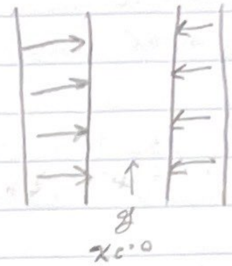
P1 - start

HW #10

1) sat water, SS, $\emptyset = 0$, Length L, q'' constant
friction factor is known.



Homog Eq to find ΔP? How would this change if going from top down?

Finding ΔP bot → top

1) mass: $\cancel{\frac{\partial \rho}{\partial t}}^{0,\,SS} + \frac{\partial \rho v}{\partial z} = 0 \Rightarrow \therefore \rho v = \text{constant} = G$

2) momentum: $\cancel{\frac{\partial \rho v}{\partial t}}^{0,\,SS} + \frac{\partial}{\partial z} \rho v^2 = -\frac{\partial P}{\partial z} - \frac{\tau_f \xi}{A_f} - \rho g \sin\theta$

w/ $\tau_f = \frac{1}{2} f \frac{G^2}{\rho}$

$\Rightarrow G^2 \frac{\partial}{\partial z}\frac{1}{\rho} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi_w}{2 A_f \rho} - \rho g$

3) enthalpy: $\cancel{\frac{\partial \rho h}{\partial t}}^{0,\,SS} + \frac{\partial}{\partial z} h \rho v = \frac{q'' \xi}{A} + \cancel{\frac{\partial P}{\partial t}}^{0,\,SS} + \cancel{q'''}^{0,\,SS}$

$\Rightarrow G \frac{\partial h}{\partial z} = \frac{q'' \xi}{A_f}$ w/ $h = x h_g + (1 - x_e) h_f = h_f + h_{fg} x_e$

$\Rightarrow \frac{\partial (h_f + h_{fg} x_e)}{\partial z} = \frac{q'' \xi}{A_f G} \Rightarrow$ w/ $\frac{\partial h_f}{\partial z} = 0$ (constant properties) $\therefore \frac{\partial x_e}{\partial z} = \frac{q'' \xi}{A_f G h_{fg}}$

• integrate x_e expression $\Rightarrow x_e = x_{e,0} + \frac{q'' \xi z}{A_f G h_{fg}}$

@ $z = 0$, $x_e = 0 \Rightarrow 0 = x_{e,0} + 0$ $\therefore x_{e,0} = 0$ $\Rightarrow x_e = \frac{q'' \xi z}{A_f G h_{fg}}$

HW#10 - cont

momentum cont... $G^2 \frac{\partial}{\partial z}\frac{1}{\rho} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi_w}{2A_\ell \rho} - \rho g$

w/ $1/\rho = v = x_e v_g + (1-x_e) v_f = v_f + v_{fg} x_e$

$\Rightarrow G^2 \frac{\partial v}{\partial z} = G^2 \frac{\partial (v_f + v_{fg} x_e)}{\partial z} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi v}{2A_\ell} - \frac{g}{v}$

$\Rightarrow v_{fg} G^2 \frac{\partial x_e}{\partial z} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi}{2A_\ell}(v_f + x_e v_{fg}) - \frac{g}{v_f + x_e v_{fg}}$

$\Rightarrow v_{fg} G^2 \frac{\partial x_e}{\partial z} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi v_f}{2A_\ell} - \frac{f G^2 \xi v_{fg}}{2A_\ell} x_e - \frac{g}{v_f + x_e v_{fg}}$

$\Rightarrow v_{fg} G^2 \frac{\partial x_e}{\partial z} + \frac{g}{v_f + x_e v_{fg}} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi v_f}{2A_\ell} - \frac{f G^2 \xi v_{fg}}{2A_\ell} x_e$

multiply through by dz & cancel partials because $P = fn(z)$, $x_e = fn(z)$

$\Rightarrow v_{fg} G^2 \, dx_e + \frac{g \, dz}{v_f + x_e v_{fg}} = -dP - \frac{f G^2 \xi v_f}{2A_\ell} dz - \frac{f G^2 \xi v_{fg} x_e}{2A_\ell} dz$

