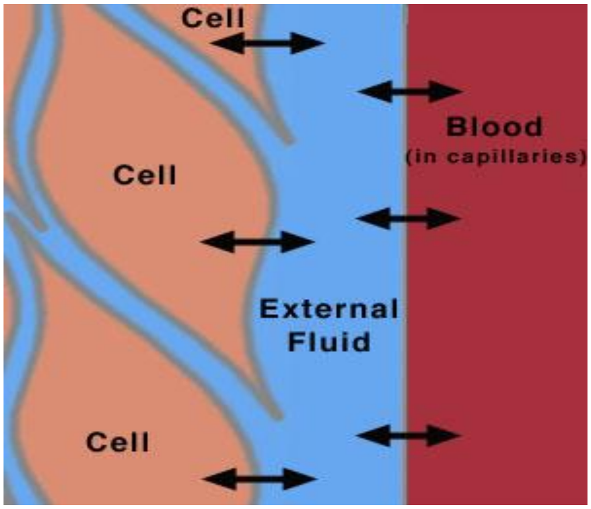
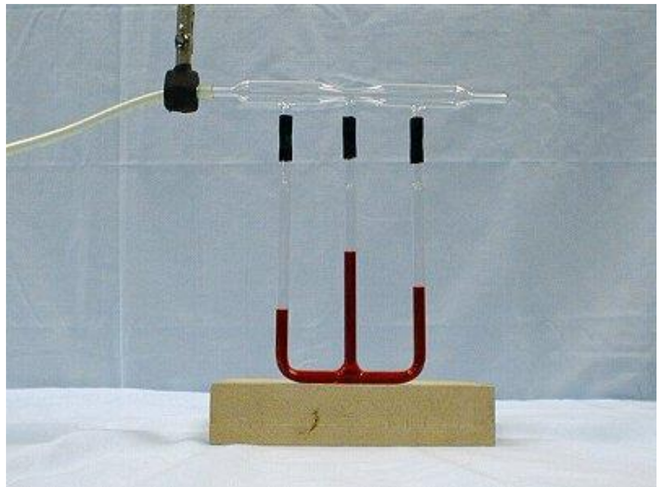
Fluids





Objective: To investigate some properties of fluids, such as density, pressure and depth, Archimedes' Principle and buoyancy, and Bernoulli's Principle

Apparatus: a) 4 desks, each with 2 drinking straws, 1 long graduated cylinder, straws, long thin tube with one sealed end, meter stick, index card or quartered sheet of printer paper (cut into 4 equal rectangles)
b) 4 desks, each with 1 medium-sized Pyrex beaker, electronic caliper (to measure thickness), wood block, scale (not at every table)
c) 4 desks, each with 2 small-sized Pyrex beakers, mineral oil, white plastic ball, narro-trimmed plastic spoon, electronic caliper (to measure thickness), scale (not at every table)

Introduction

The study of fluids is important in numerous fields of science and engineering. Physicians, nurses and veterinarians have to deal with various fluids in the body, life support systems and drug delivery systems. Engineers encounter fluids on a daily basis – from hydroelectric dams to bridges to HVAC systems, automobiles and many, many other applications.

Theory

Fluids consist of large number of atoms or molecules that generally move together and behave similarly. As individual masses, they are subject to Newton's Laws. However, it is not practical (nor possible) to analyze the motion of each water or air molecule so it is more useful to consider the behavior of groups of particles. Below is a summary of some of the relationships and laws of Fluid Statics and Dynamics, many of which you have may have already covered in lecture:

$\rho = M/V$ (Density = Mass/Volume)

$P = F/A$ (Pressure = Force/Area)

$P = P_0 + \rho g h$ (Pressure = Atmospheric Pressure + Density x Gravitational Acceleration x Depth ***h***)

In addition, the term variable *v* refers to the speed of a particle in the fluid.

Archimedes' Principle

$F_{buoyant} = \rho g V_{submerged}$ (The buoyant force experienced by an object in a liquid = The density of the liquid x Gravitational Acceleration x The object's submerged volume). **Note that the rise in volume of liquid in a container is due to the volume that the object displaces when placed in it.**

Bernoulli's Equation

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$ (Bernoulli's Equation; *y* = **height** of part of fluid, not depth)

Bernoulli's Equation is a *conservation* equation in which the total quantity on the left remains same as the total quantity on the right.. Note the similarity of the second and third terms on either side of the equation to Kinetic Energy and Potential energy respectively**. The equation is actually a restatement of the Work-Energy theorem**, with each quantity on both sides (P,$\frac{1}{2}\rho v^2$,$\rho g y$) **having the units of Energy per Volume**.

