TN 4780TA. Re-exam 2 April 2014

1. We don't know Re, so use Eq. 6.4-12 (BSL)

$$\frac{\Delta P}{L} = 150\frac{\mu V_0}{D_p^2}\frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{7}{4}\frac{\rho V_0^2}{D_p}\frac{1-\varepsilon}{\varepsilon^3}$$

$$\frac{1000}{3} = 150\frac{1.75 \cdot 10^{-5}\, V_0}{(0.075)^2}\frac{(0.65)^2}{(0.35)^3} + \frac{7}{4}\frac{1.26\, V_0^2}{0.075}\frac{0.65}{(0.35)^3}$$

$$333.3 = 4.60\,V_0 + 446\,V_0^2$$

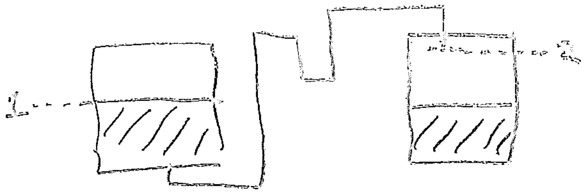
$$0 = 333.3 - 4.60\,V_0 - 446\,V_0^2 = 446\,V_0^2 + 4.60\,V_0 - 333.3$$

$$V_0 = \frac{-4.60 \pm \sqrt{(4.60)^2 + 4(333.3)(446)}}{2 \cdot 1(446)}$$

$$\frac{-4.60 \pm 771}{892}$$ Positive root applies

$V_0 = 0.86$ m/s

[$Re = \frac{(0.075)(0.86)(1.16)}{1.75 \cdot 10^{-5}} = 4275 >> 10$. Darcy's law is not a good assumption. Thus Eq. 6.4-9 is not OK. If one uses Eq. 6.4-11, one should verify that Re is >>> 10.]



2.* Take entrance surface "1" as top surface of liquid in left-hand tank, "2" as pipe outlet into 2nd tank.

Eq. 7.5-10 applies.

$V_2 = Q/(\pi R^2) = (0.01)/[\pi(0.05)^2] = 1.27$ m/s

(A) $\frac{1}{2}(V_2^2 - V_1^2) = \frac{1}{2}((1.27)^2 - 0) = 0.8106$

(B) $g(h_2 - h_1) = (-1+4-2+5-2-3)g$ (counting from final tank back to beginning)

$= 9.82(1) = 9.82$

$\hat{W} = 0$

(C) $\sum\left(\frac{1}{2}v^2 \frac{L}{R_h} f\right) = \frac{1}{2}(1.27)^2 \frac{(2+3+5+1.5+2+1+4+2+1)}{(0.1)/4} f v^2$

$= \frac{1}{2}(1.27)^2 \frac{21.5}{0.025} f = 693 f$

What is f? $Re = \frac{(0.1)(1.27)650}{0.005} = 16510$; $\frac{k}{D} = \frac{0.1}{0.0004} = 0.004$

From BSL Fig 6.7-2 I read $f \approx 0.0087$

$\rightarrow = 6.03$

(D) $\sum \frac{1}{2} v^2 e_v = \frac{1}{2}(1.27)^2 \left[\underset{\text{abrupt contraction}}{0.45} + \underset{\text{8 elbows}}{8 \cdot 1.6} \right] = 10.7$

$\therefore \frac{P_2 - P_1}{\rho} = (-0.8106) - (9.82) - 6.03 - 10.7 = 27.4$

$P_2 - P_1 = (27.4)650 = 17800$

$P_1 = 2 \cdot 10^6$; $P_2 = 2 \cdot 10^6 - 17800 = 1.98 \cdot 10^6$ Pa

* The eq. 7.5-10 is

$$\underset{\text{see (A)}}{\frac{1}{2}(v_2^2 - v_1^2)} + \underset{\text{(B)}}{g(h_2 - h_1)} + \frac{P_2 - P_1}{\rho} = \underset{0}{\hat{W}_m} - \underset{\text{(C)}}{\sum_i \left(\frac{1}{2}v^2 \frac{L}{R_h} f\right)_i} - \underset{\text{(D)}}{\sum_i \left(\frac{1}{2} v^2 e_v\right)_i}$$

3. a) The shell balance is the same as for the "falling film" in BSL or "film condensate" in FT, but the BC are different. One can use the derivation in BSL up through eq. 2.2-11 (but no further). [could also use FT derivation for flow in slit as starting pt.]

$$\tau_{xz} = (\rho g \cos\beta)x + C_1 \qquad (\cos\beta = 1 \text{ here}) \qquad \boxed{I}$$

We have no BC on τ here so we proceed w/ Newton's law of viscosity

$$-\mu \frac{dv_z}{dx} = \rho g x + C_1$$

$$\frac{dv_z}{dx} = -\frac{\rho g x}{\mu} - \frac{C_1}{\mu} \rightarrow v_z = -\frac{\rho g}{2\mu}x^2 - \frac{C_1}{\mu}x + C_2$$

BC #1: $v_z = 0$ at $x = 0$: $\quad C_2 = 0$

$v_z = V$ at $x = \delta$: $\quad V = -\frac{\rho g \delta^2}{2\mu} - \frac{C_1}{\mu}\delta$

$$C_1 = -\frac{\mu}{\delta}\left(V + \frac{\rho g \delta^2}{2\mu}\right) \qquad \boxed{II}$$

$$v_z = -\frac{\rho g}{2\mu}x^2 + \frac{x}{\mu}\left[\frac{\mu}{\delta}V + \rho g \delta\left(\tfrac{1}{2}\right)\right] = -\frac{\rho g x^2}{2\mu} + \frac{x}{\delta}V + \frac{\rho g \delta^2}{2\mu}\left(\frac{x}{\delta}\right)$$

$$= \frac{\rho g \delta^2}{2\mu}\left(\frac{x}{\delta} - \left(\frac{x}{\delta}\right)^2\right) + \frac{x}{\delta}V$$

b) Could differentiate v_z and plug in to Newton's law of viscosity, but since we solved for τ_{xz} in terms of C_1 in Eq. I and solved for C_1 in Eq. II,

$$\tau_{xz} = (\rho g x) - \frac{\mu}{\delta}\left(V + \frac{\rho g \delta^2}{2\mu}\right). \text{ At } x = \delta, \text{ this is}$$

$$\tau_{xz} = \rho g \delta - \frac{\mu}{\delta}\left(V + \frac{\rho g \delta^2}{2\mu}\right) = \frac{\rho g \delta}{2} - \frac{\mu V}{\delta}$$

4. There is no fluid that behaves as indicated.

a) Newtonian fluid: $Q_2 = 2Q_1$ (in laminar flow) NOT

b) shear-thinning power-law fluid $Q_2 > 2Q_1$ NOT

c) shear-thickening " $Q_1 < Q_2 < 2Q_1$ NOT

d) Bingham plastic $Q_2 \geq 2Q_1$ NOT

e) Newtonian, highly turbulent $Q_2 = \sqrt{2}\, Q_1$ NOT

(from $f(Re) = \text{const.}$)

(Just at the transition from laminar flow to turbulence, it's possible flow rate could decrease. This is not one of the choices.)

* $Q_2 = Q_1$ if both $Q_1 = Q_2 = 0$