integrate every term to obtain expression in terms of knowns

$$\underbrace{\int v_{fg} G^2 \, dx_e}_{1} + \underbrace{\int \frac{g \, dz}{v_f + x_e v_{fg}}}_{2} = \underbrace{-\int dP}_{3} \underbrace{- \int \frac{f G^2 \xi v_f}{2A_\ell} dz}_{4} \underbrace{- \int \frac{f G^2 \xi v_{fg} x_e}{2A_\ell} dz}_{5}$$

deal w/ each term independently

HW#10 - cont

① $\int v_{gf} \mathscr{g}^2 \, d\chi_e$ move constants out

$\Rightarrow v_{gf} \mathscr{g}^2 \int d\chi_e$ integrate

$\Rightarrow v_{gf} \mathscr{g}^2 \chi_e + C_1$ sub in expression for χ_e

$\Rightarrow v_{gf} \mathscr{g}^2 \left(\frac{q'' \xi z}{A_f \mathscr{g} h_{fg}} \right) + C_1$

$\Rightarrow$ ① $= \frac{v_{gf} \mathscr{g}^2 q'' \xi}{A_f \mathscr{g} h_{fg}} z + C_1$

② $\int \frac{g \, dz}{v_f + \chi_e v_{gf}}$ sub in expression for χ_e

$\Rightarrow \int \frac{g \, dz}{v_f + \left(\frac{q'' \xi z}{A_f \mathscr{g} h_{fg}} \right) v_{gf}}$ define $\Lambda = \frac{q'' \xi v_{gf}}{A_f \mathscr{g} h_{fg}}$

$\Rightarrow \int \frac{g \, dz}{v_f + \Lambda z} \Rightarrow g \int \frac{dz}{v_f + \Lambda z} \Rightarrow \frac{g \ln(|v_f + \Lambda z|)}{\Lambda} + C_2$

$\Rightarrow$ ② $= \frac{g A_f \mathscr{g}^2 h_{fg}}{q'' \xi v_{gf}} \ln(|v_f + \Lambda z|)$

③ $-\int dP = -P + C_3$

③ $= -P + C_3$

HW#10 - cont

④ $-\int \frac{\rho_f G^2 \xi \nu_f}{2A_f}\,dz$ nothing is a function of z

④ $= -\frac{\rho_f G^2 \xi \nu_f}{2A_f} z + C_4$

⑤ $-\int \frac{\rho_f G^2 \xi \nu_{fg}}{2A_f} x_e\,dz = -\frac{\rho_f G^2 \xi \nu_{fg}}{2A_f}\int\left(\frac{q'' \xi z}{A_f G h_{fg}}\right)dz$

$\Rightarrow -\frac{\rho_f G^2 \xi \nu_{fg}}{2A_f}\cdot\frac{q'' \xi}{A_f G h_{fg}}\int z\,dz$ w/ $\int z\,dz = \frac{z^2}{2} + C_5'$

⑤ $= -\frac{\rho_f q'' \xi^2 \nu_{fg} G}{4A_f^2 h_{fg}} z^2 + C_5$

w/ ① + ② = ③ + ④ + ⑤, group all constants

rearrange to solve for Pressure

$\Lambda = \frac{q'' \xi \nu_{fg}}{A_f G h_{fg}}$ ↓

③ = ① + ② − ④ − ⑤ + C

$$\Rightarrow -P = \frac{\nu_{fg} G^2 q'' \xi}{A_f G h_{fg}} z + \frac{g A_f G^2 h_{fg}}{q'' \xi \nu_{fg}} \ln\left(\left|\nu_f + \Lambda z\right|\right)$$

$$+ \frac{\rho_f G^2 \xi \nu_f}{2A_f} z + \frac{\rho_f q'' \xi^2 \nu_{fg} G}{4A_f h_{fg}} z^2 + C$$

