Name: Nasser Abbasi (UCI extension)

Course : MAE 91

Problem set : #1

Date : July 6, 2004

90/90

Problem 2.2

10/10

statment

we are given diagram of power plant and need to draw C.V. around it, listing flow of mass and energy into and out of the C.V.

see fig 1.1 and fig 1.2.

assumptions

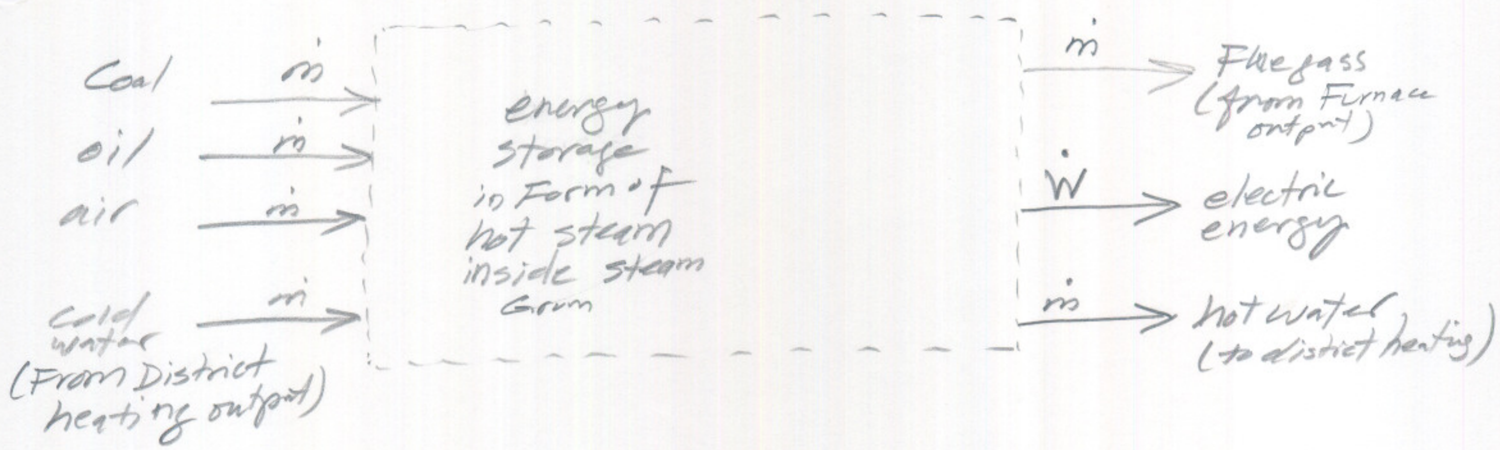
details of energy and mass flow inside C.V. are not shown. only input/out from CV are shown.

Laws used

rate of mass flow. ($\dot{m}$)

energy flow. (rate of power, or $\dot{W}$)

Steps



Numerical

N/A

problem 2.3

10/10

statment

we are given a schematic diagram of a shipboard nuclear propulsion system and need to make a C.V. for the system which includes inside it the steam flow around main turbin loop. need to identify mass flow ($\dot{m}$) and energy flow ($\dot{W}$) entering and leaving C.V.

