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2 (a). MEB between free surfaces in Tank 1 and 2.

assume laminar flow

$$f = \frac{16}{Re} = \frac{16\mu}{\rho v d}$$

$$\frac{\Delta P}{\rho} + g\Delta z + \overset{0}{\cancel{\tfrac{1}{2}\Delta v^2}} + \overset{0}{\cancel{W_s}} + F = 0$$

$$\frac{(101.3 - 500) \times 10^3}{10^3} + 9.8(-47) + \frac{2 \times 16 \times 500 \times V}{10^3 \times (0.1)^2} = 0.$$

$V = 0.537$ m/s.

$Q = VA$

$= 4.22 \times 10^{-3}$ m^3/s.

assume fully turbulent

f_F (e/D) only

$$\frac{e}{D} = \frac{1}{100} = 0.01, \quad f_F = 0.009.$$

$$(101.3 - 500) + 3.7(-47) + 2 \times \frac{0.009 \times 500 \times V^2}{0.1} = 0$$

$V = 2.52$ m/s.

$Re = 3 \times 10^7$ ✓✓ good assumption

$Q = 0.02$ m^3/s.

(b) $P_2 - P_1 + 3.7(-47) = 0.$

$P_2 = 500 + 3.7 \times 47$

$= 673.9$ KPa.

(c) $$NPSH_A = \frac{(101.3 - 2) \times 10^3}{10^3 \times 3.7} + 3 - \frac{2 \times 0.01 \times 5 \times \left(\frac{0.01}{\pi \times 0.05^2/4}\right)^2}{0.05 \times 3.7}$$

$= 15.84$ m.

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2) d) $hs = \frac{P_1}{\rho g} + z_1 - h_{fs}$

$= \frac{101.3}{3.7} + 3 - \frac{2 \times 0.01 \times 5 \times \left(\frac{0.01}{\pi \times 0.05^2/4}\right)^2}{0.05 \times 3.7}$

$= 16.4 \text{ m}$

$hp = hd - hs.$

hp

$\cancel{\frac{\Delta P}{\rho g}}^{0} + \Delta z + \cancel{\frac{\Delta v^2}{g}}^{0} + \frac{Ws}{g} + F = 0$

$2 + \frac{Ws}{g} + \frac{2 \times 0.01 \times 8 \times}{0.05 \times 3.7}\left(\frac{0.01}{\pi \times 0.05^2/4}\right)^2 = 0$

$-\frac{Ws}{g} = 24.43 \text{ m}.$

$hp = 22.43 \text{m}$

$hd = hp + hs$

$= 40.8 \text{m}$

(e) $P_F = 40.8 \times 3.7 \times 1000 \times 0.01$

$= 1510$

$P_B = \frac{P_F}{0.65} = 2324 \text{ W}$

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3(a) $\Delta P = 1000 \times 9.8 (0.05 + 0.07 \times 13.6 - 0.03)$

$= 9525.6$

$P_2 = 9525 + 101300$

$= 110.826 Pa$

$= 110.826 \text{ kPa}$

(b) $h = L \sin\theta$

$\Delta P = \rho_m g h_m - \rho_w g h_w$

$\cancel{10^3} (110 - 101.3) = \cancel{1000} \times 9.8 (L \sin 20 \times 13.6 - 0.1)$

$L \sin 20 = 0.9877 \text{ m} / 13.6$

$L = 21.2 \text{ cm}$

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4(a) $\Sigma F = (200-800)\times 10^3 \times \frac{20}{100} \times 2\times 10^{-3}$

