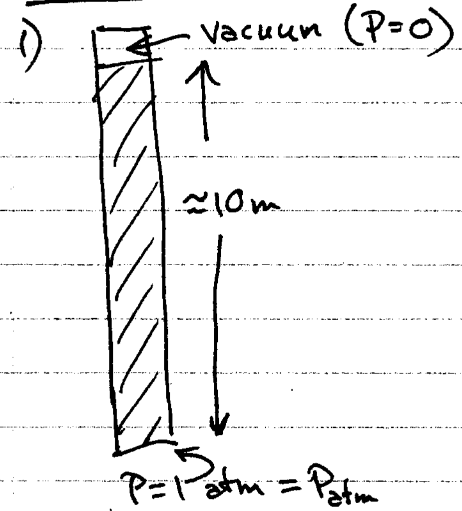
Phys 132 – HW – Unit I – Solutions

Session 1

1)



Let's call tube area A.

The force down on the bottom of the column of water is the weight $mg = \rho V g$

density ↑ ↑ Volume

$$\rho = 1\ \text{g/cm}^3 \cdot \left(\frac{1\text{kg}}{10^3\text{g}}\right)\left(\frac{100\text{cm}}{1\text{m}}\right)^3 = 10^3\ \text{kg/m}^3$$

$$V = h \cdot A = 10\text{m} \cdot A$$

The force up is provided by atmospheric pressure: $F_{up} = P_{atm} \cdot A$. Since water is at rest, $|F_{up}| = |F_{down}| \Rightarrow P_{atm} \cdot A = \rho g h A$

$$\text{So } P_{atm} = \rho g h \approx 10^3\ \text{kg/m}^3 \cdot 10\ \text{m/s}^2 \cdot 10\text{m}$$

$$= 10^5\ \text{Pa}$$

2) P (above 1 atm) at 20m should be 2× P (above 1 atm) at 10m, which we know from 1 is about 1 atm ≈ 10^5 Pa. So $P_{20m} = \rho g h = 10^3\ \text{kg/m}^3 \cdot 10\ \text{m/s}^2 \cdot 20\text{m}$

$$= 2 \times 10^5\ \text{Pa}$$

In salt water, $P_{20m} = \rho g h = 1.1 \times 10^3\ \text{kg/m}^3 \cdot 10\ \text{m/s}^2 \cdot 20\text{m} = 2.2 \times 10^5\ \text{Pa}$

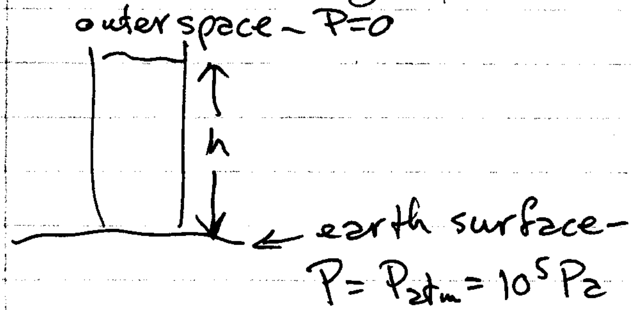
[All of these P's are pressures above 1 atm, or you may simply add 1.0×10^5 Pa to each value]

Solutions

I.1

3) We are given $\rho_{air} \approx \frac{\rho_{water}}{10^3} \approx 1\ \mathrm{kg}/\mathrm{m}^3$.

So - how high is atmosphere?



$$P_{atm} = \rho g h$$

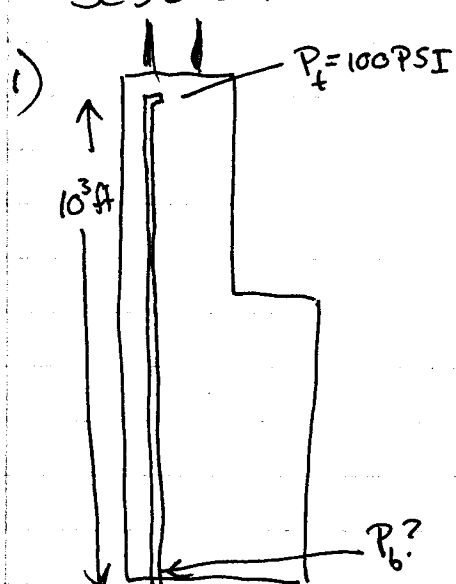
$$10^5\ \mathrm{Pa} = 1\ \mathrm{kg}/\mathrm{m}^3 \cdot 10\ \mathrm{m}/\mathrm{s}^2 \cdot h$$

So $h = 10^4\ \mathrm{m}$.

In actuality, the density of air decreases as you go up - ρ is a decreasing exponential function of height (roughly) - and the characteristic length is about $10^4\ \mathrm{m}$ - so $P_{10^4 m} \approx P_{atm}/3$

Session 2

1)



$$h = 10^3\ \mathrm{ft}\left(\frac{12\ \mathrm{in}}{1\ \mathrm{ft}}\right)\left(\frac{2.54\ \mathrm{cm}}{1\ \mathrm{in}}\right)\left(\frac{1\ \mathrm{m}}{100\ \mathrm{cm}}\right) = 305\ \mathrm{m}$$

$$P_t = 100\ \mathrm{PSI}\left(\frac{10^5\ \mathrm{Pa}}{14.7\ \mathrm{PSI}}\right) = 6.8\times10^5\ \mathrm{Pa}$$

