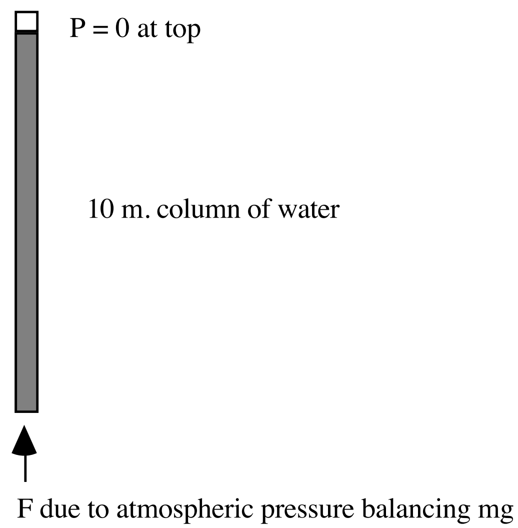
Physics 132
General Physics II/Workshop Physics II
Grinnell College

Homework Unit I

Session 1

1. We saw experimentally that a tube of water about 10 m high has about zero pressure at the top if there is one atmosphere at the bottom. Since pressure is force per unit area, the force up on that column of water is the one atmosphere times the tube's cross sectional area. Use Physics 131 knowlege about F=mg and the density of water ($1 g/cm^3 = 1000 kg/m^3$) to get the value of one atmosphere in units of Newtons/m^2, or Pascal.



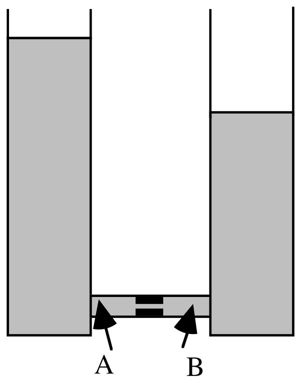
2. A scuba diver dives to a depth of 20 m below the surface in fresh water. What is the pressure on the diver at that depth? Assume that the pressure at the surface of the water is 1 atmosphere, and if you need it, that the density of fresh water is 1 g/cm^3. Would the pressure be more, less, or the same if she dove to the same depth in salt water with a density of 1.1 g/cm^3?

3. We can consider the atmosphere itself as a column of fluid with zero pressure at the top (outer space) and one atmosphere of pressure at sea level. If the density of air is about 1/1000 that of water, roughly how high is the atmosphere? How does this estimate compare with the altitude of high flying aircraft (about 10,000 m)? [The atmosphere is not really a constant density, but gets thinner as you go up, so your answer should only agree within a factor of two or so.] How does this compare to the radius of the earth of roughly 6,400,000 m? Is the atmosphere a very thick skin on the earth?

Session 2

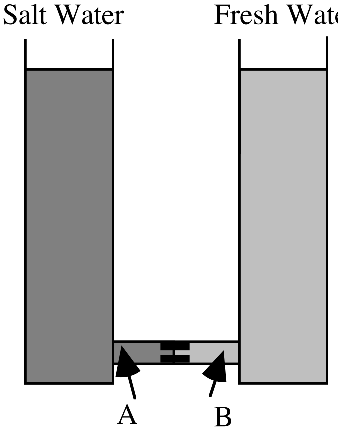
4. The Sears Tower in Chicago is about 1000 feet tall. How high must the water pressure be at ground level to supply water pressure of 100 pounds per square inch (PSI) at the top? (Session I.1 has pressure unit conversion information.)

5. Two cylinders are filled with water to different heights, and are connected with a tube as shown. The tube has a very small constriction in the middle that makes flow very slow.



Where is the pressure higher, at point A or point B? What direction do you expect the fluid to flow, to the left or right? Explain.

6. Two cylinders are filled to the same height, but with salt water (density of 1.1 g/cm^3) on the left and fresh water (density of 1.0 g/cm^3) on the right. Where is the pressure higher, at point A or point B? Why? What direction do you expect the fluid to flow, to the left or right? What do you expect the final levels of the fluids in the cylinders will be? (It is difficult to predict this exactly; an approximate answer is ok.) Explain.



Session 3

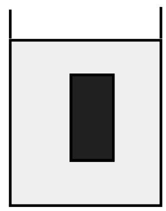
7. We earlier learned that the pressure of a fluid is due to individual atoms or molecules bouncing against the walls of the container. We can't observe any individual bounces because the time between bounces is extremely short. Let's get an idea of how many bounces there are per second. Let's imagine that we have a small cube (1 cm on a side) of

gas. The cube has about 3×10^{19} atoms in it. They are moving roughly at the speed of sound (about 300 m/sec).

a. How long does it take one atom to get across the cube at this speed, assuming it doesn't bump into any other atoms? (This is a reasonable estimate of that average time between wall collisions for an individual atom.)

b. Now, given that there are 3×10^{19} atoms in the cube, what is the rate of atom-wall collisions? Is it surprising that we don't notice any bumping?

8. Consider a cylinder completely immersed in some water (density of 1 g/cm^3), as shown.



By symmetry, there can be no net force exerted on the sides (can you explain this in your own words?). But, because pressure changes as you go down in a fluid, the pressure on the bottom is different than the pressure on the top. This leads to a net force on the cylinder.

a. Calculate the force on the top of this cylinder of radius 2 cm at a depth of 3 cm.

b. Calculate the force on the bottom of the cylinder if the cylinder has a total height of 5 cm.

c. What is the net force due to the fluid on the cylinder? Can you relate this to the volume of the cylinder?

d. Does the volume relation apply to a cylinder of arbitrary radius r and height h?

The relationship you should have gotten in part c is called Archimedes Principle. If you were particularly excited to discover it, you may feel free to run through campus naked yelling "Eureka!

9. An airplane wing cross-section is shaped as shown,

forcing air to travel a greater distance over the top of the wing compared to the bottom. This means air on top is moving faster (say 10% faster to be concrete) than at the bottom and so pressure is lower above the wing (according to Bernoulli) thereby providing a lifting force. If a plane is moving 200 m/sec, how much lifting force is generated by a wing 3m wide by 10 m long? How many 75 kg people will that lift? Use r = 1 kg/m^3 for the density of air.

[Below is a view of the wing from above—10m long and 3 m (on average) wide.]