HW#6

8.30) Dry, compressed air @ $T_{m,i} = 55°C$, $p = 15\,atm$, $\dot{m} = 0.05\,kg/s$ enters a 50 mm ϕ, 2.5 m long tube w/ $T_s = 25°C$

a) find T of air @ outlet, rate of heat transfer from air to tube wall, & power required to flow air through tube

Table A-4: $T \approx 320\,K$, $\mu = 1.94e{-5}\ N\cdot s/m^2$, $\rho = 15(1.095) = 16.42\ kg/m^3$

$c_p = 1008\ J/kg\,K$, $k = 0.0278\ W/m\cdot K$, $Pr = 0.704$

a)

$$Re = \frac{4\dot{m}}{\pi D\mu} = \frac{4(0.05)}{\pi(0.05)(1.94e^{-5})} = 65{,}631 > 10^4 \therefore \text{Turbulent}$$

& know $L/D > 10 \therefore$ Developed & w/ $Nu = \frac{hD}{k} \Rightarrow h = \frac{Nu\,k}{D}$

8.60 & $Nu = 0.023\,Re^{4/5}\,Pr^{.3}$

$$h = \frac{0.023}{50e^{-3}}(6.56e4)^{4/5}(0.704)^{.3}\,0.0278 = \boxed{82.15\ W/m^2K = h}$$

Power) Eq. 8.22a,b

$$P = \Delta p\dot{V} = \frac{\dot{m}}{\rho}\left(f\frac{\rho u_m^2}{2D}(\Delta x)\right) = \frac{\dot{m} f u_m^2 \Delta x}{2D}$$

need f from 8.21: $f = (0.79\ln(Re_D) - 1.64)^{-2}$

$$f = (0.79\ln(6.56e4) - 1.64)^{-2} = 0.0197$$

HW#6

$w/ \quad \dot{m} = vA\rho \Rightarrow v = \dot{m}/A\rho = \frac{4\dot{m}}{D^2\pi\rho} = \frac{4(0.05)}{(50e{-3})^2\pi(16.42)} = 1.551 \text{ m/s}$

$$P = \frac{(0.05)(0.0197)(1.551)^2(2.5)}{2(50e{-3})} = \boxed{0.593 \text{ W} = P}$$

$T_o)$ 8.41b

$$\frac{T_s - T_{m,o}}{T_s - T_{m,i}} = \exp\left(\frac{-PL}{\dot{m}c_p}\bar{h}\right) \Rightarrow T_{m,o} = T_s + (T_{m,i} - T_s)\exp\left(\frac{-\pi D \bar{h} L}{\dot{m}c_p}\right)$$

perimeter

$$T_{m,o} = 25 + (55-25)\exp\left(\frac{-\pi(50e{-3})(82.1)(2.5)}{(0.05)(1008)}\right) = \boxed{40.82\ ^\circ C = T_{m,o}}$$

$q)$ $\dot{m}c_p(T_{m,i} - T_{m,o}) = (0.05)(1008)(55 - 40.82) = \boxed{714.79 \text{ W} = q}$

$$\boxed{T_{m,o} = 40.82\ ^\circ C, \quad q = 714.79 \text{ W} \quad P = 0.593 \text{ W}}$$

HW#6

b) $40e^{-3}$m, find L & P to have same q

know $\dot{m}$ is the same, so w/ $q = \dot{m}c_p(T_{m,i} - T_{m,o})$ we know $T_{m,o}$ has to be the same

w/ this & $T_{m,o} = T_s + (T_{m,i} - T_s)\exp\left(-\frac{\pi D h L}{\dot{m}c_p}\right)$

set both equal & equate argument of exp to get

$$\frac{\pi D_1 h_1 L_1}{\dot{m}c_p} = \frac{\pi D_2 h_2 L_2}{\dot{m}c_p} \Rightarrow D_1 h_1 L_1 = D_2 h_2 L_2$$

$$\& \; h \propto \frac{Re^{4/5}}{D} \propto \frac{\left(\frac{1}{D}\right)^{4/5}}{D} \propto D^{-4/5} D^{-1} \propto D^{-1.8}$$

$$\Rightarrow D_1^{-0.8} L_1 = D_2^{-0.8} L_2 \Rightarrow L_2 = \left(\frac{D_2}{D_1}\right)^{0.8} L_1 = \left(\frac{40}{50}\right)^{0.8} 2.5 = 2.09\text{m}$$

$\boxed{L_2 = 2.09\text{m}}$ then power $P = \frac{\dot{m} f u_m^2 \Delta x}{2D}$

$f = (0.79\ln(Re_D) - 1.64)^{-2}$, $Re = \frac{4\dot{m}}{\pi D \mu} = 82039$

$f = 0.01877$ & $v = \frac{4\dot{m}}{D^2 \pi \rho} = 2.42$ m/s

$\Rightarrow \boxed{P = 0.144 \text{ W}}$

HW#6

8.34) NaK (56%/44%), $\dot{m} = .8$ kg/s, $D = 40e{-3}$ m, $T_s = 435$ K, $T_{m,i} = 335$ K, $T_{m,o} = 397$ K

Find L & convective heat flux @ exit.

