**Homework 3 Solutions Due 2/27**

**Problem 1.** 14.7psi is roughly 1atm which is roughly 101kPa. Your tire pressure is 35psi. And your car has a mass m = 2000kg.

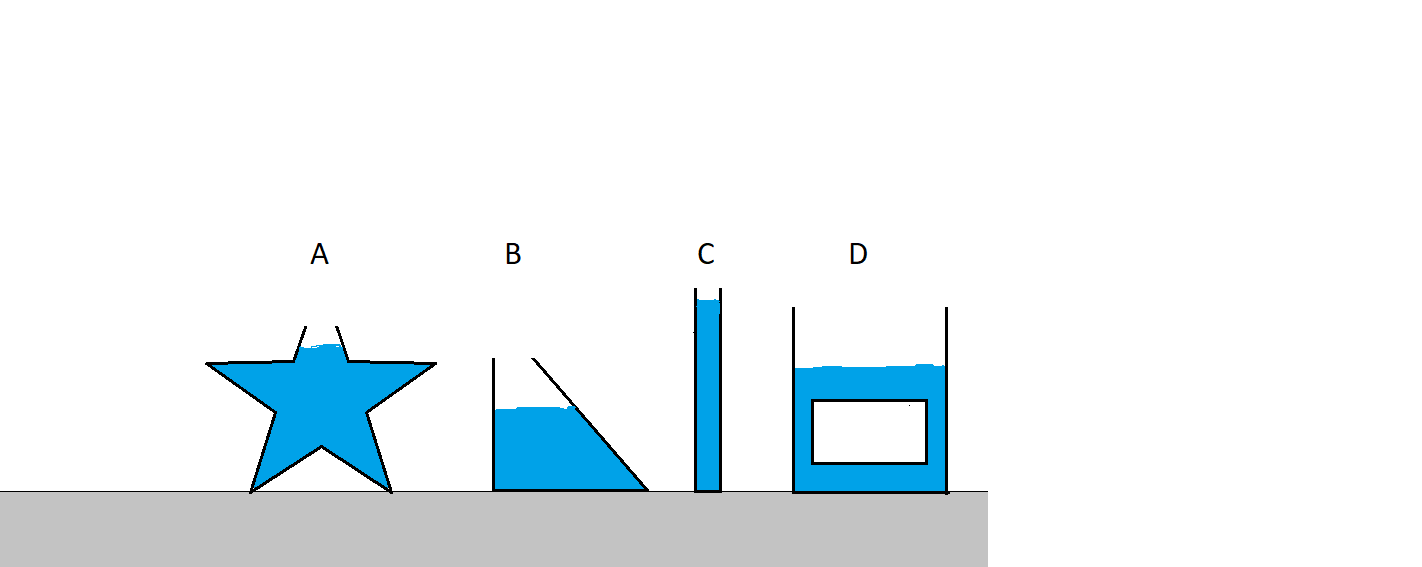
(a) What then is the area of contact between each tire and the road?



(b) If the tire pressure goes down, what must the area do, to keep the forces balanced?

