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Kang Yin Teng

CV1012 - FLUID MECHANICS SEM 2 AY 11/12

Date No.

Q1a) P_1 and P_2 experience the same shear stress,

$\Rightarrow \tau_1 = \tau_2$

$\Rightarrow \mu_1 \left(\frac{V_1}{y_1}\right) = \mu_2 \left(\frac{V_2}{y_2}\right)$

$(0.4)\left(\frac{V-3}{0.02}\right) = 0.2\left(\frac{V}{0.02}\right)$ } Relative velocity!

$20V - 60 = 10V$

$10V = 60$

$V = 6\ m/s$

Q1b) Pressure of air $= \rho g H$

$= (13600)(9.81)(0.16)$

$= 21346.56\ Pa.$

Pressure Gauge Measurement $= 21346.56 + (1000)(9.81)(4)$

$= 60586.56\ Pa.$

Q1c) $F_{V_1} = \rho g V = (1000)(9.81)(2 \times 2 \times 2) = 78480N$ at 1m from hinge.

$F_{V_2} = \rho g V = (1000)(9.81)(\frac{1}{4} \times \pi \times 2 \times 2 \times 2) = 61638.048$ at 1.15 from hinge.

$F_h = \rho g A h_c = (1000)(9.81)(2 \times 2)(1) = 39240N.$ acting at 1.333 m from hinge.

$I_c = \frac{1}{12}(2^4) = 1.333$ (3)

$\Delta y = \frac{I}{A y_c} = \frac{1.333}{2 \times 2 \times 1} = 0.333\ m.$

$\Sigma M = 0$

$(78480)(1) + (61638.048)(1.15) + 39240(1.333) = F(2)$

$\Rightarrow F = 100841.8\ N.$

Q1d) weight $= 7000\ kN. = \rho g V$

$= (1030)(9.81)(30)(8h - 12)$

$h = 4.39\ m.$

$\therefore$ dist from top $= 5 - 4.39$

$= 0.613\ m.$

$I_{yy} = \frac{1}{12}(30)(8^3) = 1280$

$V_1 = (1.39)(8)(30) + (\frac{1}{2})(8)(3)(30) = 693.6$

$BM = 1.85\ m.$

$\therefore$ For stable equilibrium $BM > BG$, $BG < 1.85m$

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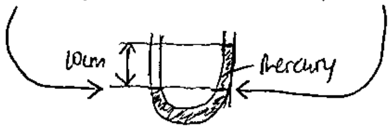
$P_1 + P_{water}(g)(0.1) = P_2 + P_{Hg}(g)(0.1)$



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2a) $P_1 - P_2 = \rho g H = (13600)(9.81)(0.1)$ $P_1 - P_2 =$
$= 13341.6$ Pa. 12360.6 Pa

$V_1 = \frac{Q}{A} = \frac{Q}{0.00785}$ ms^{-1} (A)
$V_2 = \frac{Q}{0.00196}$ ms^{-1} (B)

$P_1 - P_2 = \rho g \left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right)$

$13341.6 = 1000(9.81)\left[\frac{Q^2}{2g\,0.00196^2} - \frac{Q^2}{2g\,0.00785^2}\right]$

$Q = 0.0105\ m^3/s$

2b) By Continuity eqn, $Q_1 = Q_2$
$V_1(24) = V_2(0.4)$
$V_2 = 60V_1$ — (1)

By Bernoulli eqn, $\frac{V_1^2}{2g} + z = \frac{V_2^2}{2g} + z$
$\frac{V_1^2}{2g} + 6 = \frac{(60V_1)^2}{2g} + 0.1$
$\frac{3599V_1^2}{2g} = 5.9$
$V_1 = 0.179\ ms^{-1}$
$V_2 = 10.76\ ms^{-1}$

By momentum eqn, $F_{net} = M_{out} - M_{in}$
$F_1 - F - F_2 = M_{out} - M_{in}$
$(1000)(9.81)(24)(3) - F - (1000)(9.81)(0.4)(0.05) = (1000)(9.81)(10.76) - (1000)(9.81)(0.179)$
$F = 60234.19\ N$
$= 602\ kN$ (reaction force = equal in magnitude)

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Q3.a) $\Pi_1 = Q\, \mu^a g^b L_1^c$

$(L^3T^{-1})(ML^{-1}T^{-1})^a(LT^{-2})^b(L)^c = M^0L^0T^0$

$\Rightarrow a = 0$ ~ $M = 0$.

$\Rightarrow 3 - a + b + c = 0$

$\Rightarrow -1 - a - 2b = 0$

$b = -\frac{1}{2}$

$\Rightarrow c = -\frac{5}{2}$.