assumptions

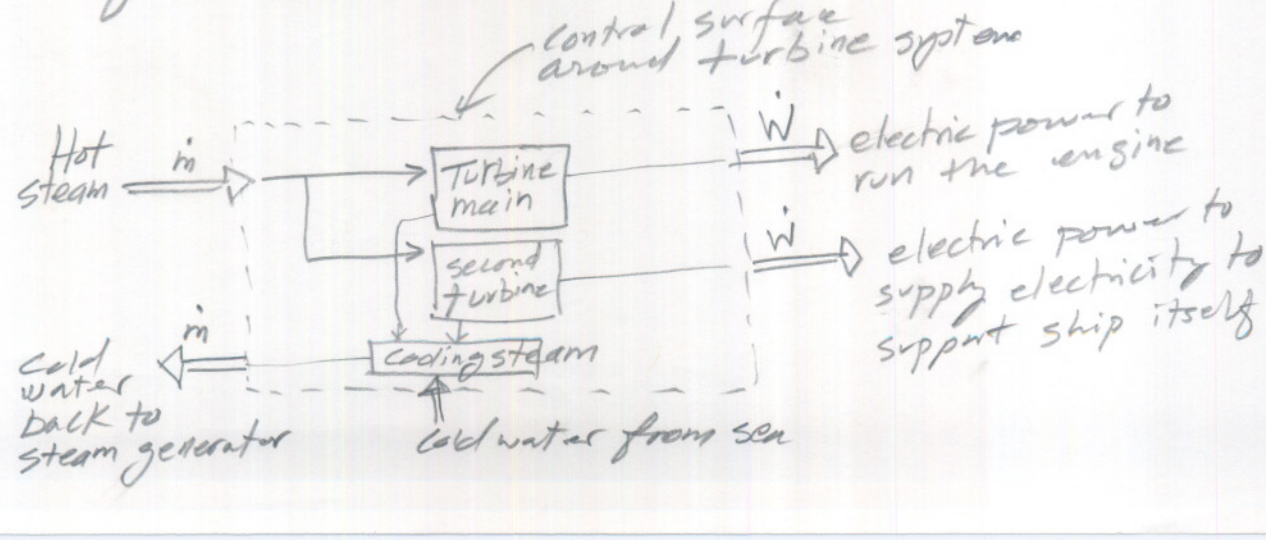
C.V. is around turbine system only

Laws used

rate of mass flow and rate of power flow.

steps

hot steam (generated by the steam generator) is send to 2 turbines. the main turbine, which is attached to the electric generator that runs the propulsion system. The second turbine is attached to an electric generator which supplies electric energy, but not clear from diagram what is the second turbine used for. I assume it generates electric power for internal use inside the ship/sub.



problem 2.4

10/10

statment

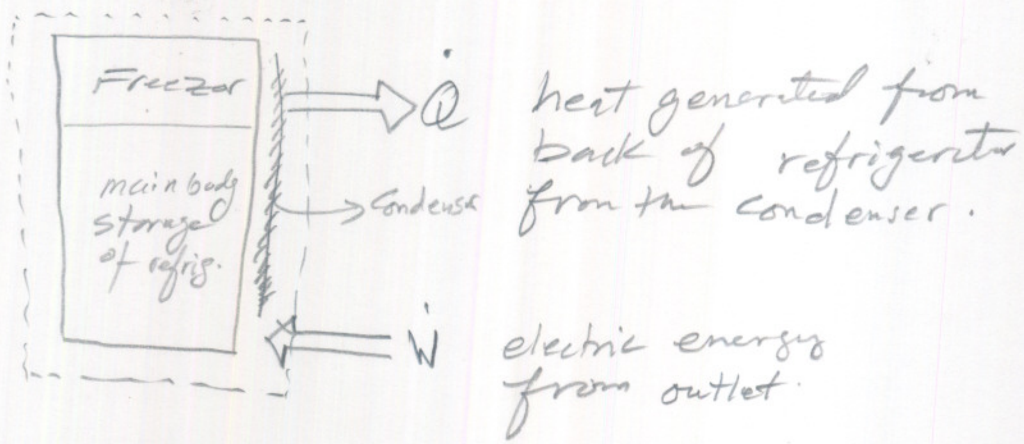
set a C.V. around Kitchen refrigerator. use fig 1.6.

assumptions

Laws used

mass flow = $\dot{m}$, energy flow = $\dot{W}$, heat flow rate = $\dot{Q}$

steps



Numerical

N/A

Please note: Fig 1.6 was missing from your web site and I did not have the book yet (was not in book store last time I visited it, and book store closed now). so solution above might not be as detailed as required.

problem 2.24

10/10

an apple has "weight" of 80 grams, Volume of 100 cm³ in a refrigerator at 8°c. asked to find apple density and list 3 intensive properties and 2 extensive properties.

assumptions

Volume of apple changes by Temp. is negligibal. so Can assume V remains 100 cm³ at 8°c.

Laws

$$\rho = \frac{m}{V} \quad , \quad v = \frac{1}{\rho}$$

intensive property does not depend on mass.
extensive property depends on mass.

steps

$$\rho = \frac{m}{V}$$

intensive properties: ρ, T, v
extensive properties: m, V

Numerical

$$\rho = \frac{m}{V} = \frac{80 (\text{grams})}{100 (cm^3)} = \frac{0.08 (Kg)}{10^{-4} (m^3)} = 800 \left(Kg/m^3\right).$$

