FINAL EXAM
CM3110
17 Dec 2008
SOLN

1. ⓐ $\frac{1}{2}$

ⓑ $\frac{q}{A} = \sigma T^4$

$110°C + 273 = 383\ K$

$= \left(5.676 \times 10^{-8} \frac{W}{m^2 \cancel{K^4}}\right)\left(383 \cancel{K}\right)^4$

$= 1221.34 \ \frac{W}{m^2}$

$= \boxed{1200 \frac{W}{m^2}}$ 2 SIG FIGS

1(c.) $f = \frac{16}{Re} = \frac{16}{100} = \boxed{0.16}$

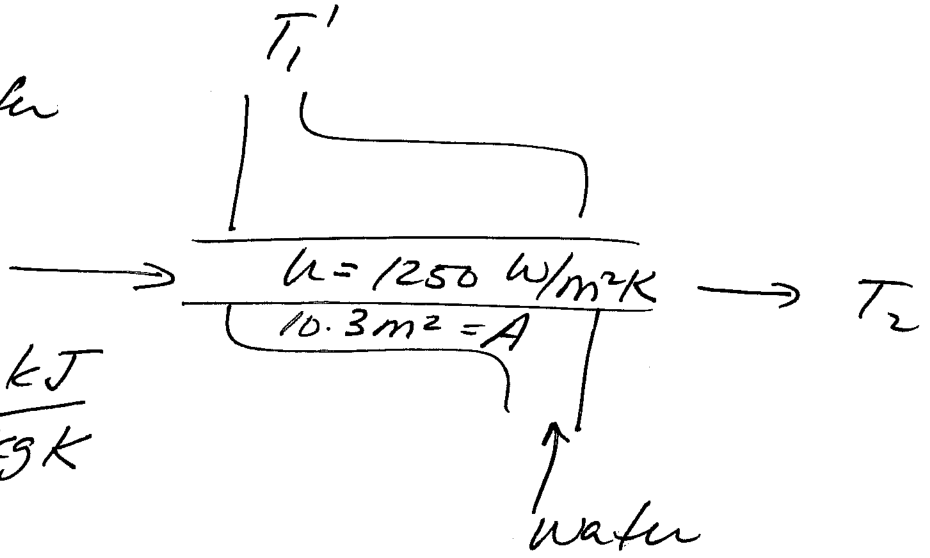
1(d.) $C_D = \frac{24}{Re} = \frac{24}{0.0100} = \boxed{2400}$

2. Super Xfer

$T_1 = 400K$

$5.2 \frac{kg}{s}$

$C_p = 11.92 \frac{kJ}{kgK}$



$T_2' = 321 K$

$0.920 kg/s$

$C_p = 4.183 kJ/kgK$

only inlets known ⇒ heat exchanger effectiveness problem

Water (hot)

$$m'C_p' = \left(\frac{0.92\ \cancel{kg}}{\cancel{s}}\right)\left(\frac{4.183\ \cancel{kJ}}{\cancel{kg}\ K}\right)\left(\frac{kW}{\cancel{kJ/s}}\right)$$

$$= \boxed{3.848\ kW/K}$$

SuperXfer (cold)

$$m\,C_p = \left(\frac{5.2\ \cancel{kg}}{\cancel{s}}\right)\left(\frac{11.92\ \cancel{kJ}}{\cancel{kg}\ K}\right)\left(\frac{kW}{\cancel{kJ/s}}\right)$$

$$= \boxed{61.984\ kW/K}$$

HOT FLUID is minimum fluid.

$$Q = \varepsilon\,(m\,C_p)_{min}\,(T_{hi} - T_{ci})$$

$$\underbrace{400 - 321}_{79\ K}$$

↗

?

$$NTU = \frac{UA}{C_{min}} = \frac{\left(1250\frac{W}{m^2K}\right)\left(10.3\,m^2\right)}{\left(3.848\,\cancel{kW}\right)\left(\frac{10^3 W}{\cancel{kW}}\right)}$$

$$\boxed{NTU = 3.3}$$

$$C_{min}/C_{max} = \frac{3.848\,kW}{61.984\,kW} = \boxed{6\times10^{-2}} \sim 0$$