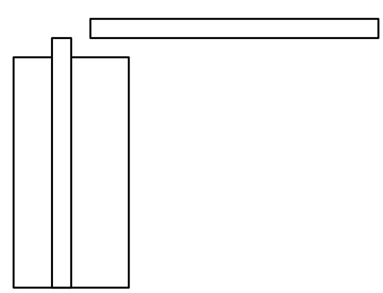
Activities

As usual, write your lab in Google Docs and share it with lab partner(s), TA and LA.

a. Results From Bernoulli's Equation (30 pts)

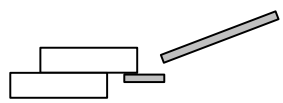
The goal of these experiments A & B is to determine qualitatively how the motion of air across a surface affects the pressure of air on the surface. Perform each experiment, noting what happens in each case and your explanation it in terms of the pressure on the surface and the velocity of the air above it. Make sure you try to explain what has happened in terms of the pressure and air velocity.

Experiment A: Partially submerge one straw deep into a graduated cylinder full of water and hold a second one perpendicular to it (as shown). *If there is a contraption of two parallel acrylic tubes that form an L-shape, use that to insert your straw (into the short tube) for ease of use and sanitation*. Make sure that the end of the horizontal straw is half-obstructed by the vertical straw and blow



(but not too hard as to eject any liquid) through the other end. **Make sure you are not pointing the horizontal straw at something that can be damaged by water, e.g., computers, monitors, well-coiffed hair, etc.** Explain what happens to the liquid in the vertical straw. (5 pts). **If you wish to see what will happen when you blow forcefully, please take the cylinder and straws outside the building and try the experiment there; this precaution is intended to avoid having respiratory vapors spew at other people**.

Experiment B: Fold an index card (or a quarter- sheet of printer paper) into an inverted-U shape and place it on a level surface. Vigorously blow air under the card in horizontal direction; using a straw to do so may help. Explain what happens. (5 pts)



Experiment C: The deeper you go underwater, the higher the pressure gets (you've probably experienced this in a swimming pool). Try to measure the pressure at the bottom of a long, graduated cylinder filled with water by submerging a long thin tube which has one end sealed into it (open end goes in first) and measuring how much the air pocket inside the tube shrinks. If you haven't yet covered Ideal Gases in lecture, you may recall that for a gas (like the air pocket in the long, thin tube), the volume of air inside contracts or expands depending on the pressure, according to the following equation:

$P_1V_1 = P_2V_2$ or $PV = constant$

So basically, you can find the pressure a**t the water/air interface inside the tube** (near bottom of the cylinder) by measuring how much the air pocket in the thin tube changes volume when it is submerged all the way.

Calculate the pressure at the aforementioned interface two ways:

• Method **a**) by measuring how much the air pocket in the thin tube changes (10 pts). *Note that there is already air inside the thin tube before it's immersed into the graduated cylinder but the* ***volume*** *of that air changes after immersion.*

• Method **b**) by using the equation for pressure as a function of depth (at cylinder bottom) (10 pts)

Note that it may not be necessary to calculate the volume of the air inside the tube, since you can just consider the ratios of the heights of the air columns before and after submersion, and using this equation: $V_{cylinder} = A_{\text{cross section}} h$

b. Density Determination – Prediction (pyrex beakers, mineral oil, white plastic ball, plastic spoon, meter stick, scale) (20 pts)

You have a beaker of mineral oil, a beaker of water, and a plastic ball. Predict if the ball will sink or float in oil, then make the same prediction for the ball in water. **To do this, you will have to calculate the densities of oil, water and the ball – remember what determines whether an object will sink or float in a fluid.** Note that your density calculation will be very sensitive to the measurements you make, so make them carefully, and average numbers as needed. Show all your calculations in your lab report, **do the experiment,** and report all three density values there to support your prediction. *Make sure you do not transfer oil to the water beaker or water to the oil beaker by wiping off the ball with a paper towel between beakers. After you are done, return the oil back to the oil bottle and dump the water. If you aren't sure which liquid is which,* ***remember that mineral oil feels slippery (touch it to check!); also, if it's scented it is baby oil, which is merely mineral oil with fragrance)***. (20 pts)

c. Density Determination – Measurement (pyrex beaker, ruler or meter stick, wood block) (25 pts)

NOTE: the order in which you do these following two experiments will affect how their results agree with one another; hint – the block is porous.