HW #10 - cont   P1 - end

to find pressure drop, take $\left(-P(z=L) \overset{(--)}{+} P(z=0)\right) = \Delta P$

$$-P(z=0) = 0 + \frac{g A_f G^2 h_{fg}}{q'' \xi v_{fg}} \ln(|v_f|) + 0 + 0 + C$$

$$-P(z=L) = \frac{v_{fg} G^2 q'' \xi}{A_f G h_{fg}} L + \frac{g A_f G^2 h_{fg}}{q'' \xi v_{fg}} \ln(|v_f + \Lambda L|)$$

$$+ \frac{f G^2 \xi v_f}{2 A_f} L + \frac{f q'' \xi^2 v_{fg} G L^2}{4 A_f h_{fg}} + C$$

the C's cancel & the $\ln(|?|)$ terms can be grouped together

$$\Rightarrow \frac{g A_f G^2 h_{fg}}{q'' \xi v_{fg}} \left(\ln(|v_f + \Lambda L|) - \ln(|v_f|)\right)$$

w/ $\ln(|v_f + \Lambda L|) - \ln(|v_f|) = \ln\left(\left|\frac{v_f + \Lambda L}{v_f}\right|\right) = \ln\left(\left|\frac{v_f}{v_f} + \frac{\Lambda L}{v_f}\right|\right) = \ln\left(\left|1 + \frac{\Lambda L}{v_f}\right|\right)$

$$\Rightarrow \boxed{\Delta P = \overset{①}{\frac{v_{fg} G^2 q'' \xi L}{A_f G h_{fg}}} + \overset{②}{\frac{g A_f G^2 h_{fg}}{q'' \xi v_{fg}}} \ln\left(\left|1 + \frac{\Lambda L}{v_f}\right|\right) + \overset{③}{\frac{f G^2 \xi_f L}{2 A_f}} + \overset{④}{\frac{f q'' \xi^2 v_{fg} G L^2}{4 A_f h_{fg}}} \quad \text{w/ } \Lambda = \frac{q'' \xi v_{fg}}{A_f G h_{fg}}}$$

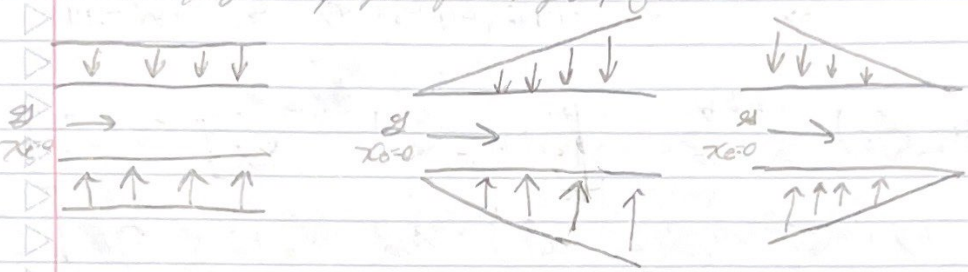
① ΔP from the heating / change of fluid densities
② ΔP from gravity   ③ ΔP from major loss
④ ΔP from viscous forces / minor loss?

If the water flowed from top → bottom ②, the gravitational pressure loss would become negative. This means the gravitational forces cause a pressure gain instead. No other term changes. ② $\frac{g A_f h_{fg}}{q'' \xi v_{fg}} \ln\left(\left|1 + \frac{\Lambda L}{v_f}\right|\right) \Longrightarrow -\frac{g A_f h_{fg}}{q'' \xi v_{fg}} \ln\left(\left|1 + \frac{\Lambda L}{v_f}\right|\right)$

P2 - start

HW #10

2) $x_e = 0$ at inlet, 2ϕ throughout, $\phi = 0$, length L, horizontal
SS, negligible property changes, $f_{2\phi}$ known



2) Find ΔP & compare each case.

Start w/ continuity equations

mass) $\xcancel{\dfrac{\partial \rho}{\partial t}}^{\,0,SS} + \dfrac{\partial \rho v}{\partial z} = 0 \Rightarrow \rho v = \text{constant} = G$

enthalpy) $\xcancel{\dfrac{\partial \rho h}{\partial t}}^{\,0,SS} + \dfrac{\partial}{\partial z}\rho v h = \dfrac{q'' \xi_h}{A_f} + \xcancel{\dfrac{\partial P}{\partial t}}^{\,0,SS} + \xcancel{q'''}^{\,0,\text{ no heat gen}}$

$\Rightarrow G \dfrac{\partial h}{\partial z} = \dfrac{q'' \xi_h}{A_f}$ but $h = h_f + h_{fg} x_e$

