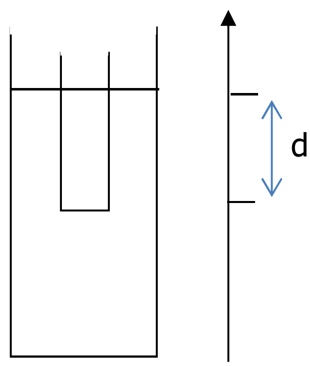
Physics 216 Lab 1, Spring 2017
Fluids

Part I: Dependence of pressure on depth

As we've seen in class, in a static fluid that has density ρ, the theoretical model for the pressure at depth d is $p = p_0 + \rho g d$. It follows that the difference in pressure between the depth d and the surface is $\Delta p = p - p_0 = \rho g d$. In other words, the difference in pressure is directly proportional to the depth.

To test this relationship, you have a large graduated cylinder and a smaller graduated cylinder with a flat base. The smaller cylinder has cross-sectional area A. You'll put water in the larger cylinder, and then the smaller cylinder can be floated in it as shown, with its bottom at a depth d.



Assuming that the smaller cylinder is in static equilibrium, convince yourself (and your instructor) that $\Delta p = p - p_0$ (the difference in pressure between the depth d and the surface), times the area of the base of the smaller cylinder, is equal to the weight of the smaller cylinder mg. That is, $\Delta p * A = mg$. Hint: what are the forces on the smaller cylinder?

√ Checkpoint 1

The equation above can be rewritten as $\Delta p = mg/A$. This means that we can directly measure the pressure difference at depth d by adjusting the total mass of the cylinder (placing small weights inside) so its bottom is in equilibrium at various depths below the surface, and then using the measured total mass and cross-sectional area to find Δp.

Fill in the table below, and use your data to find the pressure difference at four different depths. Be sure to include the proper (SI) units in the table.

Depth	Total mass	A	Δp	Uncert in Δp

√ Checkpoint 2

Using Logger Pro, make a graph of measured pressure difference Δp vs. depth in appropriate SI units. Note: "graph y vs. x" means to graph y on the vertical axis (dependent variable) as a function of x on the horizontal axis (independent variable).

We saw earlier that the theoretical model for the pressure difference between the surface and the depth d is $\Delta p = \rho g d$, so the pressure difference is directly proportional to the depth. This means the graph of Δp vs. d should be a straight line going through the origin. Based on the theoretical model, what should the numerical value of the slope of the line be equal to?

Let's see whether this model agrees with your data. Use Logger Pro to do a linear fit to your data showing the prediction of the theoretical model. If the model is good, the line should fit most of the points while passing through the origin, and the slope will be close to what you calculated. If the fit parameters don't show uncertainties, right click on the "fit results" box and find the setting to make it show you the uncertainty.

What do you conclude about how well the model describes your data?

How, specifically, would you expect your graph to be different if we'd used alcohol rather than water?

√ Checkpoint 3

Part II: Application to the atmosphere
"We live submerged at the bottom of an ocean of the element air."
--Evangelista Torricelli, for whom the pressure unit "Torr" is named (1 Torr is the same as 1 mm Hg).

Assume that the pressure at sea level ("atmospheric pressure") is due to the layer of air around the earth that constitutes the atmosphere. Further, assume that the air is a static fluid with the same density that it has at sea level. Based on these assumptions, and on the physics you know, estimate the height of the atmosphere.

Is your estimate for the height of the atmosphere likely to be an overestimate or an underestimate? Why?

√ Checkpoint 4

Part III: Buoyancy and density

In this experiment, you'll apply the concepts of density and buoyant force to determine the average density of an irregular object (a rock) in two different ways.

Method 1:

Using an electronic balance and a graduated cylinder, find the mass and the volume of your rock directly. Which should you find first to minimize systematic effects? Estimate uncertainties in the mass and the volume by estimating the uncertainty from reading the scale.

mass _______________ ± ___________________

volume _______________ ± ___________________

From these, find the density of the rock and its uncertainty. Include your work here:

density _______________ ± ___________________

Method 2:

Another way to find the density uses the weight of the rock measured in air and measured while the rock is suspended in water. Use a force sensor to find the weights. (Don't forget to first zero the sensor with no weight.)

Force probe reading, rock out of water _______________ ± ___________________

Force probe reading, rock in water _______________ ± ___________________

Use these values to figure out the average density for the rock, along with its uncertainty. Hint: To what can we ascribe the difference of the weights in these two cases?

density _______________ ± ___________________

Compare the two methods of finding the average density. Do the results agree (do their uncertainty ranges overlap)? Which method gives the most precise answer with the equipment we have? Which method might be easier to use?

√ Checkpoint 5

Part IV: Prediction experiment

Devise a method for finding the average density of an empty film canister with its lid on (including the lid). Use your method to find the average density, with uncertainty.

Now predict how much mass you would have to put in the canister to get it to just barely float in methanol. Include uncertainty.

Test your prediction. Did it work, within uncertainty?

Is it important to put the extra mass <u>inside</u> the canister? Could it just be attached to the outside? Explain.

√ Checkpoint 6