$\therefore \Pi_1 = \dfrac{Q}{g^{1/2} L_1^{5/2}}$

$\Pi_2 = \rho\, \mu^a g^b L_1^c$

$(ML^{-3})(ML^{-1}T^{-1})^a(LT^{-2})^b(L)^c = M^0L^0T^0$

$\Rightarrow 1 + a = 0 \Rightarrow a = -1$

$\Rightarrow -3 - a + b + c = 0 \Rightarrow b + c = 2$

$\Rightarrow -a + 2b = 0 \Rightarrow b = \frac{1}{2}$

$\Rightarrow c = \frac{3}{2}$

$\Pi_2 = \dfrac{\rho g^{1/2} L_1^{3/2}}{\mu}$

$\Pi_3 = L_2 \mu^a g^b L_1^c$

$(L)(ML^{-1}T^{-1})^a(LT^{-2})^b(L)^c = M^0L^0T^0$

$\Rightarrow a = 0$

$\Rightarrow 1 - a + b + c = 0 \Rightarrow b + c = -1$

$\Rightarrow -a - 2b = 0 \Rightarrow b = 0$.

$\Rightarrow c = -1$

$\Pi_3 = \dfrac{L_2}{L_1}$

$\Pi_1 = \phi(\Pi_2, \Pi_3)$

$$\frac{Q}{g^{1/2} L_1^{5/2}} = \phi\left(\frac{\rho g^{1/2} L_1^{3/2}}{\mu}, \frac{L_2}{L_1}\right)$$

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Not Sure

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3 b) $Q_{ave} = 1.4 \ m^3/s$

$\rho_{ave} = 900 \ kg\,m^{-3}$

$\mu_{ave} = 2600 \ kg/ms$

$g_{ave} = 9.81 \ m/s^2$

$L_{1ave} = 12.6 \ m$

$L_{2ave} = 6.3 \ m$

$$\pi_1 = \frac{Q}{g^{1/2} L_1^{5/2}} = 7.93 \times 10^{-4}$$

$$\pi_2 = \frac{\rho g^{1/2} L^{3/2}}{\mu} = 48.49$$

$$\pi_3 = \frac{L_2}{L_1} = 2$$

Estimate using π_1 $\Rightarrow$ $7.93 \times 10^{-4} (g^{1/2})(L^{5/2}) = Q$

$Q = 43.92 \ m^3/s$

3 c) Geometric Similarity: Similarity in length ratios

Dynamic Similarity: Similarity in Reynold's, Froude, Weber Number etc.

Kinematic Similarity: Ratio of velocity and acceleration between model and prototype constant through the flow field.

$$\frac{g_{moon}}{g_{earth}} = 0.1662$$

Using Dynamic Similarity: $Fr_e = Fr_m$

$$\frac{V_e}{\sqrt{g_e y_e}} = \frac{V_m}{\sqrt{g_m y_m}}$$

$$\frac{V_m}{V_e} = \frac{\sqrt{g_m y_m}}{\sqrt{g_e y_e}} = \frac{\sqrt{1.63 \times 1}}{\sqrt{9.81 \times 1}}$$

$V_m = 0.4076 \ V_e$

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4a) $p_1 \pi r^2 - (p_1 - \Delta p)\pi r^2 - \tau\, 2\pi r l = 0$

$\Delta p \,\cancel{\pi} r^{\cancel{2}} - 2\cancel{\pi}\cancel{r} l \tau = 0$

$\tau = \frac{\Delta p r}{2L}$ (shown)

4b) $\tau = \mu \left(\frac{du}{dy}\right)$

$\frac{\Delta p r}{2L} = \mu \left(\frac{du}{dy}\right)$

$du = -\left(\frac{\Delta p r}{2\mu L}\right) dr$

$u = -\int \frac{\Delta p r}{2\mu L} dr$

$= -\left(\frac{\Delta p r^2}{4\mu L} + c\right)$

when $r = R$, $U = 0$ at wall, $c = -\frac{\Delta p R^2}{4\mu l}$

$u = -\left(\frac{\Delta p r^2}{4\mu L} - \frac{\Delta p R^2}{4\mu l}\right)$

$= \frac{\Delta p R^2}{4\mu L}\left(1 - \left(\frac{r}{R}\right)^2\right)$ (shown).

4c) When $r = 0.04$, $V = 0.8$.

$0.8 = \frac{\Delta p\, 0.05^2}{4\mu L}\left(1 - \left(\frac{0.04}{0.05}\right)^2\right)$

$\frac{\Delta p}{4\mu l} = 888.89.$

At centerline, $r = 0$, $u = \frac{\Delta p R^2}{4\mu l} = (888.89)(0.05^2)$

$= 2.22\ ms^{-1}$

$V_{mean} = \frac{V_c}{2} = 1.11\ ms^{-1}.$

Not sure!

4d) Assuming uniform velocity,

$\tau = \mu \left(\frac{du}{dy}\right) = \mu \left(\frac{u}{y}\right).$

Assuming Q is constant.

$Q_1 = Q_2 \Rightarrow AV_1 = AV_2$

$\cancel{\pi}(0.05^2) V_1 = \cancel{\pi}(0.04^2) V_2$

$V_2 = 1.5625 V_1.$

$\frac{\tau_B}{\tau_C} = \frac{\cancel{\mu}\left(\frac{V}{y}\right)}{\cancel{\mu}\left(\frac{V}{y}\right)} = \frac{\left(\frac{\cancel{V_1}}{0.1}\right)}{\left(\frac{1.5625\cancel{V_1}}{0.08}\right)}$ ~~$= 0.512.$~~