$\Rightarrow \xcancel{\dfrac{\partial h_f}{\partial z}}^{\,0,\text{ constant properties}} + \dfrac{\partial h_{fg} x_e}{\partial z} = \dfrac{q'' \xi_h}{A_f G} \Rightarrow \dfrac{\partial x_e}{\partial z} = \dfrac{q'' \xi_h}{A_f G h_{fg}}$

assume $q'' = \alpha z + \beta$, so any general linear function

$\Rightarrow \int dx_e = \dfrac{\xi_h}{A_f G h_{fg}} \int (\alpha z + \beta)\, dz$

$\Rightarrow x_e = \dfrac{\xi_h}{A_f G h_{fg}} \left(\dfrac{\alpha z^2}{2} + \beta z \right)$

HW #10 - cont

momentum) $\frac{\partial \overset{0,\,ss}{\rho v}}{\partial t} + \frac{\partial \rho v^2}{\partial z} = -\frac{\partial P}{\partial z} - \frac{\tau_f \xi}{A_f} - \rho g \overset{0,\text{ horizontal flow}}{\sin\theta}$

w/ $\tau_f = \frac{1}{2} f \frac{G^2}{\rho}$ & $\frac{1}{\rho} = v = v_f + v_{fg} x_e$

$\Rightarrow G^2 \frac{\partial}{\partial z}\left(\frac{1}{\rho}\right) = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi}{2 A_f \rho} \Rightarrow G^2 \frac{\partial v}{\partial z} = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi v}{2 A_f}$

$\Rightarrow G^2\left(\frac{\overset{0}{\partial v_f}}{\partial z} + \frac{\partial (v_{fg} x_e)}{\partial z}\right) = -\frac{\partial P}{\partial z} - \frac{f G^2 \xi v_f}{2 A_f} - \frac{f G^2 \xi v_{fg} x_e}{2 A_f}$

$\Rightarrow G^2 v_{fg} \frac{dx_e}{dz} = -\frac{dP}{dz} - \frac{f G^2 \xi v_f}{2 A_f} - \frac{f G^2 \xi v_{fg}}{2 A_f} x_e$

multiply through by dz & integrate

$\Rightarrow \int G^2 v_{fg}\, dx_e = -\int dP - \int \frac{f G^2 \xi v_f}{2 A_f} dz - \int \frac{f G^2 \xi v_{fg}}{2 A_f} x_e\, dz$

① ② ③ ④

solve each term individually

① $\int G^2 v_{fg}\, dx_e = G^2 v_{fg} \int dx_e = G^2 v_{fg} x_e + C_1$

$\Rightarrow G^2 v_{fg} \left[\frac{\xi}{A_f G h_{fg}}\left(\frac{\alpha z^2}{2} + \beta z\right)\right] + C_1 \Rightarrow \frac{G v_{fg} \xi}{A_f h_{fg}}\left(\frac{\alpha z^2}{2} + \beta z\right) + C_1$

① $= \frac{G v_{fg} \xi}{A_f h_{fg}}\left(\frac{\alpha z^2}{2} + \beta z\right) + C_1$

② $-\int dP = -P + C_2$

② $= -P + C_2$

HW #10 - cont

③ $-\int \frac{\rho g^2 \xi \nu_f}{2A_f} dz = -\frac{\rho g^2 \xi \nu_f z}{2A_f} + C_3$

③ $= -\frac{\rho g^2 \xi \nu_f}{2A_f} z + C_3$

solve for x_e

④ $-\int \frac{\rho g^2 \xi \nu_{fg}}{2A_f} x_e \, dz = -\frac{\rho g^2 \xi \nu_{fg}}{2A_f} \int x_e \, dz$

$\Rightarrow -\frac{\rho g^2 \xi \nu_{fg}}{2A_f} \int \left[\frac{\xi}{A_f g k_{fg}} \left(\frac{\alpha z^2}{2} + \beta z \right) \right] dz$

$\Rightarrow -\left(\frac{\rho g^2 \xi \nu_{fg}}{2A_f} \right) \left(\frac{\xi}{A_f g k_{fg}} \right) \int \left(\frac{\alpha z^2}{2} + \beta z \right) dz$

