ME 106 Fluid Mechanics: Midterm 1
Fall 2014
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57/57

1. For the Bernoulli equation, does it matter if pressure is specified as absolute or relative? Justify your answer.

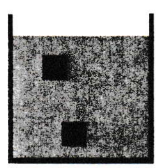
It does not matter as long as all pressures are specified the same way (ie. all absolute or all relative). Bernoulli's equation states that $P + \frac{1}{2}\rho v^2 + \rho g z = \text{constant}$. So if P is specified as absolute or relative it does not matter as long as it is defined that way throughout the system. The only thing important in Bernoulli's equation is the difference in pressure P.

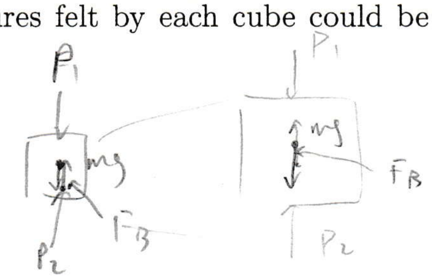
5/5

2. We know that buoyancy force is equal to the weight of water displaced. But why is it that the buoyancy force does not depend on depth, even though pressure does? That is, why is the buoyancy force on the two submersed cubes the same even though the pressures felt by each cube could be vastly different?

$F_B = \rho g \forall$

5/5



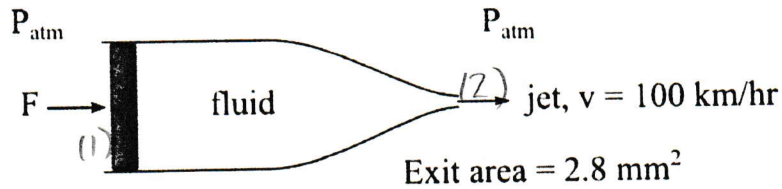


Doing a sum of forces about the cube along the vertical axis will give the equation for buoyant force. When the cube is more immersed in water the difference between p_1 and p_2 is still the same because pressure follows a linear relationship with depth*. As a result, the fact that it is lower does not affect the total sum of forces and hence buoyancy force does not depend on depth.

* and consequently the difference between p_1 and p_2 will only depend on the height of the cube.

3. Consider the syringe drawn below. Neglect viscous effects and friction between the piston and cylinder. Assume the density of the fluid is that of water (1000 kg/m^3).

(18)



Piston area = 4.4 cm^2

(a) Estimate the force F in Newtons required to eject the fluid at the speed of 100 km/hr. Careful with units.

conversions

$1\,cm^2 = (0.01\,m)^2 = 1\times10^{-4}\,m^2$

$1\,mm^2 = 1\times10^{-6}\,m^2$

$100\,\frac{km}{hr} = \frac{100\,000\,m}{3600\,s} = 27.78\,ms^{-1}$

By conservation of mass,

$Q = A_1V_1 = A_2V_2$

$\Rightarrow A_1(10^{-4})V_1 = A_2(10^{-6})V_2$

$V_1 = \frac{2.8(10^{-6})(27.78)}{4.4(10^{-4})} = 0.177\,ms^{-1}$

By bernoullis equation from (1) to (2), neglecting height changes

$\frac{1}{2}\rho V_1^2 + P_1 = \frac{1}{2}\rho V_2^2 + P_2$

where $P_2 = P_{atm}$, $P_1 = P_{atm} + \frac{F}{A_1}$

$\frac{F}{A_1} = \frac{1}{2}\rho(V_2^2 - V_1^2)$

$F = \frac{\rho(V_2^2 - V_1^2)\cdot A_1}{2} = \frac{1000(27.78^2 - 0.177^2)(4.4\times10^{-4})}{2}$

$= 169.77\,N$ ✓ 12/12

(b) Is this a reasonable force to generate with one's thumb?

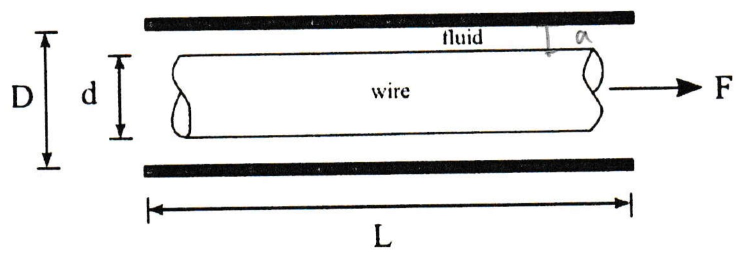
This does not seem reasonable since I weigh 67kg $= 67(9.81) = 657.27$ Newtons and that is approximately 4 times more than the force required for me to exert with just my thumb. Also I am weak 3/3

(c) Is your estimate higher or lower than the actual force one might require? Provide reasoning.