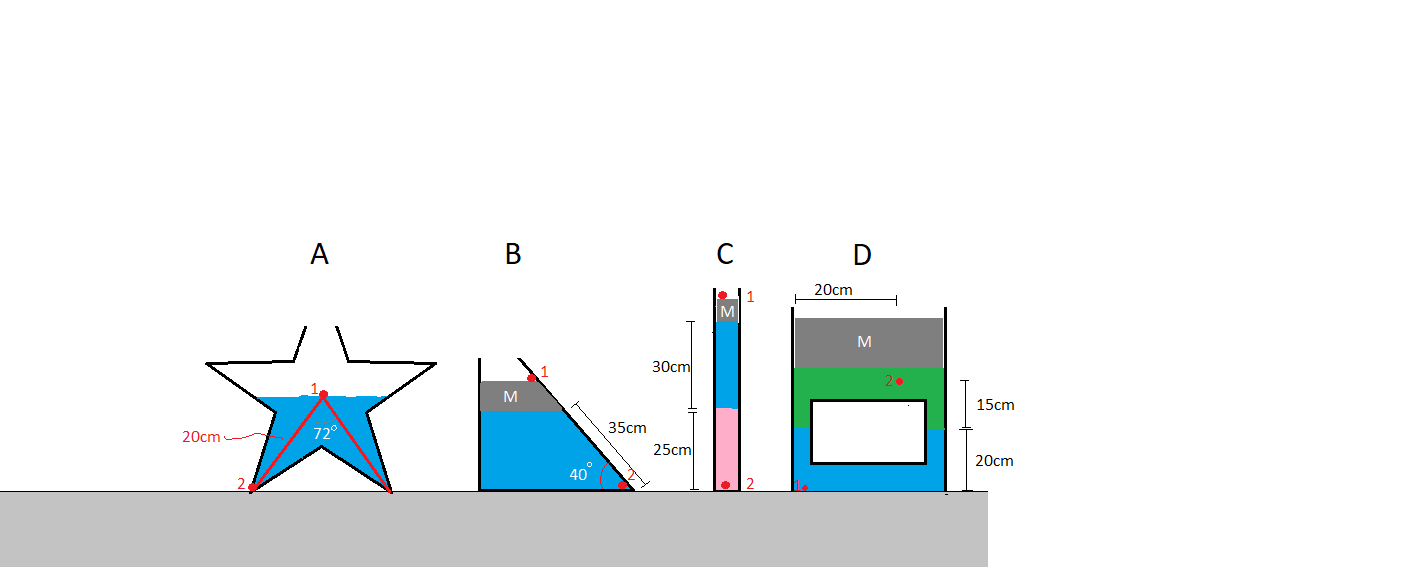
It must go up, which is ‘why’ a tire goes flat when it loses pressure.

**Problem 2.** Suppose we fill the following shapes with water, and leave them out in the open exposed to air. Rank the following shapes according to the criteria in the table (1 = hights, 4 = lowest). If the shapes have the same value, then just put them in the same row.



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Pressure at top | Force at top | Pressure at bottom | Force at bottom |
| 1 | A, B, C, D | D | C | D |
| 2 |  | B | A | B |
| 3 |  | A | D | C |
| 4 |  | C | B | A |

**Problem 3.** Let water have a density ρw = 1000kg/m3, the pink liquid have a density ρp = 500kg/m3, and the green liquid ρg = 750kg/m3. And the blocks have masses MB = 50kg, MC = 20kg, MD = 100kg, with bottom cross-section areas: AB = 0.08m2, AC = 0.01m2, and AD = 0.20m2. If the pressures P1 are given, what are the pressures P2? Note some numbers aren’t needed.



|  |  |  |
| --- | --- | --- |
| **Pressure** | **P1** | **P2** |
| **A** | 101kPa | 102.6kPa |
| **B** | 101kPa | 109.3kPa |
| **C** | 101kPa | 124.8kPa |
| **D** | 150kPa | 146.9kPa |

For A, we use P2 = P1 + ρwghw = 101kPA + (1000)g(0.20cos(36°)) = 102.6 kPa.

For B, we have to add the pressure exerted by the mass, which would be its weight over its area. So this is going to be: P2 = P1 + W/A + ρwghw = 101kPa + (50)g/(0.08) + (1000)g(0.35sin(40°)) = 109.3kPa.

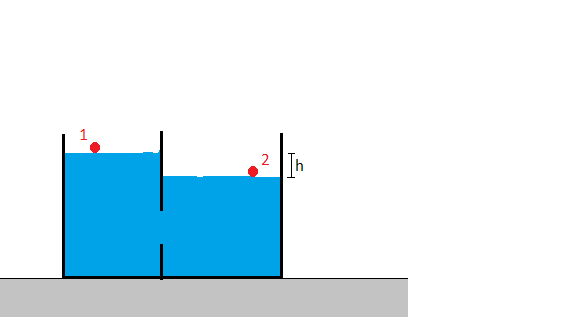
For C, we have to add the pressure exerted by the mass, which would be its weight over its area, and then the pressure from the pink liquid below that. So

P2 = P1 + W/A + ρwghw + ρpghp = 101kPa + (20)g/(0.01) + (1000)g(0.30) + (500)g(0.25) = 124.8kPa.