$$\Rightarrow \boxed{\varepsilon = 0.97}$$

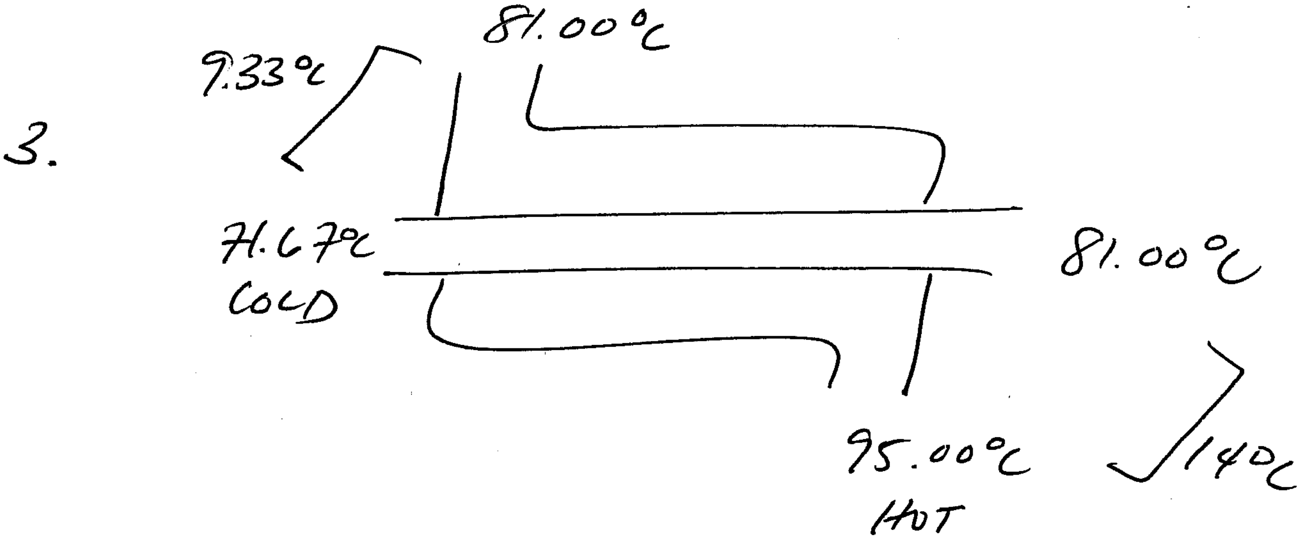
$$Q = (0.97)\left(3.848\frac{kW}{K}\right)(79K)$$

$$= 294.9\ kW$$

$$= \boxed{290\,kW}$$

no more then 2 sig figs due to ε

3.



ⓐ $$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = \frac{9.33 - 14}{\ln\left(\frac{9.33}{14}\right)}$$

$$= \frac{-4.67}{-0.4058} = 11.5075\,°C$$

$$= \boxed{11.51°C}$$

ⓑ 1-2 Shell + tube

$$Z = \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}} = \frac{95 - 81}{81 - 71.67} = \frac{14}{9.33} = 1.5$$

$$Y = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} = \frac{81 - 71.67}{95 - 71.67} = \frac{9.33}{23.33} = 0.4$$

1-2 Shell + tube

$F_T = 0.8$ (lecture 14 + Geankoplis)

$\Delta T_m = (0.8)(11.51°C) = 9.208°C$

$= \boxed{9.2°C}$

ⓒ 2-4 shell + tube

$F_T = (0.96)(11.51°C) = 11.0496°C$

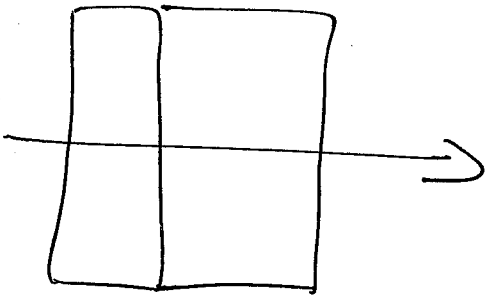
$= \boxed{11°C}$

ⓓ higher ΔT_m is better since

$$Q = UA\underbrace{\Delta T_m}_{\text{larger } \Delta T_m \text{ means}}$$

we can use smaller area or lower U to get same Q

4. $\frac{q_x}{A} = 1040 \frac{BTU}{h\,ft^2}$



ⓐ $h = \infty$ or very high — no resistance at that wall

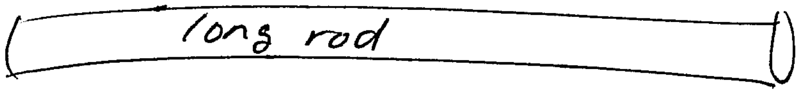
ⓑ Fourier's Law

$$\frac{q_x}{A} = -k \underbrace{\frac{dT}{dx}}_{-7\,{}^\circ F/ft}$$

$$k = \frac{q_x}{A}\left(\frac{-1}{dT/dx}\right) = \left(\frac{1040\ BTU}{h\,ft^2}\right)\left(\frac{-1}{-7\,{}^\circ F/ft}\right)$$