$\Rightarrow -\frac{\rho g \xi^2 \nu_{fg}}{2A_f^2 k_{fg}} \left(\frac{\alpha z^3}{6} + \frac{\beta z^2}{2} + C_4' \right)$

④ $= -\frac{\rho g^2 \xi \nu_{fg}}{2A_f k_{fg}} \left(\frac{\alpha z^3}{6} + \frac{\beta z^2}{2} \right) + C_4$

rearrange to solve for pressure

② = ① - ③ - ④ , group constants $\Rightarrow$ ② = ① - ③ - ④ + C

$-P = \frac{g \nu_{fg} \xi}{A_f k_{fg}} \left(\frac{\alpha z^2}{2} + \beta z \right) + \frac{\rho g^2 \xi \nu_f z}{2A_f}$

$+ \frac{\rho g^2 \xi \nu_{fg}}{2A_f k_{fg}} \left(\frac{\alpha z^3}{6} + \frac{\beta z^2}{2} \right) + C$

HW#10

pressure drop is $\Delta P = -P(z=L) + P(z=0)$

$-P(z=0) = 0 + 0 + 0 + C$

$$-P(z=L) = \frac{g v_{fg} \xi}{A_6 h_{fg}}\left(\frac{\alpha L^2}{2} + \beta L\right) + \frac{f g^2 \xi v_f L}{2A_6} + \frac{f g^2 \xi v_{fg}}{2A_6 h_{fg}}\left(\frac{\alpha L^3}{6} + \frac{\beta L^2}{2}\right) + C$$

$\Rightarrow$ pressure drop for any linear $q'' = \alpha z + \beta$ is given as

$$\Delta P = \frac{g v_{fg} \xi}{A_6 h_{fg}}\left(\frac{\alpha L^2}{2} + \beta L\right) + \frac{f g^2 \xi v_f L}{2A_6} + \frac{f g^2 \xi v_{fg}}{2A_6 h_{fg}}\left(\frac{\alpha L^3}{6} + \frac{\beta L^2}{2}\right)$$

For each case a) constant, b) linear increasing, c) linear decreasing

know $P_e = \xi_a \int q'' dz$ for all three cases

a) $P_e = \xi_a \int (\alpha_a z + \beta_a) dz$, but $\alpha_a = 0$, so

$$\frac{P_e}{\xi_a} = \int \beta_a \, dz \Rightarrow \frac{P_e}{\xi_a} = \beta_a \left(z\Big|_0^L\right) \Rightarrow \frac{P_e}{\xi_a} = \beta_a L \quad \therefore \beta_a = \frac{P_e}{\xi_a L}$$

b) $P_e = \xi_a \int (\alpha_b z + \beta_b) dz$, but $\beta_b = 0$ as the heat flux $= 0$ @ the entrance

$$\Rightarrow \frac{P_e}{\xi_a} = \int \alpha_b z \, dz \Rightarrow \frac{P_e}{\xi_a} = \frac{\alpha_b}{2}\left(z^2\Big|_0^L\right) = \frac{\alpha_b L^2}{2} \Rightarrow \alpha_b = \frac{2P_e}{\xi L^2}$$

c) $P_e = \xi_a \int (\alpha_c z + \beta_c) dz$, know $\alpha_c = -\alpha_b$ because there's only 1 slope that solves the equality of total power

$$\Rightarrow \frac{P_e}{\xi_a} = -\alpha_b \int z \, dz + \beta_c \int dz \Rightarrow \frac{P_e}{\xi_a} = -\frac{\alpha_b}{2}\left(z^2\Big|_0^L\right) + \beta_c\left(z\Big|_0^L\right) = \frac{-\alpha_b L^2}{2} + \beta_c L$$

$$\Rightarrow \beta_c L = \frac{P_e}{\xi_a} + \frac{\alpha_b L^2}{2} \quad \Rightarrow \quad \beta_c = \frac{P_e}{\xi_a L} + \frac{\alpha_b L}{2}$$