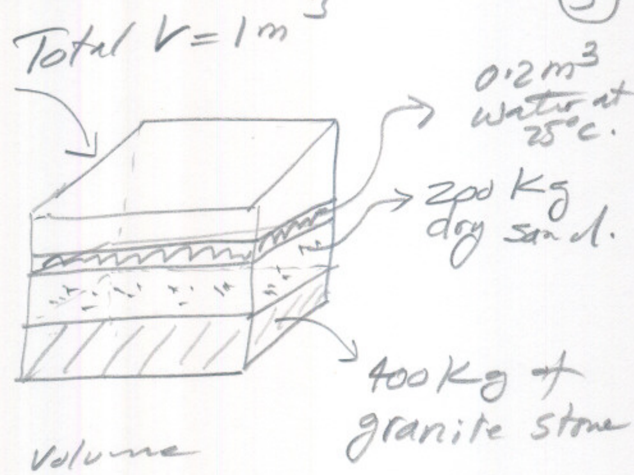
intensive: $\rho = 800\ Kg/m^2$, $T = 8°c$, $v = \frac{1}{\rho} = 0.00125 \frac{m^3}{Kg}$.

extensive: $m = 0.08\ Kg$.

$$V = 100\ cm^3 = 10^{-4}\ m^2.$$

problem 2.41

10/10



we are given a $1\,m^3$ container. it contains 400 kg of granite stone, 200 kg dry sand, $0.2\,m^3$ water at 25°c, and rest is air.
Need to find average speific volume and density of the $1\,m^3$ container.

assumptions

all substances are at 25°c.

$\rho_{air} = 1.1\ kg/m^3$

Laws

$$\rho = \frac{m}{V} \quad , \quad v = \frac{1}{\rho}$$

steps

$$\text{average speific Volume} = \frac{\text{Total Volume}}{\text{Total mass}} = \frac{V_T}{m_T}$$

but V_T is given. so need to find m_T.

m_T = mass of granite + mass of dry sand + mass of water + mass of air.

$$= m_g + m_s + m_w + m_a$$

$$= m_g + m_s + \rho_w V_w + \rho_a V_a \quad \text{——— (1)}$$

but $V_a = V_T - (V_g + V_s + V_w)$

$$= V_T - \left(\frac{m_g}{\rho_g} + \frac{m_s}{\rho_s} + V_w\right) \quad \text{——— (2)}$$

from (1) and (2)

$$m_T = m_g + m_s + \rho_w V_w + \rho_a \left(V_T - \left(\frac{m_g}{\rho_g} + \frac{m_s}{\rho_s} + V_w\right)\right)$$

→

Numerical

From Table A.4

$\rho_w = 997 \ \text{kg/m}^3$

From Table A.3

$\rho_g = 2750 \ \text{kg/m}^3$

$\rho_s = 1500 \ \text{kg/m}^3$

hence average $v = \frac{V_T}{m_T} = \dfrac{V_T}{m_g + m_s + \rho_w V_w + \rho_a \left(V_T - \left(\frac{m_g}{\rho_g} + \frac{m_s}{\rho_s} + V_w\right)\right)}$

but $V_T = 1 \ m^3$

$m_g = 400 \ \text{kg}$

$m_s = 200 \ \text{kg}$

$V_w = 0.2 \ m^3$

hence

$$\text{average } v = \frac{1}{400 + 200 + (997)(0.2) + 1.1\left(1 - \left(\frac{400}{2750} + \frac{200}{1500} + 0.2\right)\right)}$$

$$= \frac{1}{799.4 + 1.1\left(1 - (0.1455 + 0.133 + 0.2)\right)}$$

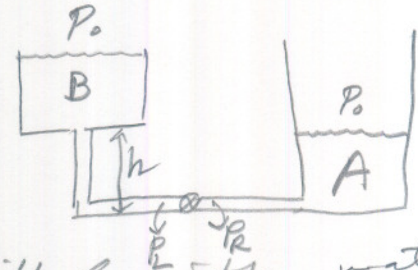
$$= \frac{1}{799.4 + 1.1(0.32)} = \boxed{0.00125 \ \frac{m^3}{kg}}$$

So average $\rho = \frac{1}{\text{average } v} = \frac{1}{0.00125} = \boxed{800 \ \frac{kg}{m^3}}$

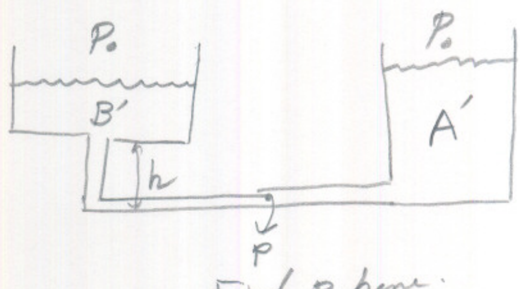
problem 2.76 10/10

statment

initial state of system:



2 cylinders B and A are filled with water.
$\rho = 1000\ kg/m^3$. A has 100 kg and B has 500 kg.
cross sectional areas are $A_A = 0.1\ m^2$, $A_B = 0.25\ m^2$.
$h = 1\ m$. need to find pressure at each side of the valve. call it P_L and P_R.
now, open valve. water flows to an equilibrium, need to find pressure at valve location:



assumptions:

Laws

$P = \frac{F}{A}$ (pressure $= \frac{\text{Force}}{\text{cross sectional area}}$)

Pressure due to a column of water of hight h is $\rho_w g h$.

$W = mg$ (weight = mass x gravitional acc.).

Conservation of mass.

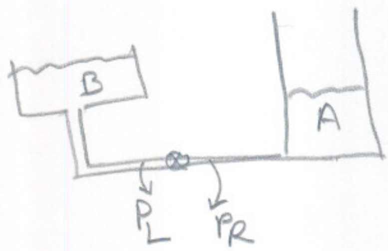
steps

$\longrightarrow$

in initial state, we need to find P_L and P_R.

$P_L = P_0 +$ Pressure due to water mass B + Pressure due to column water h.

$$= P_0 + \frac{\text{Weight of B water}}{A_B} + \rho g h$$

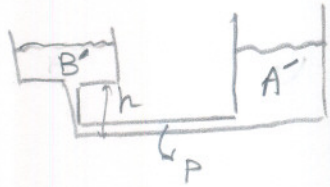


$$\boxed{P_L = P_0 + \frac{m_B g}{A_B} + \rho g h} \quad \text{——— (1)}$$

$P_R = P_0 +$ Pressure due to water mass A.

$$\boxed{P_R = P_0 + \frac{m_A g}{A_A}} \quad \text{——— (2)}$$

now open valve. we have same pressure on both sides of where valve was.



i.e $P_L = P_R = P$

i.e $$\frac{m_{B'} g}{A_B} + \rho g h = \frac{m_{A'} g}{A_A} \quad \text{——— (3)}$$

and any water flow from B to A, or from A to B will keep same total mass as before. (conservation of mass).

i.e $$m_{B'} + m_{A'} = m_B + m_A \quad \text{——— (4)}$$

so we have 2 equations, (3) and (4) with 2 unknowns, m_B' and m_A'. we solve for m_B' and m_A'

and then find $\boxed{P = \frac{m_A' g}{A_A}}$

⟶

hence from 4, $m_{B'} = m_B + m_A - m_{A'}$

substitute into 3, we get

$$\frac{(m_B + m_A - m_{A'})\,g}{A_B} + \rho g h = \frac{m_{A'}\,g}{A_A}.$$

$$\frac{m_B g + m_A g - m_{A'} g}{A_B} + \rho g h = \frac{m_{A'} g}{A_A}.$$

$$A_A m_B g + A_A m_A g - A_A m_{A'} g + A_B \rho g h A_A = A_B m_{A'} g$$

$$\boxed{m_{A'} = \frac{A_A m_B g + A_A m_A g + A_B A_A \rho g h}{(A_B + A_A)\,g}}$$

so $P = \dfrac{m_{A'} g}{A_A}$ (from RHS of 4).

hence $P = \dfrac{\dfrac{\cancel{A_A} m_B g + \cancel{A_A} m_A g + A_B \cancel{A_A} \rho g h}{(A_A + A_B)\cancel{g}}\,g}{\cancel{A_A}}$

gauge pressure

$$\boxed{P_g = \frac{g}{A_A + A_B}(m_B + m_A + A_B \rho h)}$$

so absolute $\boxed{P = P_g + P_0}$ —— 6

<u>Numerical</u>

→

$A_A = 0.1\ m$

$A_B = 0.25\ m^2$

$m_B = 500\ kg$

$m_A = 100\ kg$

$g = 9.81\ m/s^2$

$\rho = 1000\ kg/m^3$

$P_o = 101325\ Pa$

from equation (1) $P_{Left} = P_o + \frac{m_B g}{A_B} + \rho g h$

$$= 101325 + \frac{(500)(9.81)}{0.25} + 1000(9.81)(1)$$

$$= \boxed{130,755\ Pa}$$

from (2) $P_{Right} = P_o + \frac{m_A g}{A_A}$

$$= 101325 + \frac{(100)(9.81)}{0.1} = \boxed{111,135\ Pa}$$

after valve is open.