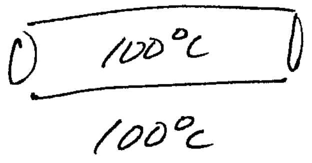
$$\boxed{= 149 \frac{BTU}{h\,ft\,{}^\circ F}}$$

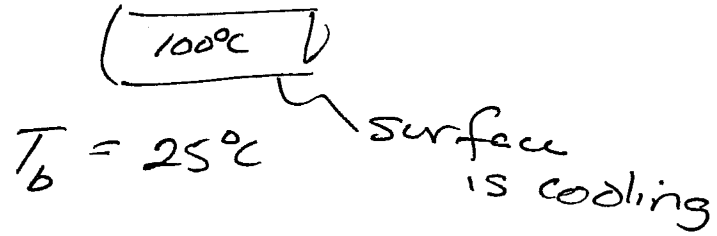
5.

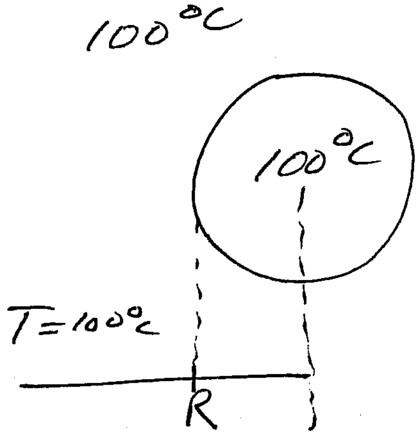


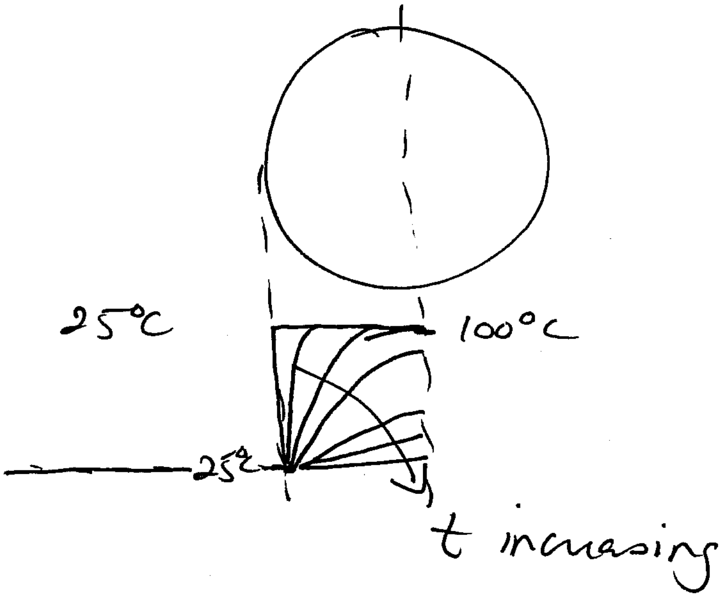
t<0

t ≥ 0









MICROSCOPIC ENERGY EQN

$$\frac{\partial T}{\partial t} + \underset{③}{\cancel{v_r}}\frac{\partial T}{\partial r} + \frac{\underset{③}{\cancel{v_\theta}}}{r}\frac{\partial T}{\partial \theta} + \overset{③}{\cancel{v_z}}\frac{\partial T}{\partial z}$$

$$= \frac{k}{\rho \hat{C}_p}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\underset{②}{\cancel{\frac{\partial^2 T}{\partial \theta^2}}} + \overset{④}{\cancel{\frac{\partial^2 T}{\partial z^2}}}\right) + \overset{①}{\cancel{\frac{S}{\rho \hat{C}_p}}}$$

Assume: ① no source (no electricity, no rxn)

② θ symmetry

③ $v_r = v_\theta = v_z = 0$

④ long rod $\frac{\partial T}{\partial z} \sim 0$

ⓐ

$$\boxed{\frac{\partial T}{\partial t} = \frac{k}{\rho \hat{C}_p}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)\right)}$$