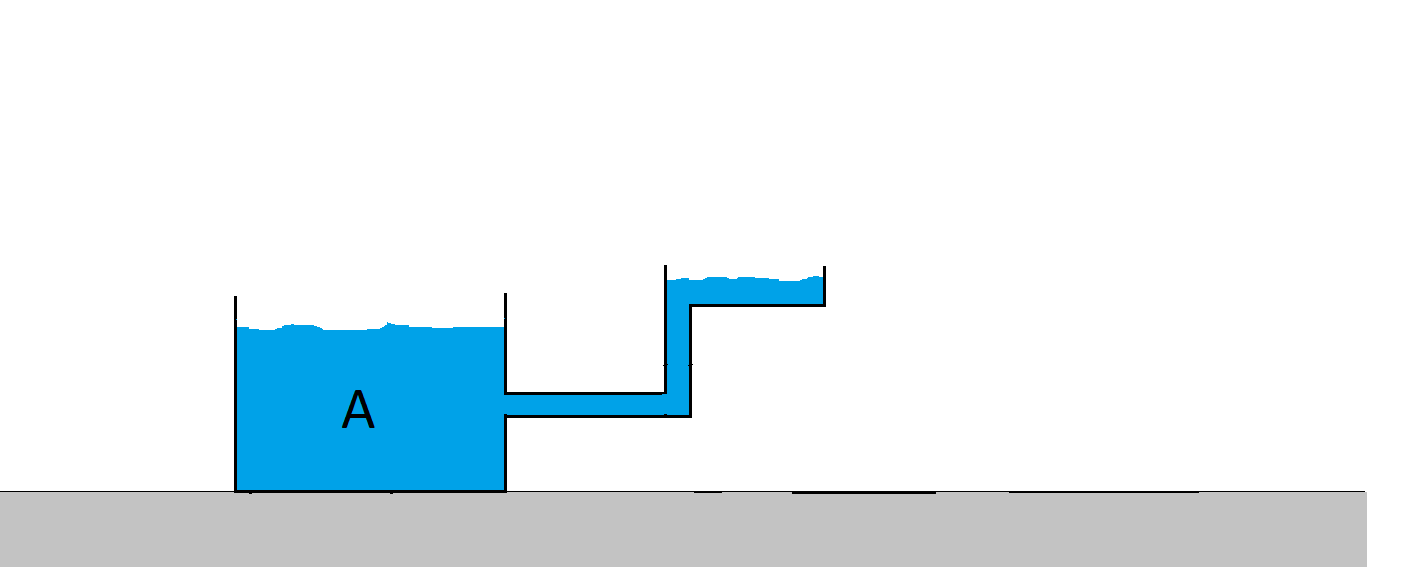
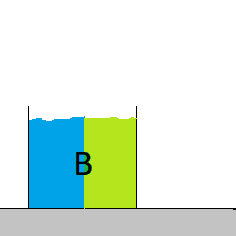
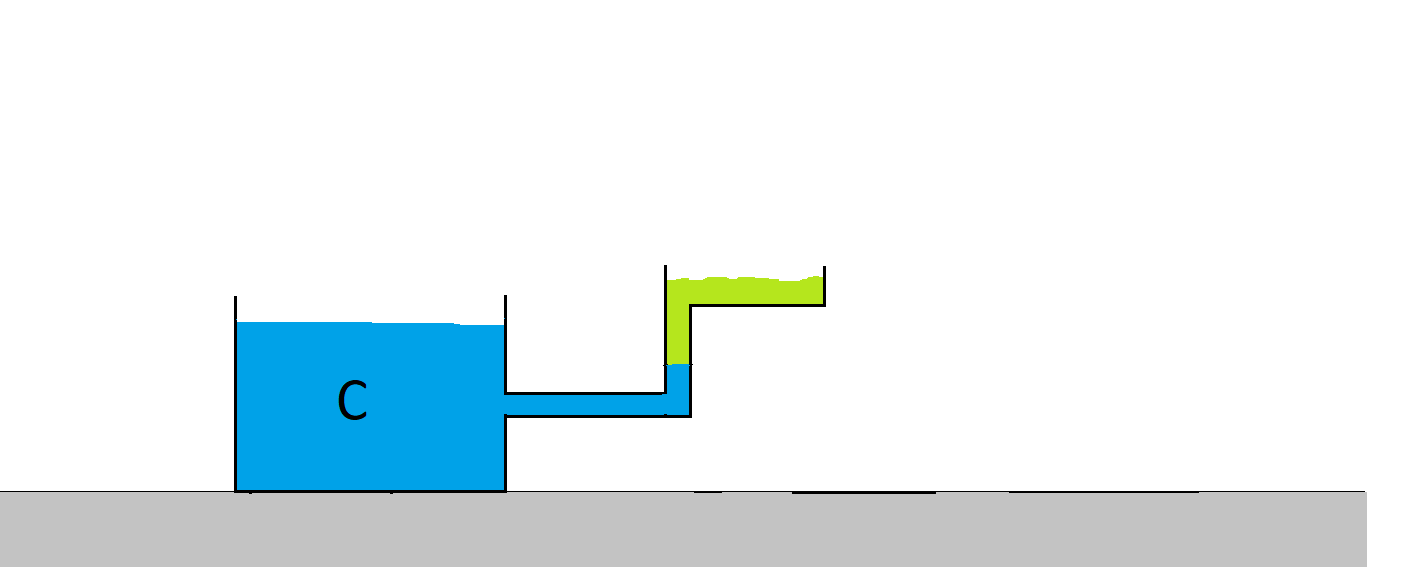
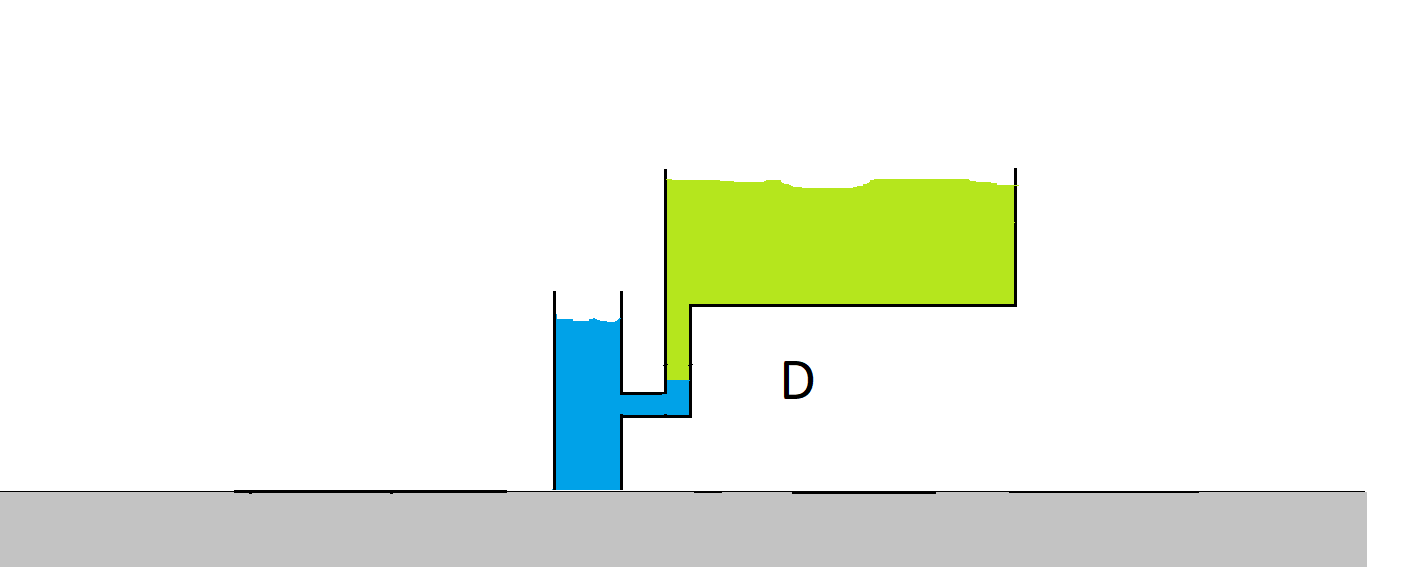
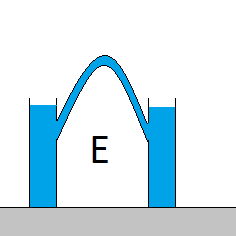
