AY2013/14 Semester 2

Yes, U Can!

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$g = 9.81 ms^{-2}$

1. a. $\mu = 0.38\ N.s\ m^{-2}$

$V = 1\ ms^{-1}$

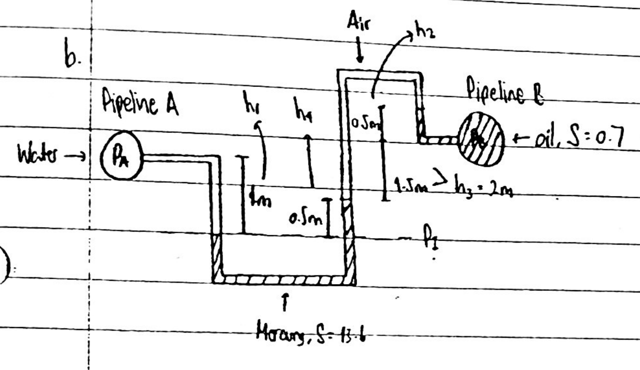
$y = \frac{1}{2}(4.5mm - 0.5mm) = 2 \times 10^{-3}\ m$ ← thickness of plate

$A = (0.2m)^2 = 0.04\ m^2$

- $\tau = \frac{F}{A} = 2 \cdot \mu \cdot \frac{V}{y}$ ← 2 stationary plates → double the friction

$\Leftrightarrow F = 15.2N$ ※

b.



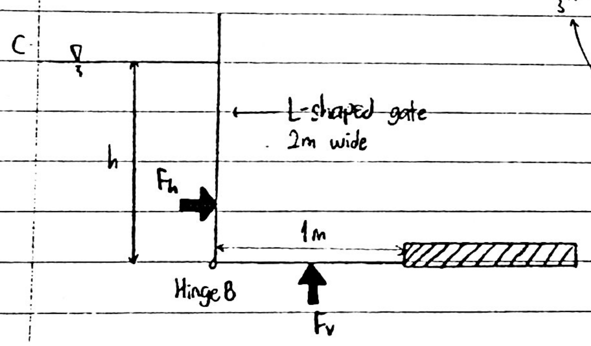
- $P_I = P_I$

$\Leftrightarrow P_A + \gamma_w \cdot h_1 = P_B - \gamma_o \cdot h_2 + \gamma_a \cdot h_3 + \gamma_m \cdot h_4$

$\Leftrightarrow P_A - P_B = -\gamma_o \cdot h_2 + \gamma_m \cdot h_4 - \gamma_w \cdot h_1$

$= 53{,}464.5\ Pa$ ※

c.



$h_{c,h} = \frac{1}{2}h$

$y_{c,h} = \frac{2}{3}h$ ← $\frac{1}{3}$ rule applies

$h_{c,v} = y_{c,v} = h$

$A_h = (2m) \cdot h$

$A_v = (2m)(1m)$

- $\Sigma \tau = 0$ ← about to topple down

$\Leftrightarrow F_v \times \frac{1}{3}h = F_v \times 0.5m$

$\Leftrightarrow \cancel{\gamma_w} \times A_h \times h_c \times \frac{1}{3}h = \cancel{\gamma_w} \times A_v \times h_v \times 0.5m$

$\Leftrightarrow \cancel{(2m)} \times h \times \frac{1}{2}h \times \frac{1}{3}h = \cancel{(2m)}(1m) \times h \times 0.5m$

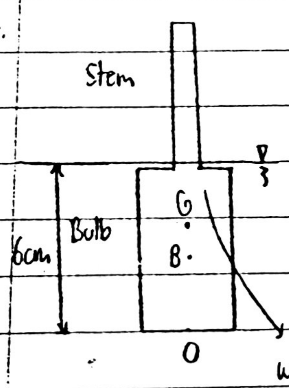
$\Leftrightarrow h^2 = 3m^2$

$\Leftrightarrow h \approx 1.732\ m$ ※

Assume that the gate door is weightless & volumeless.

no weight / no buoyancy force

d.



water acting through the stem

$\phi_1 = 10^{-2}\ m$

$\phi_2 = 2 \times 10^{-2}\ m$

$h = 6 \times 10^{-2}\ m$

$m = 4 \times 10^{-2}\ kg$

$OG = 4 \times 10^{-2}\ m$

ϕ_1 is used for I_{yy}.

- $\Sigma F = 0$

$\Leftrightarrow F_b = W$

$\Leftrightarrow \rho_{liquid} \cdot V_{bulb} = m \cdot g$

$\Leftrightarrow \rho_{liquid} = m \div V_{bulb}$

$\approx 2{,}122.066\ kg\ m^{-3}$ ※

- $OB = 3 \times 10^{-2}\ m$ ← homogeneous cylinder immersed → B is at centre of gravity of that cylinder. (not the whole chunk)

→ $BG = 10^{-2}\ m$

$BM \approx \frac{I_{yy}}{V_1} \approx 2.6042 \times 10^{-5}\ m < BG$

- Unstable Equilibrium

2\. a. i. $P_A = P_A$

$\Leftrightarrow P_1 + \cancel{\gamma_w y} + \gamma_m \times h = P_2 + \cancel{\gamma_w y} + \gamma_w \times h$

$\Leftrightarrow P_2 - P_1 = (\gamma_m - \gamma_w)\cdot h$

$= 6{,}180.3$ Pa.

remember this is water!

