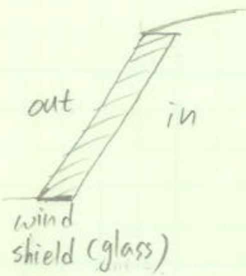
HW #5

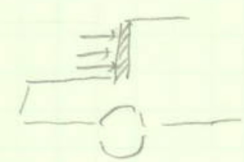
1. i) at rest. ($T_{out} \leq T_{in}$)



$$Q = A \cdot \frac{T_{in} - T_{out}}{\frac{l}{k_{glass}} + \frac{1}{h_{in}} + \frac{1}{h_{out}}}$$

ii) at driving along the freeway. ① or ②.

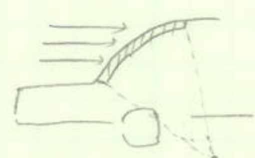
①. when assummed the wind shield as a flat plate.



(eq 12.2.34) $\overline{Nu} = 0.68 (Re_L)^{1/2} \cdot Pr^{1/3} = \frac{h_{out} \cdot L}{k_{glass}} \Rightarrow$ get h_{out} !!

$$Q = A \cdot \frac{T_{in} - T_{out}}{\frac{l}{k_{glass}} + \frac{1}{h_{in}} + \frac{1}{h_{out}}}$$

② when assummed the wind shied as a pipe or cylinder.



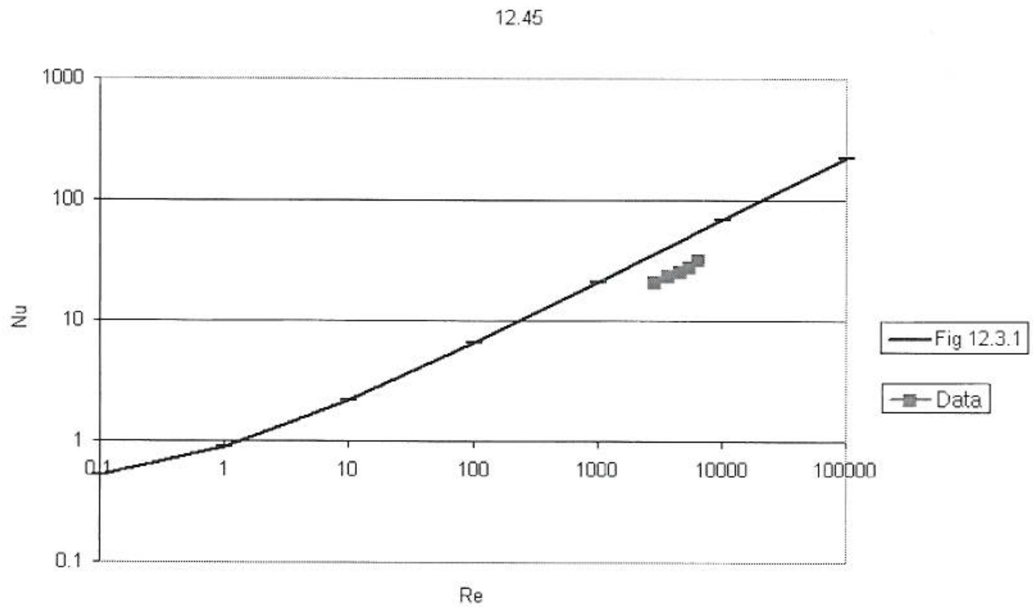
(eq. 12.3.5) $\frac{Nu}{Pr^{0.3}} = (0.35 + 0.56 \cdot Re^{0.52})$.

$Nu = Pr^{0.3}(0.35 + 0.56 Re^{0.52}) = \frac{h_{out} \cdot D}{k} \Rightarrow$ get h_{out} !!

$$\Rightarrow Q = A \cdot \frac{T_{in} - T_{out}}{\frac{l}{k_{glass}} + \frac{1}{h_{in}} + \frac{1}{h_{out}}}.$$

2. - cooling oil from 145 ~ 180 °F to 120 °F by using heat exchangers
   - posts designed to keep permafrost frozen (the posts absorb cold from the winter air and transfer it to the soil)
   - the pipe line of a zigzag pattern (expanded surface area of the pipeline accelerate the loss of heat)

12.45



U(m/s)	h(W/㎡℃)	Re	Nu
1	18.2	2390.75	26.3
1.25	19.9	2988.4	28.75
1.5	21.3	3586.12	30.77
1.75	23.1	4183.8	33.38
2	26.6	4781.5	38.43

12.54

$R_{in} = R_1$ $\quad$ at R_1, $h = h_1(z)$

$R_{out} = R_2$ $\quad$ at R_2, $h = h_2(z)$

$T_{R_1} = T_{R_2} = T_R$

$$\rho C_p u_z \frac{\partial T}{\partial z} = k\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)\right]$$