P2

HW #10 - cont

for each heat flux $q'' = \alpha z + \beta$, the constants are given as

a) constant $\alpha_a = 0$, $\beta_a = \dfrac{P_e}{\xi L}$

b) linear increasing $\alpha_b = \dfrac{2P_e}{\xi L^2}$, $\beta_b = 0$

c) linear decreasing $\alpha_c = \dfrac{-2P_e}{\xi L^2}$, $\beta_b = \dfrac{P_e}{\xi L} + \dfrac{P_e}{\xi L} = \dfrac{2P_e}{\xi L}$

This means the pressure drops for each q'' are given as:

a)
$$\Delta P_a = \frac{G v_{fg} \xi}{A_f h_{fg}}\left(\frac{P_e L}{\xi L}\right) + \frac{f G^2 \xi v_f L}{2A_f} + \frac{f G^2 \xi v_{fg}}{2A_f h_{fg}}\left(\frac{P_e L^2}{2\xi L}\right)$$

$$\Delta P_a = \frac{G v_{fg} P_e}{A_f h_{fg}} + \frac{f G^2 \xi v_f L}{2A_f} + \frac{f G^2 v_{fg} P_e L}{4 A_f h_{fg}}$$

b)
$$\Delta P_b = \frac{G v_{fg} \xi}{A_f h_{fg}}\left(\frac{2P_e L^2}{2\xi L^2}\right) + \frac{f G^2 \xi v_f L}{2A_f} + \frac{f G^2 \xi v_{fg}}{2A_f h_{fg}}\left(\frac{2P_e L^3}{6\xi L^2}\right)$$

$$\Delta P_b = \frac{G v_{fg} P_e}{A_f h_{fg}} + \frac{f G^2 \xi v_f L}{2A_f} + \frac{f G^2 v_{fg} P_e L}{6 A_f h_{fg}}$$

c)
$$\Delta P_c = \frac{G v_{fg} \xi}{A_f h_{fg}}\left(\frac{-2P_e L^2}{2\xi L^2} + \frac{2P_e L}{\xi L}\right) + \frac{f G^2 \xi v_f L}{2A_f} + \frac{f G^2 \xi v_{fg}}{2A_f h_{fg}}\left(\frac{-2P_e L^3}{6\xi L^2} + \frac{2P_e L^2}{2\xi L}\right)$$

w/ $\dfrac{-2P_e L^2}{2\xi L^2} + \dfrac{2P_e L}{\xi L} = \dfrac{2P_e}{\xi} - \dfrac{P_e}{\xi} = \dfrac{P_e}{\xi}$ & $\dfrac{2P_e L^2}{2\xi L} - \dfrac{2P_e L^3}{6\xi L^2} = \dfrac{P_e L}{\xi} - \dfrac{P_e L}{3\xi} = \dfrac{2P_e L}{3\xi}$

$$\Delta P_c = \frac{G v_{fg} P_e}{A_f h_{fg}} + \frac{f G^2 \xi v_f L}{2A_f} + \frac{f G^2 v_{fg} P_e L}{3 A_f h_{fg}}$$

P2 - end

HW #10 - cont

all of the pressure drops are

a) $\Delta P_a = \dfrac{g v_{fg} P_e}{A_f h_{fg}} + \dfrac{f g^2 \xi v_f L}{2 A_f} + \dfrac{f g^2 v_{fg} P_e L}{4 A_f h_{fg}}$

b) $\Delta P_b = \dfrac{g v_{fg} P_e}{A_f h_{fg}} + \dfrac{f g^2 \xi v_f L}{2 A_f} + \dfrac{f g^2 v_{fg} P_e L}{6 A_f h_{fg}}$

c) $\Delta P_c = \dfrac{g v_{fg} P_e}{A_f h_{fg}} + \dfrac{f g^2 \xi v_f L}{2 A_f} + \dfrac{f g^2 v_{fg} P_e L}{3 A_f h_{fg}}$

For each pressure drop, the first two terms are the same. The first term is the ΔP from the total heating / change in fluid density & the second term is the ΔP from the major losses. These terms being equal for all cases makes sense because the total heating & density change are the same for each case. Also, the wall doesn't physically change for each case, so there will be no difference in major loss.