from (5)

$$P = \frac{g}{(A_A + A_B)}(m_B + m_A + A_B \rho h) + P_o$$

$$= \frac{(9.81)}{(0.1 + 0.25)}\left(500 + 100 + (0.25)(1000)(1)\right) + 101325$$

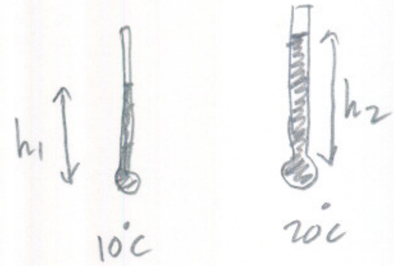
$$= \boxed{125,149.28\ Pa}$$

Problem 2.78

10/10

statment we are asked to find relative change in volume in mercury due to change in temp. from 10°c to 20°c.

So initial state is at 10°c
final state is at 20°c.



assumptions.

P_0 is same at 10°c and 20°c.
i.e ΔP is same at initial and final state.

Laws

density of mercury changes according to

$$\boxed{\rho_{Hg} = 13.595 - 2.5\,T} \quad \text{—— } 0$$

$$\rho g h = \Delta P$$

steps

since ΔP did not change. we can find the change in h between 10°c and 20°c. this gives the relative change in volume.

$$\text{i.e \% relative change in Volume} = \boxed{\frac{h_2 - h_1}{h_1} \times 100} \quad \text{—— } 1$$

where h_2 = hight at 20°c.
h_1 = hight at 10°c.

let ρ_2 = density at 20°c.
let ρ_1 = density at 10°c.

⟶

hence

$$\rho_1 g h_1 = \Delta P$$

$$\rho_2 g h_2 = \Delta P.$$

so $\rho_1 h_1 = \rho_2 h_2$.

so $$\boxed{h_2 = \frac{\rho_1 h_1}{\rho_2}} \text{ ——— } (2)$$

sub (2) into (1).

$$\% \text{ Volume change} = \frac{\frac{\rho_1 h_1}{\rho_2} - h_1}{h_1} (100)$$

$$\boxed{\% \text{ V change} = \left(\frac{\rho_1}{\rho_2} - 1 \right) 100} \text{ ——— } (3)$$

Numerical

From (3) and (0)

$$\% \text{ Volume change} = \left[\left(\frac{13.595 - 2.5(10)}{13.595 - 2.5(20)} \right) - 1 \right] 100$$

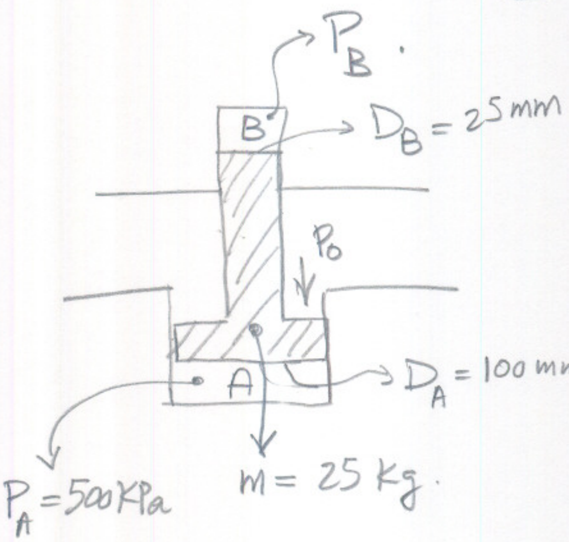
$$= \left(\frac{13570}{13545} - 1 \right) 100 = \boxed{0.18\ \%}$$

Problem 2.85

10/10

Two cylinders connected by piston of mass 25 Kg

cylinder A used as hydraulic left, $P_A = 500\ KPa$. need to find gas pressure in B.