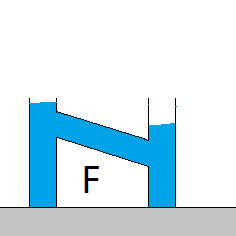
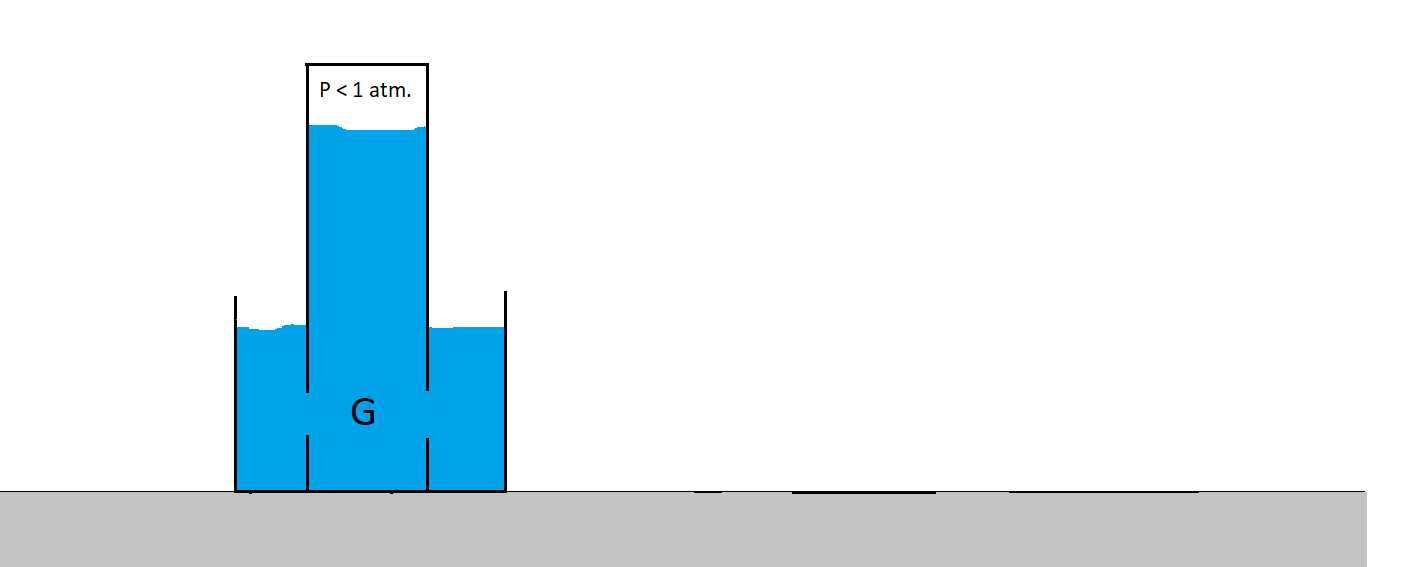
For D, we must go up, rather than down. We can accomplish this by using a negative height.

