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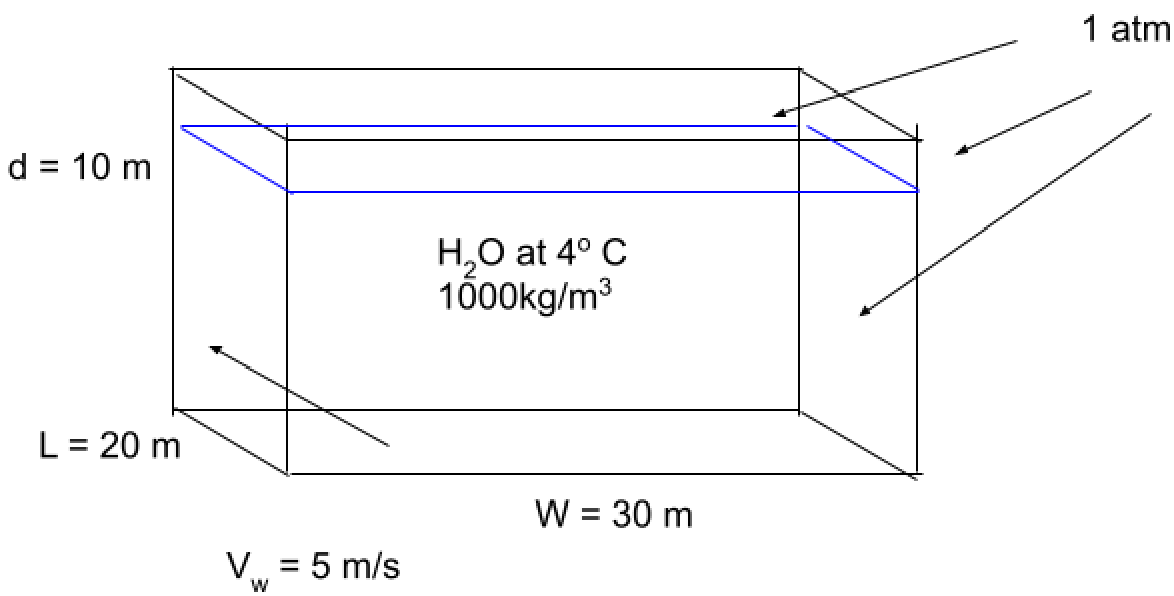
PH 212

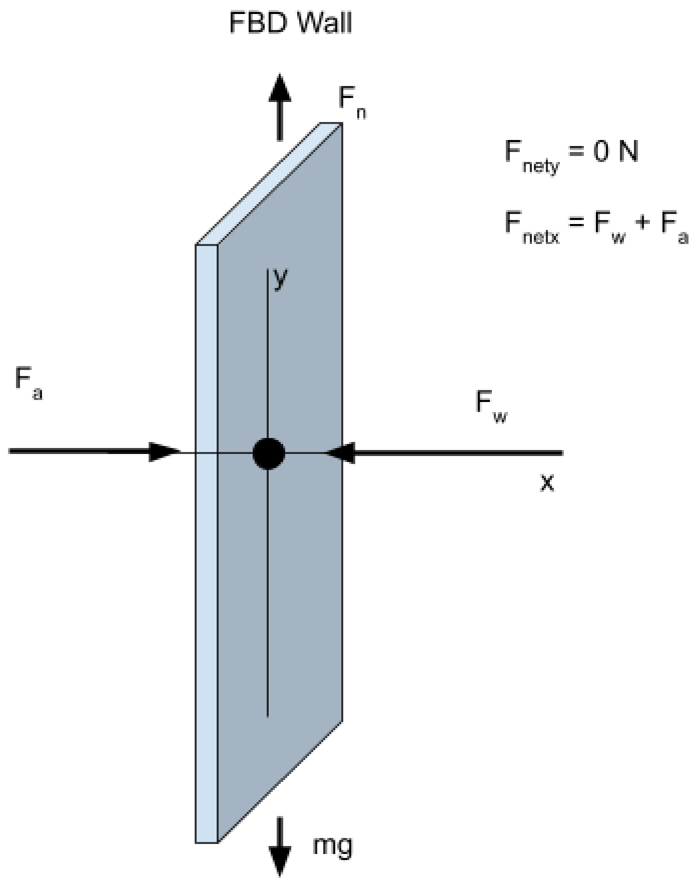
HIP 4

A very large aquarium 10.0 meters deep, 20.0 meters wide and 30.0 meters long and is filled with fresh water at 4ºC. A wind is blowing parallel to the 20-meter wall at a speed of 5.0meters per second. Where the wind isn't blowing, the air pressure is exactly 1.0atm.

Find the net force against the 20-meter wall.



To begin this problem we must draw a free body diagram of the wall and identify the forces acting upon it.



The assumption is made that $F_w > F_a$ and since they are acting in opposite directions, we expect there to be a F_{net} in the direction of F_w.

Since the wall is experiencing a differential pressure gradient on the wall by the water.