Use $P_t + \rho g h_t = P_b + \cancel{\rho g h_b}^{\,0}$

$$P_b = 6.8\times10^5\ \mathrm{Pa} + 10^3\ \frac{\mathrm{kg}}{\mathrm{m}^3}\cdot 10\ \mathrm{m}/\mathrm{s}^2 \cdot 305\ \mathrm{m}$$

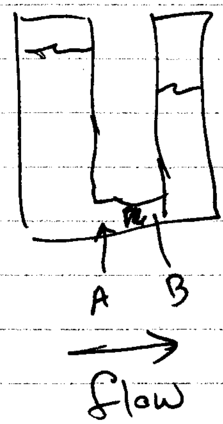
$$= 3.7\times10^7\ \mathrm{Pa}$$

(I assumed 100 PSI included 1 atm of atmos pressure ~ not obvious in problem)

Solutions

I.2

2) Pressure is higher at point A, since water column is higher on the left.



Since we assume capillary connection dominated by viscosity, we know flow must be to the right

3) Now, cylinders have different contents:

$$\rho_L = 1.1\times10^3\ kg/m^3 \qquad \rho_R = 1\times10^3\ kg/m^3$$

~~So if~~ If heights are initially the same,

$$P_A = \rho_L g h \qquad P_B = \rho_R g h, \quad \text{so} \quad P_A = 1.1\times P_B.$$

So, fluid will ~~flow~~ flow from left (salt) to right (fresh). This will continue until $P_A = P_B$, or

$$\rho_L g h_L = \rho_R g h_R, \quad \text{or} \quad h_R = \frac{\rho_L}{\rho_R} h_L = 1.1 h_L$$

assuming densities don't change appreciably from mixing a little bit of salt water over to the right. (Our answer is off about 10% because of this – should be more like $h_R = 1.09 h_L$ – but I didn't want you to worry about this.)

Solutions I.3

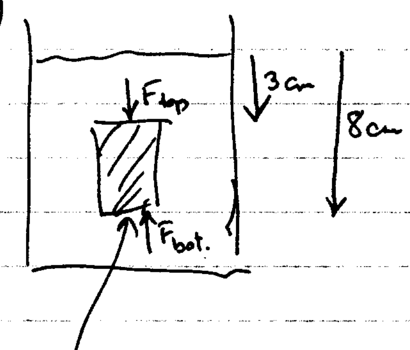
Session 3

1) a) $T_{crossing} = d/v = \dfrac{10^{-2}\,m}{300\,m/s} = 3.3\times10^{-5}\,sec$

b) $\text{Rate of hits} = \dfrac{\#\,hits}{\text{time per hits}} = \dfrac{3\times10^{19}}{3.3\times10^{-5}\,sec} = 9\times10^{23}\,hits/sec$

No chance of observing individual hits at this rate!!

2)



$A = \pi(.02m)^2$

a) $F_{top} = P_t \cdot A = (1\,atm + \rho g h_{top})A$

$= (10^5\,Pa + 10^3\,kg/m^3 \cdot 10\,m/s^2 \cdot .03\,m)A$

b) $F_{bottom} = P_b \cdot A = (10^5\,Pa + 10^3\,kg/m^3 \cdot 10\,m/s^2 \cdot .08\,m)A$

c) $F_{net} = F_{bottom} - F_{top}$

$$= (P_b - P_t)A = \Big[\underbrace{(10^5\,Pa - 10^5\,Pa)}_{\text{atmosphere terms}} + (\rho g h_{bot} - \rho g h_{top})\Big]A$$

$= 10^3\,kg/m^3 \cdot 10\,m/s^2 \cdot .05\,m \cdot \pi(.02m)^2$

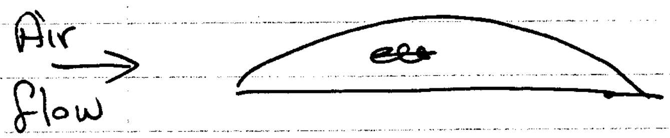
$= 0.628N$

d) $F_{net} = \rho g \underbrace{(h_{bott} - h_{top})}_{h_{cyl}} A = \rho g V_{cyl}$

Usually expressed as the weight of the water displaced. Eureka!

Solutions I.3

3)



We assume air travels from leading edge to trailing edge of wing in same time, regardless of path (a good approximation).

So, $v_{air} = \frac{\text{path}}{\text{time}}$, and since path over top is 10% longer, $v_{top} = 1.1 \times v_{bottom}$

$= 1.1 \times 200\,\text{m/s} = 220\,\text{m/sec}$

Assuming a negligible height difference between top & bottom,

$$P_b + \tfrac{1}{2}\rho v_b^2 = P_t + \tfrac{1}{2}\rho v_t^2$$

$$\text{So } P_b - P_t = \tfrac{1}{2}\rho\left(v_t^2 - v_b^2\right)$$

$$= \Delta P = \tfrac{1}{2}\, 1\tfrac{\text{kg}}{\text{m}^3}\left[(220\,\text{m/s})^2 - (200\,\text{m/s})^2\right] = 4200\,\text{Pa}$$

$F_{net} = P_b \cdot A - P_t A = \Delta P \cdot A = 4200\,\text{Pa} \cdot (3\,\text{m} \times 10\,\text{m}) = 1.26 \times 10^5\,\text{N}$

One 75 kg person weighs $mg = 75\,\text{kg} \cdot 10\,\text{m/s}^2 = 750\,\text{N}$,

So this would support 168 such people