The final term, however, does change based on each case. The general form is $\dfrac{1}{x} \dfrac{f g^2 v_{fg} P_e L}{A_f h_{fg}}$ where x is a constant.

For case a) $\frac{1}{x} = \frac{1}{4}$, b) $\frac{1}{x} = \frac{1}{6}$, c) $\frac{1}{x} = \frac{1}{3}$. This term corresponds to the pressure drop from heating, which is given as $\mu_m = \mu_f + \mu_{fg} x_e$, so the higher the void fraction, the higher the 2ϕ viscosity. Therefore, the case w/ the highest average void fraction will have the highest pressure drop. This is seen in case c w/ the highest pressure drop. The case w/ the lowest void fraction, case b, will be the one w/ the lowest pressure drop.

P3 - start

HW # 10 - cont

3) $D = 0.01\,m$, $q'' = 500\ kW/m^2$, $T_{in} = T_{sat} - 15°C$, $G = 1000\ kg/m^2 s$

Find onset of 2ϕ flow, channel length where $x_e(L) = 1$

Start w/ conservation Equations

mass) $\cancel{\frac{\partial \rho}{\partial t}}^{0, SS} + \frac{\partial \rho v}{\partial z} = 0 \Rightarrow \rho v = \text{constant} = G$

enthalpy) $\cancel{\frac{\partial \rho h}{\partial t}}^{0, SS} + \frac{\partial h \rho v}{\partial z} = \frac{q'' \xi}{A_f} + \cancel{\frac{\partial p}{\partial t}}^{0, SS} + \cancel{q'''}^{0, no\ gen}$

$\Rightarrow G \frac{\partial h}{\partial z} = \frac{q'' \xi}{A_f} \Rightarrow \frac{\partial h}{\partial z} = \frac{q'' \xi}{A_f G}$ w/ $h = h_f + x_e h_{fg}$

$\Rightarrow \frac{\partial}{\partial z}\left(h_f + x_e h_{fg}\right) = \frac{q'' \xi}{A_f G} \Rightarrow h_{fg} \frac{\partial x_e}{\partial z} = \frac{q'' \xi}{A_f G} \Rightarrow \frac{\partial x_e}{\partial z} = \frac{q'' \xi}{A_f G h_{fg}}$

all constant wrt z $\overset{\int}{\Rightarrow}$ $x_e = \frac{q'' \xi}{A_f G h_{fg}} z + C$

where $C = x_e(z=0) = x_e$ @ 15° below T_{sat}

$$C = \frac{h(p_{atm}, t_{sat}(p_{atm})) - h_f}{h_{fg}} = \underline{-0.02797 = x_{e,0}}$$

To find T_f, know T increases in 1ϕ fluid & = T_{sat}

1ϕ: $h = h_{f,sat} + x_e h_{fg}$, have h, find T from pyXsteam
2ϕ: $T_f = T_{sat}$

p3-end

HW#10 - cont

use the correlations to find T_W for 2ϕ

$$q'' = \left\{ \left[F h_L (T_w - T_b) \right]^2 + \left[S h_{pool} (T_w - T_s) \right]^2 \right\}^{1/2}$$

$$F = \left[1 + \chi P_r \left(\frac{\rho_l}{\rho_v} - 1 \right) \right]^{0.35}, \quad S = \left(1 + 0.055 F^{0.1} Re_L^{0.16} \right)^{-1}$$

$$h_L = 0.023 \, (k_l/d) \, Re^{0.8} \, Pr^{0.4}$$

$$h_{pool} = 55 \, p_r^{0.12} \, q''^{2/3} \left(-\log(p_r) \right)^{-0.55} M^{-0.5}$$