1) Design and describe an experiment to measure the density of the wood block based on the definition of Density. Then, **do the experiment**. **You can use a weighing scale for this part**. (10 pts)

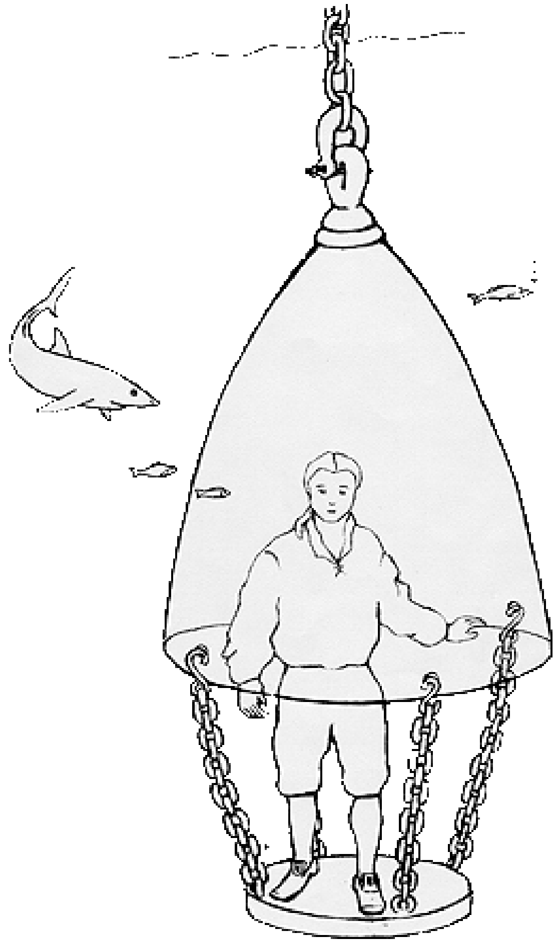
2) Design a **different** experiment to find out the density of the wood block *using only a beaker, water, and a meter stick*. Then, **do the experiment**. **Do not use a weighing scale for this part.** Note that the rise in volume of liquid in a container is due to to the volume that the object displaces when placed in it. (15 pts)

Questions (25 pts)

Write the results from the four activities above in the hand-in sheet. Then answer these questions:

1. Would the amount of water on the block that was absorbed by the block of wood affect the result of the experiment? (5 pts) Would that water make your calculated density artificially high or artificially low? (5 pts)

2. At the very top of this write-up, there is a photo (on the right) of a tube of varying diameters, and the columns of liquid under it climbing up to different heights. Focusing on the **horizontal tube of varying diameters**, how would you explain this in terms of Bernoulli's Law? (5 pts)



3. In the days before scuba gear, some divers descended to underwater depths in *diving bells*, which are basically just upside-down containers whose open ends face down (towards the water; see the illustration below). The bell allows the person inside to breathe the air trapped inside it, observe underwater objects and marine life, and work under the water. If the bell is submerged to a depth of 30m below sea level, what is the water pressure at the air-water interface inside the bell? (5pts) Recall the thin tube and graduated cylinder previously. If the air pressure inside the bell before submersion into the water was 1 atm (101.825 kPa), roughly what air pressure does the person experience at that depth? (5pts)

4. (EXTRA CREDIT) In *Part (a), Experiment C,* you were told that you could calculate (via Method **b**) the pressure at the water/air interface inside the tube (near the bottom of the cylinder) by measuring the depth of the water from the water surface (air-water interface at **top** of the graduated cylinder) down to the bottom of the graduated cylinder (where the bottom, open part of the long thin tube also is). What if you had instead measured the depth from the water surface *down to the air-water interface inside the tube near the bottom of the cylinder* - would this result in a more accurate calculation of the pressure? Discuss with your lab partner(s) and explain why or why not. (5 pts)