ⓑ initial condition

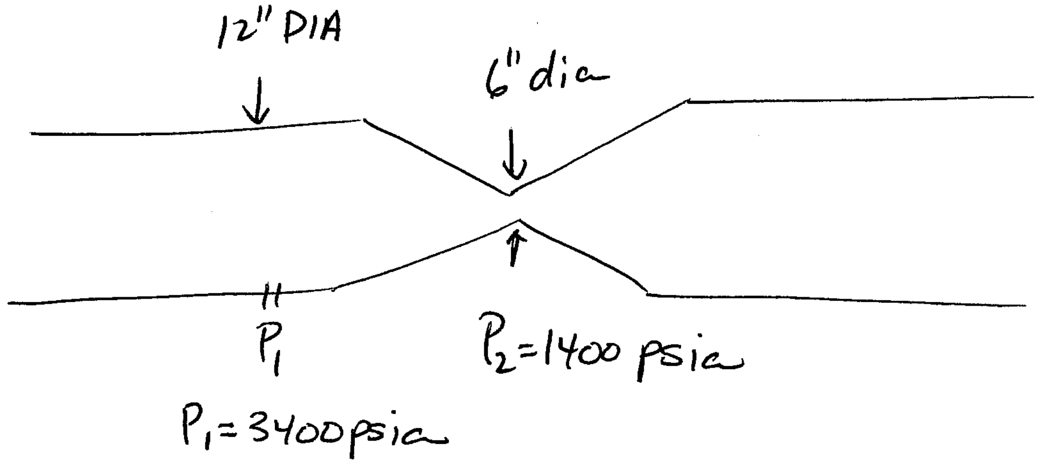
$T = 100°C \quad \forall r, \quad t=0$

boundary condition

$$\frac{q_r}{A} = h(\underset{25^\circ C}{\underset{\parallel}{T_b}} - T) \quad \text{at } r=R \quad t \geq 0$$

$$\begin{cases} \frac{q_r}{A} = 0 & \text{at } r=0 \quad t \geq 0 \\ \text{or} & \\ T = \text{finite} & \text{at } r=0 \end{cases}$$

6. BONUS



WHAT is VOL FLOW RATE?

MEB

$$\frac{\Delta P}{\rho} + \frac{\Delta V^2}{2\alpha} + \cancel{g\Delta z} \cancel{+F} = \frac{\cancel{W_{s,on}}}{\cancel{m}}$$

horisontal neglect no moving parts

Δ = out − in , $\alpha = 1$ turbulent

$$\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} = 0$$

$$\frac{V_2^2 - V_1^2}{2} = \frac{P_1 - P_2}{\rho} = \frac{3400\frac{lb_f}{in^2} - 1400\frac{lb_f}{in^2}}{62.25\frac{lbm}{ft^3}}$$

$$V_2^2 - V_1^2 = \frac{\left(\frac{2000\ \cancel{lbf}}{\cancel{in^2}}\right)(2)\left(\frac{32.174\ ft\ \cancel{lbm}}{s^2\ \cancel{lbf}}\right)}{62.25\ \frac{\cancel{lbm}}{ft^3}}\left(\frac{12\ \cancel{in}}{\cancel{ft}}\right)^2$$

$$= 297,706\ \frac{ft^2}{s^2}$$

MACRO MASS BAL:

$$\text{MASS}_{in} = \text{MASS}_{out}$$

$$\rho V = \cancel{\rho} V_1 A_1 = \cancel{\rho} V_2 A_2$$

$$V_1 = \frac{A_2}{A_1} V_2 = \frac{(0.5\ ft)^2 \cancel{\pi}}{(1\ ft)^2 \cancel{\pi}} V_2$$

$$\boxed{V_1 = 0.25\ V_2}$$

$$V_2^2 - V_1^2 = 297,706\ \frac{ft^2}{s^2}$$

$$V_2^2 - (0.25)^2 V_2^2 = 297,706\ \frac{ft^2}{s^2}$$

$$V_2^2 = \frac{297,706 \frac{ft^2}{s^2}}{\underbrace{1-(0.25)^2}_{0.9375}}$$

$$V_2^2 = 317,553 \frac{ft^2}{s^2}$$

$$\boxed{V_2 = 563.5 \frac{ft}{s}}$$

$$\dot{V} = V_2 A_2 = \left(563.5 \frac{ft}{s}\right) \frac{\pi (0.5)^2}{4} ft^2$$

$$= 110.65 \frac{ft^3}{s}$$

$$= \boxed{110 \frac{ft^3}{s}}$$