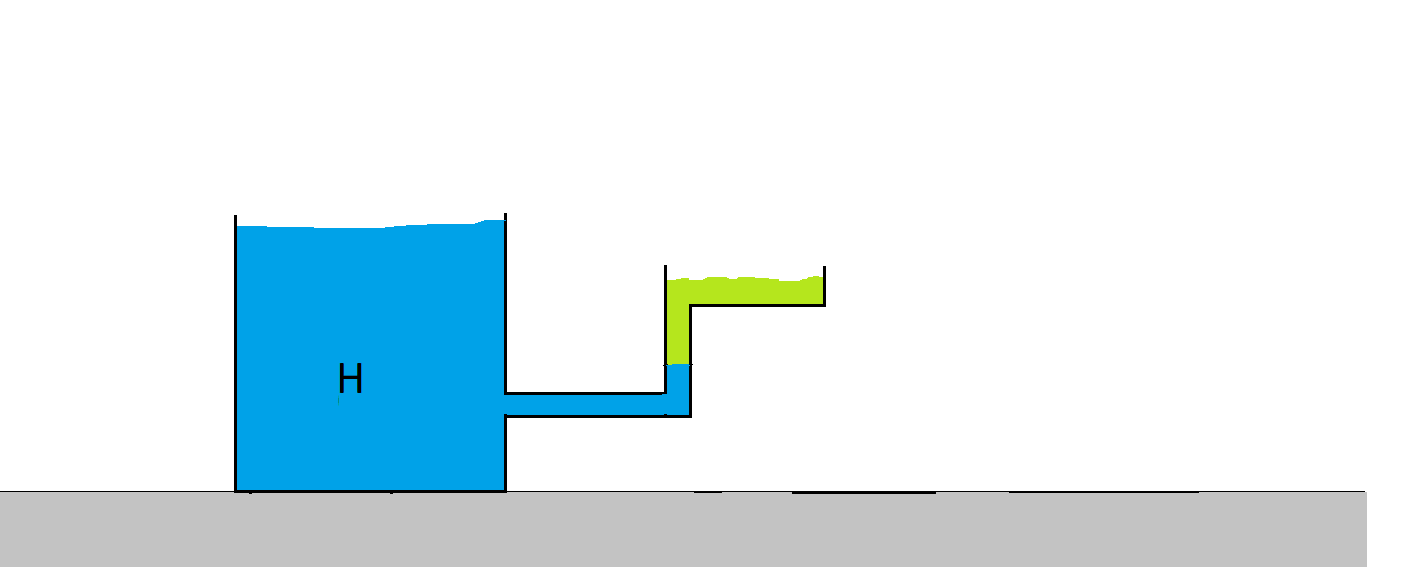
P2 = P1 + ρwghw + ρgghg = 150kPa + (1000)g(-0.20) + (750)g(-0.15) = 146.9kPa.

