.

Eq. 14.2-3 is for fixed heat flux, not fixed wall T.]

2. Because we assume tube is at uniform T at all times, can do macroscopic energy balance

Heat in from water = accumulation (No heat loss to air)

$h A \Delta T = V \rho C_p\, dT/dt$

$h (2\pi R_1 L)(T_1 - T) = \pi (R_2^2 - R_1^2) L \rho C_p \frac{dT}{dt}$

$\frac{dT}{dt} = \frac{h\, 2\pi R_1 L}{\pi (R_2^2 - R_1^2) L \rho C_p}(T_1 - T) = \frac{2 h R_1}{(R_2^2 - R_1^2)\rho C_p}(T_1 - T)$

for simplicity, define const $\frac{2 h R_1}{(R_2^2 - R_1^2)\rho C_p} = K$

$\frac{dT}{dt} = K(T_1 - T) = -\frac{d}{dt}(T_1 - T)$

$\frac{d(T_1 - T)}{(T_1 - T)} = -K\, dt \rightarrow \ln(T_1 - T) = -Kt + C_1$

at $t = 0$, $T = T_0 \rightarrow C = \ln(T_1 - T_0)$

$\rightarrow \ln\left(\frac{T_1 - T}{T_1 - T_0}\right) = -(Kt)$ or

$\left(\frac{T_1 - T}{T_1 - T_0}\right) = \exp(-K t)$

[If we plug in the properties of Aluminum, $\rho = 2700\ kg/m^3$, $C_p = 922\ J/(kg\, K)$, $K = 1.43$. This suggests the wall comes 95% of the way to the water T in about 2 sec. As I wrote at the start of the exam, it actually takes very roughly 4 sec. On an exam, you work the problem given the assumptions you're told to make. Probably I overestimated $R_1$; vel. is greater and the thermal mass of the pipe greater, too.]

3. Because both opposite surfaces are perfectly insulated, there is no conduction along axial direction. This is equivalent to a cylinder of infinite length. Fig. 11.5-2 applies.

This problem involves superposition. First change is from 100° to 0° at surface. Dimensionless temp is

$$\underset{T_0}{100°} \text{ to } \underset{T_1}{0°} \qquad \left(\frac{T-100}{0-100}\right)$$

Second change is in opposite direction + equal in magnitude to first. Therefore

$$\frac{T-100}{0-100} = \left[\begin{matrix}\text{Value from chart}\\ \text{for } t = 160\text{ s}\end{matrix}\right] - \left[\begin{matrix}\text{Value from chart}\\ \text{for } t = 40\text{ s}\end{matrix}\right]$$

$$\alpha = \frac{k}{\rho c_p} = \frac{34.6}{11340\,(125.7)} = 2.43 \cdot 10^{-5}$$

For 160 s, $\frac{\alpha t}{R^2} = (2.43 \cdot 10^{-5})(160)/(0.1)^2 = 0.389$

40 s, " = " (40) " = 0.097

a) For $r=0$, $r/R = 0$, $\frac{\alpha t}{R^2} = 0.389$, Fig 11.5-1 gives $\frac{T-T_0}{T_1-T_0} \approx 0.82$

" " = 0.097 " " 0.15

$$\frac{T-100}{0-100} = 0.82 - 0.15 = 0.67 \rightarrow T = 33°C$$

b) For $r/R = 0.5$, $\frac{\alpha t}{R^2} = 0.389$, Fig gives $\frac{T-T_0}{T_1-T_0} \doteq 0.88$

0.097 0.37

$$\frac{T-100}{0-100} = 0.88 - 0.40 = 0.48 \rightarrow T = 52°C$$

[Note that the position closer to the edge feels the second change more strongly than the part further inside, which has just begun to feel the effects of the change that started at 40 s.]

4. This problem is similar to BSL1 9.2. How is it different?

- no B.C. at $r=0$ (that $q_r$ must be finite); instead, fixed $T$ at $r=R$
- B.C. at $r=R_1$ is not fixed $T$, but Newton's law of cooling.

Which difference affects the derivation first? The BC on $q$ at $r=0$, which is introduced just after Eq. 9.2-7. The last equation that can be used directly is <u>Eq. 9.2-7</u>