Table A.7) $\bar{T}_m = \frac{335+397}{2} = 366$ K, $\rho = 887$ kg/m³, $k = 25.6$ W/m·K

$\nu = 6.52e{-7}$ m²/s, $Pr = 0.026$, $c_p = 1130$ J/kg·K

$Re = \frac{4\dot{m}}{\pi D \nu \rho} = \frac{4(0.8)}{\pi(0.04)(6.52e{-7})(887)} = 44{,}032 > 10{,}000$ ∴ Turbulent

Check $Pe_D = Re_D\, Pr = (44{,}032)(0.026) = 1144.8$ ∴ Eq 8.65)

$Nu = 5.0 + 0.025 Pe_D^{0.8} = 11.997 \Rightarrow h = \frac{k\, Nu}{D} = \frac{(25.6)(11.997)}{(0.04)}$

$h = 7678.31$ W/m²·K

Eq) 8.41a $L = \frac{\dot{m} c_p}{\pi D h} \ln\left(\frac{\Delta T_i}{\Delta T_o}\right) = \frac{(0.8)(1130)}{\pi(0.04)(7680)} \ln\left(\frac{100}{38}\right) = \boxed{0.906 \text{ m} = L}$

Know $q'' = h(T_s - T_{m,o}) = h(435-397) = \boxed{291{,}776 \text{ W/m}^2 = q''}$

HWH6

8.36) Hg , $\dot{m} = 0.25$ kg/s heated 325K→375K , 25e-3 m ϕ @ 400K
Find L w/ liquid metal & compare to $Pr \geq 0.7$

Table A-5) $\bar{T}_m = \frac{375-325}{2} = 350K$, $C_p = 137.7$ J/kgK, $\mu = 0.1309e{-2}$ Ns/m²,
$k = 9.18$ W/mK , $Pr = 0.0196$

$Re = \frac{4\dot{m}}{\pi D \mu} = \frac{4(0.25)}{\pi(0.025)(0.1309e{-2})} = 9726.21 \approx 10{,}000$ ∴ turbulent, don't use Dittus-Boelter

$Pe = RePr = Re(0.0196) = 190.645$

8.65
$Nu = 5 + .025 Pe^{0.8} = 5 + .025(190.645)^{0.8} = 6.668$

$h = \frac{k\,Nu}{D} = \frac{9.18}{0.025} Nu = 2449.30$ W/m²K

Eq 8.41) $L = \frac{\dot{m} c_p}{\pi D h} \ln\left(\frac{\Delta T_i}{\Delta T_o}\right) = \overbrace{\frac{(0.25)(137.7)}{\pi(0.025)(2449)}}^{0.1614} \ln\left(\frac{400-325}{400-375}\right) = \boxed{0.1966\,m = L_1}$

if $Pr \geq 0.7$, h given by 8.60)

$h = \frac{k}{D}(0.0243)Re^{4/5}Pr^{0.4} = \frac{9.18}{0.025} \underbrace{(0.0243)(Re)^{4/5}Pr^{0.4}}_{7.314} = 2715.69$ W/m²K

& $L = \frac{\dot{m} c_p}{\pi D h} \ln\left(\frac{\Delta T_i}{\Delta T_o}\right) = \boxed{0.1773\,m = L_2}$

$L_1 > L_2$ where L_2 is assuming $Pr \geq 0.7$

HW#6

8.42) HT GR, coolant tubes 20e-3 m ϕ & 780e-3 m L, He @ 600K → 1000K, $\dot{m}$ = 8e-3 kg/s per tube

Table A-4) a) He; $\bar{T}$ = 800 K, P = 1 atm, ρ = 0.06272 kg/m³, c_p = 5193 J/kg K,

k = 0.304 W/m·K, μ = 382e-7 N·S/m², ν = 6.39e-4 m²/s, Pr = 0.654

b) air; $\bar{T}$ = 800 K, P = 1 atm, ρ = 0.4354 kg/m³, c_p = 1099 J/kg·K,

k = 57.3e-3 W/m k, ν = 84.93e-6 m²/s, Pr = 0.709

a) Find T_s & q

$$Re = \frac{4\dot{m}}{\pi D \mu} = \frac{4(8e\text{-}3)}{\pi(0.02)(382e\text{-}7)} = 13{,}332.4 > 10{,}000 \therefore \text{Turbulent}$$