$\bullet\ \frac{P_1}{\gamma_w} + \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_2}{\gamma_w} + \frac{\overset{0}{V_2^2}}{2g} + \cancel{z_2}$

$\Leftrightarrow P_2 - P_1 = \frac{1}{2}\rho_w V_1^2$

$\Leftrightarrow V_1 \approx 3.515\ ms^{-1}$

$\bullet\ Q = A_1 \cdot V_1$

$\approx 0.442\ m^3 s^{-1}$

b. $\sum F_y = 0$

$\phi_1 = 10^{-1}\ m$

$V_1 = 30 ms^{-1}$

$\phi_2 = 4\times 10^{-2} m$

$V_2 = 30 ms^{-1}$

$\bullet\ \sum F_x = \dot{M}_{out} - \dot{M}_{in}$

$\Leftrightarrow -F = \rho_w A_2 \cdot V_2^2 - \rho_w \cdot A_1 \cdot V_1^2$

$\Leftrightarrow F \approx 5{,}937.610\ N$ ⋇

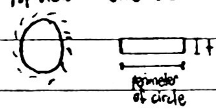
$\bullet\ Q_{loss,y} = Q_{in,x} - Q_{out,x}$

$\Leftrightarrow A_{loss} \cdot V_{out}' = A_1 \cdot V_1' - A_2 \cdot V_2'$

$\Leftrightarrow A_{loss} \approx 6.597\times 10^{-3}\ m^2$.

$A_{loss} = \text{Perimeter} \times t$ rectangular shape

$\Leftrightarrow h \approx 4.200$ mm. ⋇



3\. a. i. Because in order to satisfy both Reynolds and Froude numbers, both the prototype and model must use different liquids.

ii. $\bullet\ Fr_M = Fr_P$

$\Leftrightarrow \frac{V_m}{(g L_m)^{\frac{1}{2}}} = \frac{V_p}{(g \cdot L_p)^{\frac{1}{2}}}$

$\Leftrightarrow \frac{V_m}{V_p} = \left(\frac{L_m}{L_p}\right)^{\frac{1}{2}}$

$\bullet\ Re_M = Re_P$

$\Leftrightarrow \frac{V_M L_M}{\nu_M} = \frac{V_p \cdot L_p}{\nu_p}$

$\Leftrightarrow \frac{\nu_M}{\nu_p} = \frac{V_M \cdot L_M}{V_p \cdot L_p} = \left(\frac{L_M}{L_p}\right)^{\frac{3}{2}}$

open-channel flow → ~~water discharge from orifice to water tank.~~

b. $S_M = 1.3$

$\mu_w = 0.001\ Nsm^{-2}$

$Q_p = 0.005 m^3 s^{-1}$

$\frac{L_M}{L_p} = \frac{1}{10}$

i. By using Froude number, $\frac{V_M}{V_p} = \left(\frac{L_M}{L_p}\right)^{\frac{1}{2}}$.

$\hookrightarrow \frac{Q_M}{Q_p} = \frac{A_M \cdot V_M}{A_p \cdot V_p} = \left(\frac{L_M}{L_p}\right)^2 \cdot \left(\frac{L_M}{L_p}\right)^{\frac{1}{2}}$ ~~$\Leftrightarrow Q_M \approx 1.581\times 10^{-5}\ m^3 s^{-1}$.~~

Here, the assumption is the liquid used in both M&P is the same.

ii. $\frac{\mu_M}{\mu_p} = \frac{\rho_M}{\rho_p}\left(\frac{L_M}{L_p}\right)^{\frac{3}{2}}$ ~~$\Leftrightarrow \mu_M \approx 4.111\times 10^{-5}$~~

Yes, U Can!

c. $\frac{P}{\rho n^3 D^5} = f\left(\frac{Q}{n \cdot D^3}, \frac{gH}{n^2 D^2}\right)$ Meaning: A pretty straightforward question; do it by yourself.

d. $Q = 0.15\,m^3 s^{-1}$ $\rightarrow v \approx 2.122\,ms^{-1}$

$D = 0.3m$

$L = 300m$

$f = 0.02$

$\eta = 80\%$

$$\cdot \overset{0}{\frac{p_1}{\gamma_w}} + \overset{\approx 0}{\frac{V_1^2}{2g}} + z_1 + 0.5\frac{v^2}{2g} + h_p = \overset{0}{\frac{p_2}{\gamma_w}} + \overset{\approx 0}{\frac{V_2^2}{2g}} + z_2 + 1\cdot\frac{v^2}{2g} + \overset{h_L}{f\cdot\frac{L\cdot V^2}{2gD}}$$

$$\Leftrightarrow h_p = \left(1 - 0.5 + f\cdot\frac{L}{D}\right)\cdot\frac{v^2}{2g} + (z_1 - z_2)$$

$$\Leftrightarrow h_p \approx 24.705m$$

$\hookrightarrow \eta \cdot P_{supplied} = P_{needed} = \gamma_w \cdot Q \cdot h_p$

$\Leftrightarrow P_{supplied} \approx 45{,}441.759\,W$

$(\approx 45.441\,kW)$

4\. a. · Laminar flow → friction factor depends on Re but not $\frac{\varepsilon}{D}$.