It is lower, because in actuality there are viscous forces and friction present that require a greater force to overcome and to increase the water velocity to 100 $\frac{km}{hr}$ at the exit. 3/3

4. Consider a machine to coat wire in plastic. Assume the wire is drawn through the center of a cylindrical die (conduit) filled with hot liquid plastic as shown.

17/17



(a) Determine the force F in Newtons required to pull the wire at 3 m/s with D = 2 mm, d = 1 mm, L = 50 cm. Note, the liquid plastic is non-Newtonian, but we can assume a constant shear rate and an apparent viscosity $\mu = 0.8$ Pa·s for the given conditions.

$\tau = \mu \frac{du}{dy}$ +5 $\quad \tau = \frac{F}{A}$ where $A = \pi d L$ $\quad \frac{du}{dy} = \frac{V}{a}$

where $a = \frac{D-d}{2}$

$\frac{F}{\pi d L} = \mu \frac{V}{a}$ + 2

$F = \frac{\mu V}{\left(\frac{D-d}{2}\right)} \pi d L$ + 3

$= \frac{0.8(3)\pi(0.001)(0.5)}{\left(\frac{2-1}{2}\right)(10^{-3})}$

$= 7.54$ Newtons ✓ +3

$F = \int \tau \, dA$

$= \int_0^L \frac{\mu v}{a} \frac{2\pi d}{2} dl$

$= \frac{L \mu v}{a} \pi d$

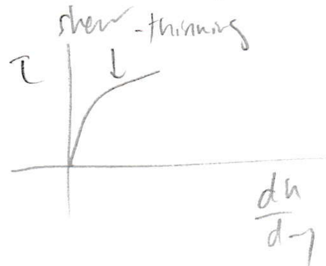
$= \frac{\mu v \pi d L}{\left(\frac{D-d}{2}\right)}$

(b) Would the plastic ultimately coat more effectively once the wire exits the conduit if it was shear thinning or shear thickening? Why?

✓ +4 Shear thinning because if its shear thinning then it becomes easier to move when the velocity... increases (just like paint because its also shear thinning).

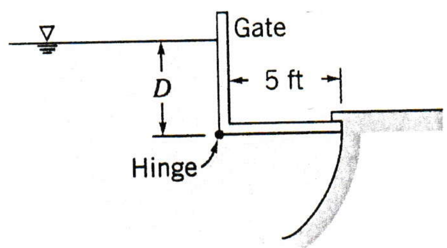
since τ decreases -

As a result, when it exits, if it is shear thinning, it will coat more effectively.



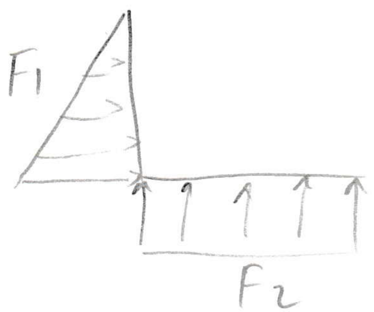
12

5. An L-shaped gate is used to regulate water height. At what water height D will the gate begin to flip open? Neglect the mass of the gate and friction of the hinge.



L = 5

Doing sum of forces



assume width b

(area of triangle)

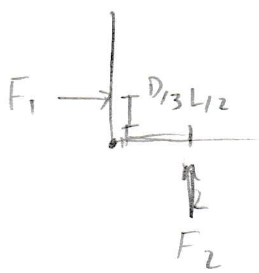
$$F_1 = \frac{\rho g D(D) b}{2}$$

(area of rectangle)

$$F_2 = \rho g D L b$$

$$\sum M_H = 0$$

Doing sum of moments about hinge (the reaction locations are $\frac{1}{3}$ way up from triangle and middle of rectangles)



$$F_1\left(\frac{D}{3}\right) = F_2\left(\frac{L}{2}\right)$$

4/4

$$\frac{\rho g D^3 b}{6} = \frac{\rho g D L^2 b}{2}$$

4/4

$$D^2 = 3L^2$$

$$D = \sqrt{3} L$$

4/4

$$D = 8.66 \text{ ft}$$