Assumptions

—

Laws

$P = \frac{F}{A}$, weight = mass × grvity = mg.

$$Area = \pi r^2 = \pi \left(\frac{D}{2}\right)^2 = \frac{\pi}{4} D^2$$

steps

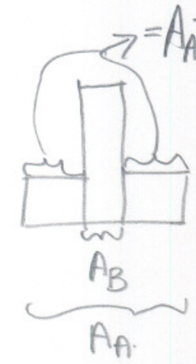
doing a Free body diagram, and looking at Forces in Vertical axis, we set

$\downarrow P_B A_B$

$\downarrow mg$

$\downarrow P_0 (A_A - A_B)$

$\uparrow P_A A_A$



"notice that Force due to P_0 is only due to acting on area of piston exposed to P_0."

hence $P_B A_B + mg + P_0 (A_A - A_B) = P_A A_A$

or $\boxed{P_B = \frac{P_A A_A - mg - P_0 (A_A - A_B)}{A_B}}$ — (1)

→

<u>numerical</u>

$P_A = 500 \times 10^3$ Pa

$A_A = \frac{\pi}{4} D_A^2 = \frac{\pi}{4} (100 \times 10^{-3})^2 = \frac{\pi}{4} (0.1)^2$

$A_B = \frac{\pi}{4} D_B^2 = \frac{\pi}{4} (25 \times 10^{-3})^2 = \frac{\pi}{4} (0.025)^2$

$m = 25$ kg.

$P_o = 101325$ Pa

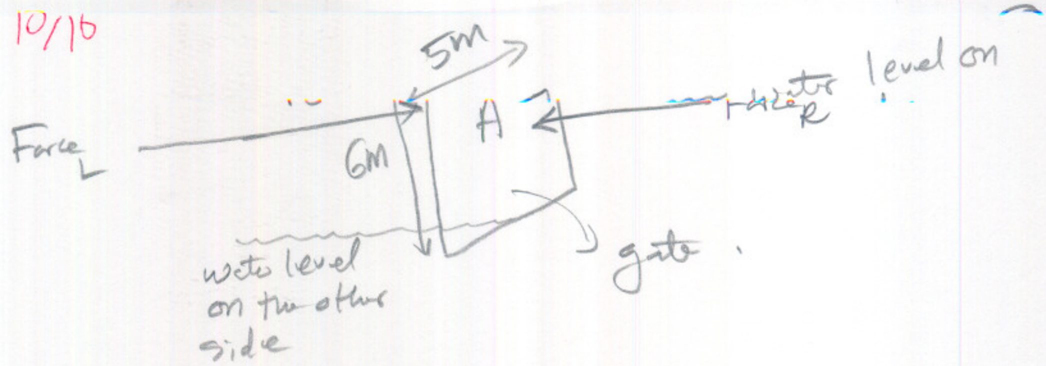
so from (1) we get

$$P_B = \frac{(500 \times 10^3)\left(\frac{\pi}{4}(0.1)^2\right) - 25 \times 9.81 - 101325\left(\frac{\pi}{4} 0.1^2 - \frac{\pi}{4} 0.025^2\right)}{\frac{\pi}{4} 0.025^2}$$

$$= \frac{2935 \ (N)}{0.000491 \ (m^2)} = 5{,}977{,}596.7 \text{ Pa}$$

so $\boxed{P_B \simeq 6 \text{ MPa}}$

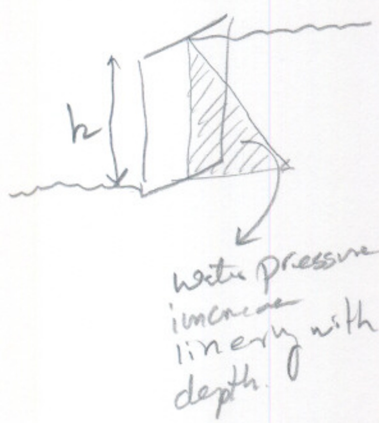
Problem 2.86 10/10



a gate of area A $(5 \times 6 \ m^2)$. on one side, water has pressure on wall. on the other side, we have air pressure. need to find net horizontal Force on gate.

assumptions
Pressure on gate increases linearly with depth. Pressure on right side (water side) is
So average pressure
$P_0 + \rho g \frac{h}{2}$

Laws
Pressure due to a column h of water $= \rho g h$.
Net Force on gate $= F_R - F_L$
$P = \frac{F}{A}$



Steps
Net Force $= F_R - F_L$

$$\boxed{\begin{aligned} \text{Net Force} &= \left(P_0 + \rho g \tfrac{h}{2}\right)A - P_0 A \\ &= \rho g \tfrac{h}{2} A \end{aligned}}$$

Numerical
$\rho = 997 \ kg/m^3$, $A = 5 \times 6 = 30 \ m^2$, $h = 6m$ $\Longrightarrow$ Net Force $= (997)(9.81)\left(\frac{6}{2}\right)(30) = \boxed{880{,}251 \ N}$