· Transitional flow

· Smooth flow → friction factor depends on both Re and $\frac{\varepsilon}{D}$.

· Wholly turbulent flow → friction factor depends on Re but not $\frac{\varepsilon}{D}$.

b. $L = 100m$

$\phi = 0.1m$ $\rightarrow v \approx 1.273\,ms^{-1}$

$Q = 0.01\,m^3 s^{-1}$

$h_L = 5m$

$\varepsilon = 0$ (smooth pipe)

$h_L = f\cdot\frac{L\cdot v^2}{2\cdot g\cdot D} = 5m$

$\Leftrightarrow f \approx 0.0605$

$\hookrightarrow Re \approx 1000 \Rightarrow$ Laminar flow

Assumption(s) made:

· Flow is uniform, steady, ideal (inviscid) and developed.

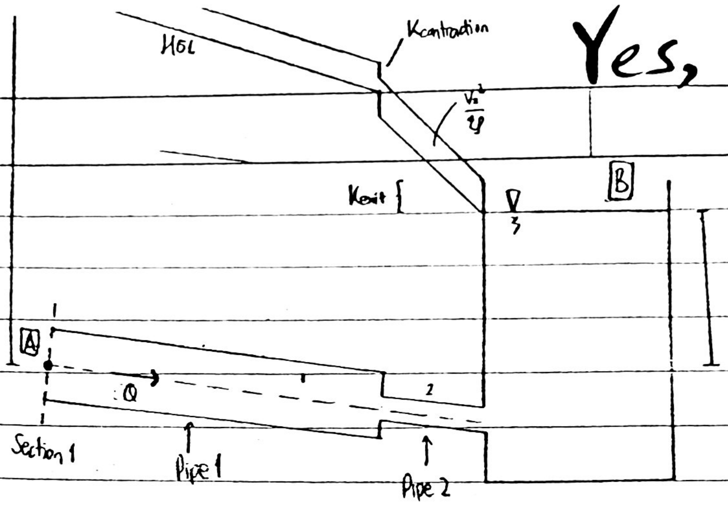
· Fluid is incompressible and continuous. (continuum hypothesis)

· Mass is conserved. (↳ may not be, check uncertainty principle in quantum mechanics.)

c. [On the next page]

ntusu

Yes, U Can!



→ steeper gradient line is ~~caused by the increase in~~ energy loss in pipe 2 due to an increase in velocity.
↓
since $f_1 \propto f_2$, $V_2 \uparrow$, $h_{L,2} \uparrow$.

c. $L_1 = 60m$
$\phi_1 = 0.3m$
$f_1 = 0.02$
$P_A = 17m$
$L_2 = 5m$
$\phi_2 = 0.1m$
$\varepsilon_2 = 10^{-4}m \rightarrow \frac{\varepsilon_2}{D_2} = 10^{-3}$
$K_{Lc} = 0.5$
$K_{Le} = 1.0$
$\nu_w = 10^{-6} m^2 s^{-1}$

i. • $A_1 V_1 = A_2 V_2$
$\Leftrightarrow V_2 = 9 V_1$

• $Re = \frac{V_2 \cdot L_2}{\nu_w}$

• $\frac{P_A}{\gamma_w} + \underset{V_A = V_1}{\frac{V_1^2}{2g}} + z_A = \frac{P_B}{\gamma_w} + \underset{0}{\frac{V_B^2}{2g}} + \underset{\approx 0}{z_B} + \underset{h_{L,1}}{f_1 \cdot \frac{L_1 \cdot V_1^2}{2gD_1}} + \underset{K_{contraction}}{0.5\frac{V_1^2}{2g}} + \underset{h_{L,2}}{f_2 \cdot \frac{L_2 \cdot V_2^2}{2gD_2}} + \underset{K_{exit}}{1 \cdot \frac{V_2^2}{2g}}$

$\Leftrightarrow 17m + (-8m) = \left(-1 + f_1 \cdot \frac{L_1}{D_1} + 0.5\right)\frac{V_1^2}{2g} + \left(f_2 \cdot \frac{L_2}{D_2} + 1\right) \cdot \frac{V_2^2}{2g}$

$\Leftrightarrow 9m = (3.5 + 4050 f_2 + 81) \cdot \frac{V_1^2}{2g}$

$\Leftrightarrow (84.5 + 4050 f_2) \cdot V_1^2 = 176.58 \, m^2 s^{-2}$

HAPPY ITERATING!