To find this we must recall that $F = \int dF$

Let's redefine dF in terms of dy (y being the depth of the fluid)

$dF = P_w*dA \rightarrow dA = L\ dy;\ P_w = P_{atm}+\rho_w*g*y \rightarrow dF = (P_{atm}+ \rho_w*g*y)\ L\ dy$

We can now substitute this into our force equation.

$F_w = \int (P_{atm}+ \rho_w*g*y)\ L\ dy \rightarrow F_w = \int P_{atm}L+ \rho_w*g*y*L\ \ dy \rightarrow$

$F_w = P_{atm}*L*y+ 1/2\rho_w*g*y^2*L\ \Big|_0^d \rightarrow$ $F_w = P_{atm}*L*d+ 1/2\rho_w*g*d^2*L$

This force will be negative, since in our example it is pointing in the negative x direction.

Now we have to find the force caused by the air pressure on the wall. For this we will use Bernoulli's equation $P_1 + 1/2\rho_f{*}v_1^2 + \rho_f{*}g{*}h_1 = P_2 + 1/2\rho_f{*}v_2^2 + \rho_f{*}g{*}h_2$

We know that P_1 = 101300 Pa (1 atm) and v_1 = 0 m/s and since there is no change in height both height dependant functions will equal each other, and cancel out, we are left with $P_1 = P_2 + 1/2\rho_f{*}v_2^2$

Solve for $P_2 \rightarrow P_2 = P_1 - 1/2\rho_f{*}v_2^2$

Now that we have the pressure of the moving air we can us F = P*A to find the force of the air on the wall.

$F_a = (P_{atm} - 1/2\rho_f{*}v_2^2){*}(L{*}d) \rightarrow F_a = P_{atm}{*}L{*}d - 1/2\rho_f{*}v_2^2{*}L{*}d$

This force will be positive since in this example it is pointing in the positive x direction.

Now that we know the force caused by the water and force caused by the air we can solve for F_{netx}.

$F_{netx} = F_w + F_a \rightarrow F_{netx} = -(P_{atm}{*}L{*}d + 1/2\rho_w{*}g{*}d^2{*}L) + (P_{atm}{*}L{*}d - 1/2\rho_f{*}v_2^2{*}L{*}d)$ → The force due to atmospheric pressures cancel out → $F_{netx} = -1/2\rho_w{*}g{*}d^2{*}L + 1/2\rho_f{*}v_2^2{*}L{*}d$ → F_{netx} = -9813062.5 N → $|F_{netx}| = 9.83 \times 10^6$ N

This force is acting from the inside acting against the wall. If we use the equation to find the pressure and then the force at depth 10, 9, 8, 7, … and so on and add them together we will get an approximation of the force caused just by the depth in the fluid. When this is done we find that the force is in the same order of magnitude, it is then reasonable to conclude that this answer is accurate. Also when doing a unit check, the units come out to be kg*m/s^2 which is a Newton.

SciLab code of calculations:

```
//HIP 4
clear
clc

P_atm=101300 //Pa
rho_w=1000 //kg/m^3
rho_a=1.225 //kg/m^3
g=9.81 //m/s^2
L=20 //m
d=10 //m
v_a=5 //m/s

F_w = -((P_atm*L*d)+(.5*rho_w*g*d^2*L)) //N
F_a = ((P_atm*L*d)-(.5*rho_a*v_a^2*L*d)) //N
F_net = F_w + F_a

printf("Magnitude of Net Force of air and water on wall: %5.3f N \n", F_net*-1)
```

Lecture Time: Name:

CATEGORY	EXEMPLARY (1.5)	ACCOMPLISHED (1)	DEVELOPING (0.5)	EMERGENT (0)
Problem Statement and Introduction	A new learning tool for our class is written	The problem is clearly presented for reader in your own words.	The problem is directly copied or is hard to follow.	You jump into some calculation
Picture	Your sketch could be dropped into a graphic novel as it stands.	There is a clear sketch, larger than a credit card, of the problem set up with important features and data noted	There is some sketch of the problem setup	What sketch?
Physics Tools	Appropriate physics tools are correlated to the exercise in textbook quality and size	Appropriate physics tools are correlated to the exercise. Appropriate tools include: pictures, FBDs, conservational laws utilized, etc...	Some physics tools are correlated to the exercise.	There are a few equations written.
Problem Solution Presentation	Solution is very clearly presented with intriguing asides or annotations	Solution is complete and clearly presented making no significant intuitive demands on the reader.	In your solution I have to read between the lines	Cliff notes version of solution with only high points present
Form	Your solution can serve as solution manual.	Drawing is larger than a credit card, organization is fluid, notation used is clear.	I could figure the path of your solution with effort.	You can read it.
Units		All units correctly given	Calculations & quantities are presented with units	Some units at the results
Solution		Correct	You are close	None/Not reasonable
Significant Figures		Correct Sig Figs	Makes effort to use correct significant figures	Copies the number from the calculator
Reasonableness	Provides more than one type of Reasonableness check.	Gives one clear rationale for appropriateness of the solution in the setting	Asserts that the answer is reasonable but really hasn't given any evidence	No discussion
All Self Graded		Done	Not Done	Done, but your self-assessment is different from mine by at least two steps.