**Problem 4.** The concept of pressure can be useful in determining the physical possibility of different fluid configurations. For instance, consider an open container of water with two compartments, open to the atmosphere. The water cannot be in this configuration, with two different heights, because it would violate the equation P2 = P1 + ρgh. This is because we know that P1 = Patm., and P2 = Patm., and so it cannot be that Patm. = Patm. + ρgh, unless h = 0. So the water levels must be equal.



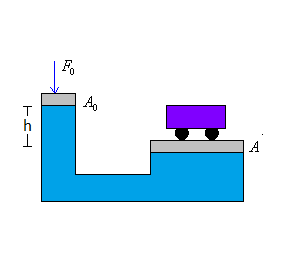
Now consider the following open containers (legal in physics problems, not when driving). The blue and green liquids are immiscible and could have different densities. Indicate which of the following situations are possible, and where applicable, how the densities of the blue and green liquids must compare.



|  |  |
| --- | --- |
| A | Not possible |
| B | Not possible, unless ρg = ρb |
| C | Possible: ρg < ρb |
| D | Possible: ρg < ρb |
| E | Possible |
| F | Not possible |
| G | Possible |
| H | Possible: ρg > ρb |

**Problem 5.** This problem illustrates the force-magnifying properties of fluids (and the mechanism behind power steering, power breaks, hydraulic lifts, etc.). Consider trying to lift a car. We cannot exert the requisite force ourselves, but we can use fluids to magnify the effects of the force we can exert, by increasing the area over which the force acts. So consider the diagram below. We exert a force F0 at the narrow piston (cross section area A0 = 0.5m2) and this force gets multiplied, by the fluid (water), to the other piston (cross section area A = 10m2), supporting the car. Take the car’s mass to be 1200kg.



(a) What is the weight of the car?

Well,



(b) What pressure, P, must the right piston be exerting then, to raise the car at constant velocity?

And this is,



(c) Supposing the height difference between the two pistons is h = 10cm, what force, F0, must we exert then?

Let P0 be the pressure at the left piston, and P be that at the right piston. Then these are related via:



And so the force you’re exerting is:



This is about 20 lbs.

(d) If the height difference between the two pistons were 0m, instead, what force would be required? How does this compare to the previous one?