8.60) $Nu = 0.023\, Re^{4/5} Pr^{0.4} = 38.72$

$$h = \frac{k}{D} Nu = \frac{0.304(38.72)}{0.02} = 588.484 \text{ W/m}^2/\text{K}$$

8.41b) $$\frac{T_s - T_{m,o}}{T_s - T_{m,i}} = \exp\left(-\frac{\pi D \bar{h} L}{\dot{m} c_p}\right) \approx .5 = \frac{T_s - 1000}{T_s - 600}$$

$\Rightarrow .5 T_s - .5(600) = T_s - 1000 \Rightarrow 0.5 T_s = 1000 - 0.5(600)$

$$\boxed{T_s = 1400.0 \text{ K}}$$

$$q = \dot{m} c_p (T_{m,o} - T_{m,i}) = (8e\text{-}3)(5193)(1000-600) = \boxed{16{,}617.6 \text{ W}}$$

<u>HW#6</u>

b) if air, find $\dot{m}$ if q & T_s are the same. Find outlet temp of air.

know $q = \dot{m} c_p (T_{mo} - T_{mi}) \Rightarrow \dot{m} = \frac{q}{c_p} \cdot \frac{1}{(T_{mo} - T_{mi})}$

$\frac{hD}{k} = 0.023 Re^{4/5} Pr^{0.4} \Rightarrow h = \frac{k}{D} 0.023 Re^{4/5} Pr^{0.4}$

$Re = \frac{4\dot{m}}{\pi D \mu} \Rightarrow h = \frac{k}{D} 0.023 \left(\frac{4\dot{m}}{\pi D \mu}\right)^{4/5} Pr^{0.4}$

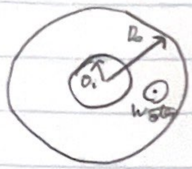
$\frac{T_s - T_{mo}}{T_s - T_{mi}} = \exp\left(\frac{-D\pi L h}{\dot{m} c_p}\right) \Rightarrow T_{mo} = T_s - (T_s - T_{mi}) \exp\left(\frac{-D\pi L h}{\dot{m} c_p}\right)$

plug in values each step & get

$$\boxed{\begin{aligned} T_{mo} &= 890.18 \text{ K} \\ \dot{m} &= 0.05204 \text{ kg/s} \end{aligned}}$$

converges after 6 steps w/ error of 1e-10

HW#6

8.73) 

water @ $\dot{m} = 0.03$ kg/s, $T_{m,i} = 25°C$

inner heated w/ $q' = 3000$ W/m, outer insulated

How long to get 85°C? $T_{s,inner}$ @ outlet? (fully developed)

Table A.6) $\bar{T} = \frac{85-25}{2} + 25 + 273 = 328\ K$, $c_p = 4183\ J/kgK$,

$\mu = 332e^{-6}\ Ns/m^2$, $k = 0.673\ W/mK$, $Pr = 2.07$

8.34) $q = \dot{m} c_p (T_{m,o} - T_{m,i}) = q'L \Rightarrow L = \dfrac{\dot{m} c_p (T_{m,o} - T_{m,i})}{q'}$

$L = \dfrac{(0.03)(4183)(85-25)}{3000} = \boxed{2.51\ m = L}$

T_s) 8.1) $Re = \dfrac{\rho u_m D}{\mu}$ 8.5) $\dot{m} = \rho u_m A \Rightarrow u_m = \dfrac{\dot{m}}{\rho A}$

$\Rightarrow Re = \dfrac{\dot{m} D}{\mu A} = \dfrac{\dot{m}(D_o - D_i)}{\frac{\pi}{4}(D_o^2 - D_i^2)\mu} = \dfrac{4\dot{m}}{\pi(D_o + D_i)\mu} = \dfrac{4(0.03)}{\pi(0.075)(332e^{-6})} = 1534$

$Re < 2300$ ∴ laminar, Table 8.3) $\frac{D_i}{D_o} = 0.5$ ∴ $Nu_{ii} = 6.24$

Eq 8.69) $h_i = \dfrac{k Nu_i}{D_h}$ w/ Eq 8.71) $D_h = D_o - D_i = 0.025\ m$

$h_i = \dfrac{6.24(0.673)}{0.025} = 168\ W/m^2K$ Eq 8.67) $q_i'' = h_i (T_{s,i} - T_m)$

$\Rightarrow T_{s,i} = T_{m,o} + \dfrac{q_i''}{h_i} = T_{m,o} + \dfrac{q'/\pi D_i}{h_i} = 85 + \dfrac{3000}{\pi(0.025)(168)} = \boxed{312.36°C = T_{s,i}}$