$= -120\ N$ (to the left)

$$\iiint_V \frac{\partial(\rho v)}{\partial t}\, \partial V + \iint_S \rho v v \cdot \hat{n}\, dS = \Sigma F$$

$$\Sigma F = \iint_S P \cdot \hat{n}\, dS$$

$$= \iint_{S_1} P_1 \cdot \hat{n}\, dS_1 + \iint_{S_2} P_2 \cdot \hat{n}\, dS_2$$

$$= -P_1 S_1 + P_2 S_2$$

where $S_1 = S_2$

$$= S_1 (P_2 - P_1)$$

(b) $\frac{\partial^2 V_x}{\partial y^2} = 0$

$\frac{\partial V_x}{\partial y} = C_1$

$V_x(y) = C_1 y + C_2$

$V_x(y=0) = 0$

$C_2 = 0$

$V_x(y=h) = 0.1$

$C_1 = \frac{0.1}{h}$

$V_x(y) = 0.1\,(y/h)$

$$\text{average} = \frac{\int_0^z \int_0^h V_x(y)\, dy\, dz}{zh}$$

$$= \frac{\int_0^z \left[\frac{0.1y^2}{2h}\right]_0^h dz}{zh}$$

$= 0.05\ m/s$

min $= 0$ and max $= 0.1\ m/s$

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6) (a) $$\frac{P_B^2 - P_J^2}{2 \times \frac{8.314 \times 293}{16\times10^{-3}}} + \left(\frac{1}{\frac{\pi \times 0.2^2}{4}}\right)^2 \left[\cancel{\ln\left(\frac{P_J}{733}\right)} + \frac{2\times 0.005 \times 10\times10^3}{0.2}\right] = 0$$

ignore

$$P_J = 831595 \text{ Pa}$$

(b) mass flow = 1 kg/s.

$$\frac{P_C^2 - P_J^2}{2\times \frac{8.314 \times 293}{16\times10^{-3}}} + \left(\frac{1}{\frac{\pi\times0.2^2}{4}}\right)^2 \left[\frac{2\times0.005\times10\times10^3}{0.2}\right] = 0$$

$$P_C = 733 \times 10^3$$

$$\rho_C = \frac{P_C}{RT/M} = \frac{733\times10^3}{\frac{8.314 \times 293}{16\times10^{-3}}} = 4.81 \text{ kg/m}^3$$

$$\frac{1}{\frac{\pi\times0.2^2}{4} \times 4.81} = 6.62 \text{ m/s}$$

(c) $$L_{min} = \frac{0.01}{4\times0.01}\left[\left(\frac{101.3}{1}\right)^2 - \ln(101.3)^2 - 1\right]$$

$$= \underline{2576 \text{ m}}$$ //

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7(a) $0.007 = \frac{1}{0.05} h^{2/3} \times 10 \times h \times \left(\frac{1}{\sqrt{200}}\right)$

$h^{5/3} = 0.00049$ m

$h = 0.0103$ m.

(b) $\frac{h_3}{h_2} = \frac{-1 + \sqrt{8 \times 36 + 1}}{2}$

$= 8$

$h_3 = 8 h_2$

$h_L = \frac{(h_3 - h_2)^3}{4 h_3 h_2} = \frac{(7 h_2)^3}{4 \times 8 h_2^2}$

$= \underline{10.718\, h_2}$ // $= \underline{0.162}$ m //

$Fr = \frac{u}{\sqrt{gh}}$

$6 = \frac{q/h}{\sqrt{gh}} = \frac{\frac{0.007}{0.2}}{\sqrt{9.8}\, h^{3/2}}$

$6 = \frac{0.035}{\sqrt{9.8}\, h^{3/2}}$

$h = 0.0151$

(c) No, channel height is not a function of pressure in open channel.

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8(a) $Bo \Rightarrow \frac{mg}{\varphi L} = 1$

$$\frac{50 \times g}{0.07 \times 0.4} = 1$$

$$g = \frac{0.4 \times 0.07}{50}$$

$$= 0.00056 \, m/s^2$$

(b) Reynolds

$$\frac{V_{model}}{V_{actual}} = 20$$

$$Re_M = Re_A$$

$$\frac{\rho V_1 L_1}{\mu} = \frac{\rho V_2 L_2}{\mu}$$

$$\frac{V_1}{V_2} = \frac{L_2}{L_1}$$

$$= \underline{20}$$