Repeating the analysis, with h = 0, we have:



And so the force you’re exerting is:



This is closer to 110 lbs or something. This is larger, but still easier than lifting the car yourself.

(e) Would making h negative, i.e., raising the right piston above the left one increase or decrease the force we must exert?

Raising the car’s piston above our piston would just increase the force further. Bad idea.

(f) How would increasing/decreasing the area A0 affect the force we must exert?

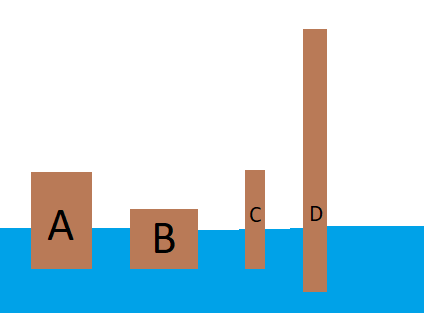
Proceding from car to us. P is unaffected, which makes P0 the same as before. But then increasing/decreasing A0 would increase/decrease the force F0, which we must exert, since it’s equal to P0A0.

(g) How would increasing/decreasing the area A affect the force we must exert?

Proceding from car to us. P would be decreased/increased, which would decrease/increase P0, which would decrease/increase the force we must exert.

**Problem 6.** How does the densities of the following floating objects compare? Might want to use N2L in conjunction with what we know about the buoyant force.

|  |  |
| --- | --- |
| A | 2 |
| B | 1 |
| C | 2 |
| D | 3 |



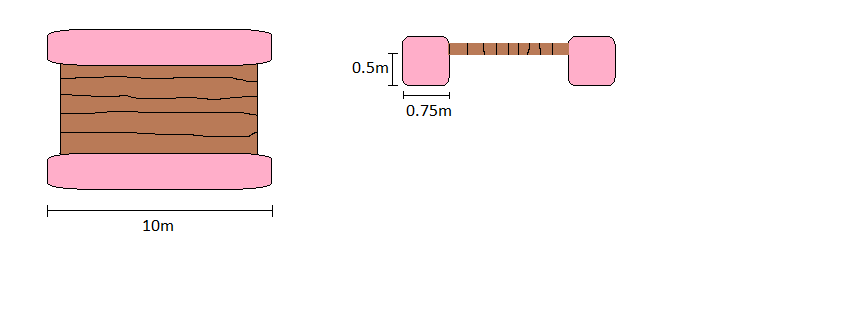
Well, if they’re floating, then the bouyant force must match their weight. And so we must have:



So their densities are in proportion to the ratio Vsubmerged/V. This would make:

ρB > ρA = ρC > ρD

**Problem 7.** Consider a raft connected to pontoons filled with air, with dimensions as shown below. The mass of the wood raft + pontoons is 100kg.



(a) If we put the raft in water, to what depth will the raft sink below water level?

Let h be the depth. Then we have:



(b) How many 50kg people could the raft carry before it is submerged, i.e., depth = 0.50m?

Repeating,



(c) Now suppose the pontoons are strapped on such that the 0.75m side is vertical, and the 0.5m side is horizontal. To what depth will the pontoons submerge?

So,

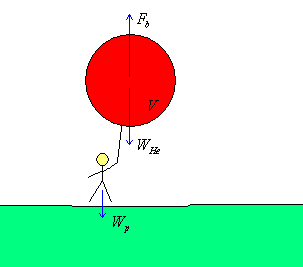


(d) And how many people could the raft hold now?

Can see that nothing changes, so you’ll still get n = 148.

**Problem 8.** Calculate the volume of a Helium balloon necessary to lift you off the ground. Air has a density of 1.2kg/m3. And He2 at room temperature has apparently a density of 0.18kg/m3 (don’t neglect this). And we’ll take your mass to be 70kg.

The forces are:

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To achieve lift-off we need that the sum of forces acting on you/balloon are greater than zero. So

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And so you would need around a balloon of volume 69m3 approximately.

**Problem 9.** Suppose you accidentally drop your car keys (their density is ρ = 4000kg/m3) overboard on a boat trip to Catalina Island. Say the depth of the water there is 500m. How long does it take for them to hit the bottom? Remember kinematics? Of course you do.