Boundary conditions $\begin{cases} T = T_R & \text{at } r = R_1 \\ T = T_R & \text{at } r = R_2 \end{cases}$

$$\int_{R_1}^{R_2} \rho C_p u_z \frac{\partial T}{\partial z} r \cdot dr = k\left[r\frac{\partial T}{\partial r}\right]_{R_1}^{R_2} = kR_2\frac{\partial T}{\partial r}\Big|_{R_2} - kR_1\frac{\partial T}{\partial r}\Big|_{R_1}$$

$$\langle T\rangle = \frac{\int_{R_1}^{R_2} u_z \cdot T \cdot 2\pi r\, dr}{\int_{R_1}^{R_2} u_z \cdot 2\pi r\, dr} = \frac{\int_{R_1}^{R_2} u_z \cdot T \cdot 2\pi r \cdot dr}{Q}$$

$$\int_{R_1}^{R_2} u_z \cdot T \cdot r\, dr = \frac{\langle T\rangle Q}{2\pi}$$

$$\rho C_p \frac{d}{dz}\left[\frac{Q}{2\pi}\langle T\rangle\right] = kR_2\frac{\partial T}{\partial r}\Big|_{R_2} - kR_1\frac{\partial T}{\partial r}\Big|_{R_1}$$

$(\rho Q = \omega)$

$$\omega C_p \frac{d\langle T\rangle}{dz} = 2\pi k\left(R_2\frac{\partial T}{\partial r}\Big|_{R_2} - R_1\frac{\partial T}{\partial r}\Big|_{R_1}\right)$$

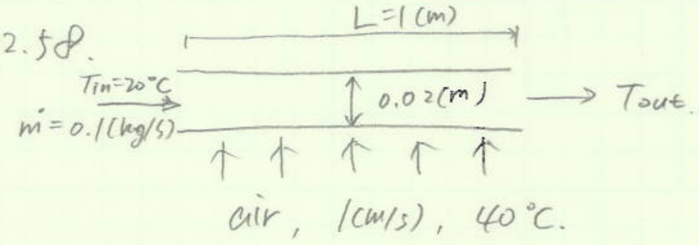
$$k\frac{\partial T}{\partial r}\Big|_{R_1} = h_1[\langle T\rangle - T_R] \qquad -k\frac{\partial T}{\partial r}\Big|_{R_2} = h_2[\langle T\rangle - T_R]$$

$$\omega C_p \frac{d\langle T\rangle}{dz} = 2\pi[T_R - \langle T\rangle](R_2h_2 + R_1h_1)$$

$$\frac{d(T_R - T)}{(T_R - T)} = \frac{-2\pi}{\omega C_p}(R_2h_2 + R_1h_1)\,dz$$

$$\Rightarrow \frac{T - T_R}{T_1 - T_R} = \exp\left[-\frac{2\pi(R_2h_2 + R_1h_1)z}{\omega C_p}\right]$$

12.58.



* Internal flow. (assume $\overline{T}_{fluid} = 25°C$)

$$(Re_D)_{in} = \frac{4\dot{m}}{\pi \cdot D \cdot \mu} = \frac{4 \times 0.1}{\pi \times 0.02 \times 0.891 \times 10^{-3}} = 7145 \rightarrow \text{turbulent!!}$$

$$(\overline{Nu}_D)_{in} = \frac{h_{inside} \cdot D}{k_{water}} = 0.023 (Re_D)_{in}^{0.8} \cdot Pr^{0.4} \quad \text{(Dittus-Bolter Eqn)}$$

$$h_{inside} = \frac{k_{water}}{D} \times 0.023 (Re_D)_{in}^{0.8} \cdot Pr^{0.4} = 1747.25 \ (W/m^2 \cdot K)$$ (5)

* External flow.

$$(Re_D)_{out} = \frac{\rho U D}{\mu} = \frac{1.127 \times 1 \times 0.02}{1.918 \times 10^{-5}} = 1175.2$$

$$(Nu_D)_{out} = 0.3 + \frac{0.62 (Re_D)_{out}^{1/2} \cdot Pr^{1/3}}{[1 + 0.4/(Pr^{2/3})]^{1/4}} \left[1 + \left(\frac{Re_D}{282000} \right)^{5/8} \right]^{4/5}$$

$$= 17.72.$$

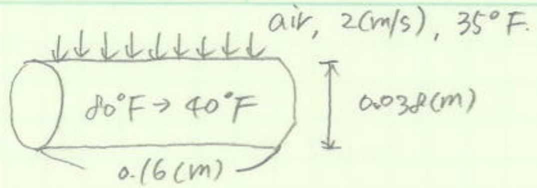
$$h_{outside} = \left(\frac{k_{air}}{D} \right) (Nu_D)_{out} = 23.6 \ (W/m^2 \cdot K)$$ (5)

$$T_{out} = T_a + (T_{in} - T_a) \exp\left(- \frac{\pi D \overline{h}}{\dot{m} C_p} L \right)$$

$$\overline{h} = \frac{1}{\frac{1}{h_{inside}} + \frac{1}{h_{outside}}}$$

$$= 20.07 \ °C$$ (10)