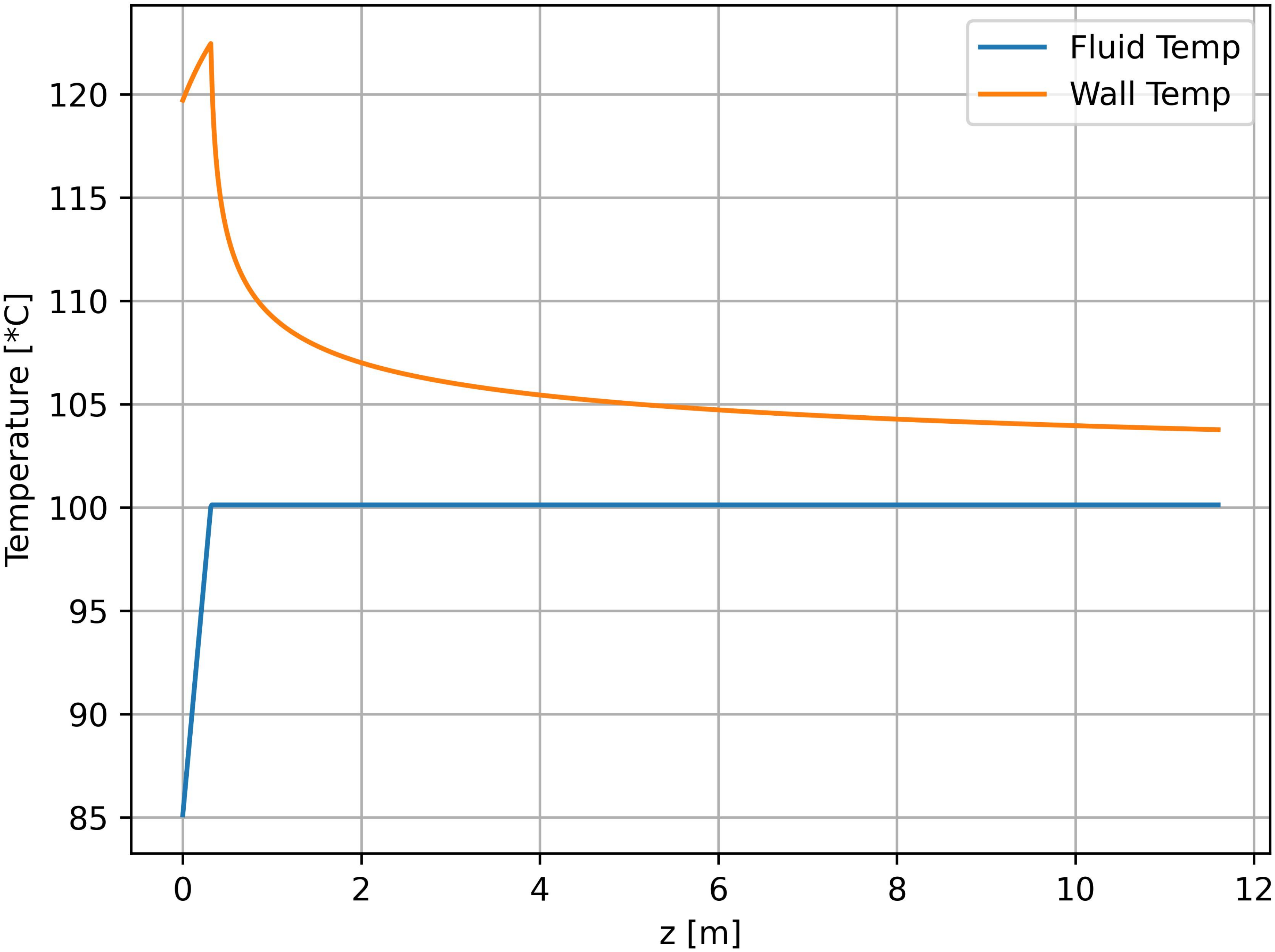
use $Re = \dfrac{g D_h}{\mu_b}$ w/ $D_h = \dfrac{4A_b}{\xi}$

$\mu_b = 3.3345e\text{-}10$ MPa·s
$c_p = 4.184e3$ J/kgK
$k_b = 0.67$ W/mK

$Pr = \dfrac{c_p \mu_b}{k_b}$ find μ_b, c_p, k_b from pyXsteam & google

& $p_r = \dfrac{p_{total}}{p_c} = \dfrac{0.10325 \text{ MPa}}{22.06395 \text{ MPa}} = 0.00459$

Solve for the root w/ scipy to get $T_{w,2\phi}$



Fluid Temp
Wall Temp
Temperature [*C]
z [m]
85
90
95
100
105
110
115
120
0
2
4
6
8
10
12