Just gotta do N2L,

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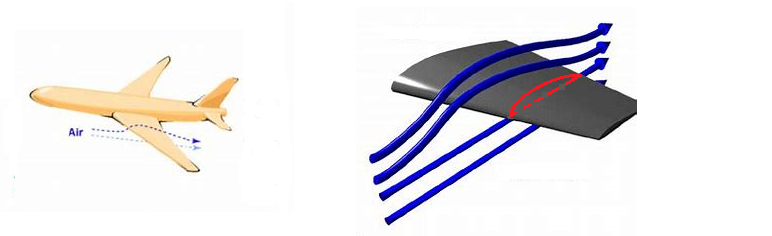
Now, Vsubmerged = Vkeys, so:

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Now the relevant kinematics equation is:



**Problem 10.** Consider an airplane flying through the air, as shown below left. In order to generate lift, an airplane wing is designed to have a sort of ‘humped’ upper contour, compared to its bottom contour (this is a simplification but conveys the general idea). When a stream of air hits the wing, ‘half’ will flow over the top and ‘half’ will flow over the bottom. But the part that flows over the top must flow faster, due to the longer distance it must travel (because of the humped’ contour), to reconnect with the bottom half of the stream. In order for that air to flow faster it must accelerate, which requires a pressure drop. So the air pressure on the top of the wing will be lower than the pressure at the bottom, and a net upward force will be generated.



Suppose our airplane has a mass m = 200 000kg, and it’s wings have a total area A = 320m2. Let the bottom contour be flat, and the top one humped, and 15% longer. At what speed would our plane have to fly before the lift provided by the air matches the plane’s weight? You can take the density of air to be ρ = 1.2kg/m3, and the difference in height between the top and bottom of the wing to be negligible.

The lift force is just this:



we can figure out the pressure difference from Bernoulli’s equation:

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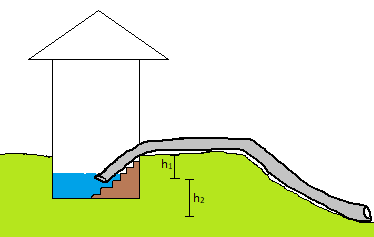
So the force is:

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And we need this to match the weight, so:



**Problem 11.** Suppose, contrary to experience, it actually rained in CA. And on that one day, of course your basement flooded. Making some rough measurements, you estimate there’s about 10m3 of water. How can you get the water out of your basement? Well one way is to grab a bucket. Or we could use a hose (or connect a bunch of pipes more likely). But how do you get the water to flow up hill through the pipe? One possibility is this. On the right end hook up a vacuum cleaner or something and suck some of the air out of the hose. Suppose you succeed in reducing the pressure in the hose to 0.5atm, that h2 = 3m, and that also the hose has a constant diameter of d = 4cm.



(a) To what height h1 could you just barely draw water up to the top of the hose?

If it just barely gets there, the velocity of the water would be zero, and so comparing the water in the basement, to the water at the top of the hose.



(b) Then the water will come rushing out the other end of the hose. So right before it gets to the end, you remove the vacuum cleaner, restoring the right end of the hose to atmospheric pressure. What will be the speed of the water flowing through (that end of) the hose?

Same old equation,



(c) How long will it take the basement to drain?

We use the f.r. equation:



(d) The pressure at the top of the hose is different now that water is flowing through the hose. What would now be the water’s pressure and speed at the top? Note you know one of these, w/o really doing a calculation, because the hose’s diameter is constant.

Once more unto the brink. So the velocity of the water must be constant throughout the hose, due to the flow rate equation. Compare any two points on the hose and it must be true that f.r.1 = f.r.2. This implies A1v1 = A2v2. But the A’s are the same throughout the hose, so v1 = v2. Now let’s get the pressure…



(e) What is the pressure at the opening of the hose, in the basement? Perhaps you thought it was atmospheric, but it’s not, though you can still say that the pressure of the water in the basement, far from the hose, at the surface, is atmospheric, and you can reasonably say that the velocity of that water is zero.

So,