12.61



(air) $\rho = 1.28\,(kg/m^3)$

$\mu = 172.1 \times 10^{-7}\ (N \cdot s/m^2)$

$k = 24.3 \times 10^{-3}\,(W/m \cdot K)$

(cucumber) $\rho = 964\,(kg/m^3)$

$k = 0.62\,(W/m \cdot {}^\circ C)$

$$Re_D = \frac{\rho u D}{\mu} = \frac{1.28 \times 2 \times 0.038}{172.1 \times 10^{-7}} = 5643.9$$

$$\overline{Nu}_D = \frac{\bar{h} \cdot D}{k} = 0.35 + 0.56\, Re^{0.52} \simeq 50.35 \Rightarrow \bar{h} \simeq 32.2$$

$$Bi = \frac{\bar{h} \cdot r}{k_{cucumber}} = \frac{32.2 \times 0.019}{0.62} = 0.986$$

$$\theta = \frac{4.44 - 1.67}{26.67 - 1.67} = 0.11$$

Use Fig 11.1.4 (d) !!

$$\Rightarrow X_{Fo} = \frac{\alpha t}{r^2} \simeq 2 \Rightarrow t \simeq 2 \cdot \frac{r^2}{\alpha}$$

(a) $2\,(m/s) \longrightarrow 4\,(m/s)$

$Re_D = 11287.8 \qquad \overline{Nu}_D = 72.05 \qquad \bar{h} = 46.07$

$Bi \simeq 1.412$

$\theta = 0.11$

> Use fig 11.1.4(d)

$$X_{Fo} \simeq 1.5 = \frac{\alpha t}{r^2} \Rightarrow t = 1.5\,\frac{r^2}{\alpha} \Rightarrow$$ time saving is 25% (5)

(b) $33^\circ F = 0.56\,^\circ C$

$Bi \simeq 0.986$

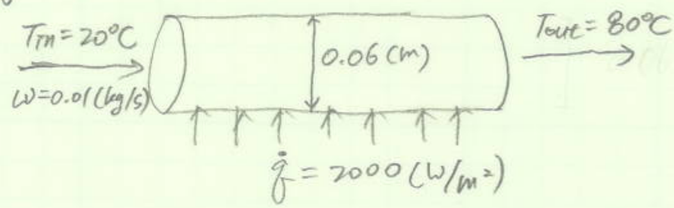
$$\theta = \frac{4.44 - 0.56}{26.67 - 0.56} = 0.15$$

> Use Fig 11.1.4 (d)

$$X_{Fo} \simeq 1.7 = \frac{\alpha t}{r^2} \Rightarrow t = 1.7\,\frac{r^2}{\alpha} \Rightarrow$$ time saving is 15% (5)

12.66

(Water) $C_p = 4181 \; (J/kg\,°C)$



(a) $Q = \dot{q}(2\pi r L) = w C_p (T_{out} - T_{in})$

$$\Rightarrow L = \frac{0.01 \times 4181 \times 60}{2000 \times \pi \times 0.06} = \underline{6.654 \; (m)}$$ (2)

(b) $\dot{q} = \text{constant} \Rightarrow \underset{(\text{fluids} - \text{wall})}{\Delta T} = \text{constant}$

$$Re_D = \frac{4w}{\pi \cdot D \cdot \mu} = \frac{4 \times 0.01}{\pi \times 0.06 \times 352 \times 10^{-6}} = 603 \rightarrow \text{laminar !!}$$

$$Pr = \frac{\mu C_p}{k} = \frac{352 \times 10^{-6} \times 4181}{0.67} = 2.2$$

$$\left. \frac{2z}{Re_D \cdot Pr \cdot D} \right|_{z = 6.654} = 0.1671 \Rightarrow Nu_D = 4.36 \; (\text{from Fig. 12.5.5})$$ (4)

$$Nu_D = \frac{hD}{k} \Rightarrow h = Nu_D \frac{k}{D} = 4.36 \times \frac{0.67}{0.06} = 48.7 \; (W/m^2 \cdot K)$$

$$\dot{q} = h(T_{surface} - T_{fluid})$$

At the outlet, ($T_{fluid} = 80\,°C$),

$$T_{surface} = \frac{\dot{q}}{h} + T_{fluid} = \frac{2000}{48.7} + 80 = \underline{121 \; (°C)}$$

10.