**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 sheet of printer paper
b) 4 desks, each with 1 pyrex beaker, ruler or meter stick, wood block, scale, mineral or baby oil
c) 4 desks, each with 2 pyrex beakers, mineral oil, white plastic ball, plastic spoon, meter stick, scale

**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:

\[ \rho = \frac{M}{V} \quad \text{(Density = Mass/Volume)} \]

\[ P = \frac{F}{A} \quad \text{(Pressure = Force/Area)} \]
\[ P = P_0 + \rho g h \quad \text{(Pressure = Atmospheric Pressure + Density x Gravitational Acceleration x Depth)} \]

\[ F_{\text{buoyant}} = \rho g V_{\text{submerged}} \quad \text{(The buoyant force experienced by an object in a liquid = The density of the liquid x Gravitational Acceleration x The object's submerged volume)} \]

\[ P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2 \quad \text{(Bernoulli's Equation)} \]

Bernoulli's Equation is a conservation equation in which the total quantity on the left remains same as the total quantity on the right. It 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**

a. Results From Bernoulli's Equation

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 container of water and hold a second one perpendicular to it (as shown). Make sure that the end of the horizontal straw is half-obstructed by the vertical straw, and blow hard 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.

**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. Using a straw, vigorously blow air under the card. Explain what happens.

**Experiment C:** The deeper you go under water, 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 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:
\[ P_1 V_1 = P_2 V_2 \quad \text{or} \quad PV = \text{constant} \]

So basically, you can find the pressure at 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 two ways:

a) by measuring how much the air pocket in the thin tube changes, and
b) by using the equation for pressure as a function of depth

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:  
\[ V_{\text{cylinder}} = A_{\text{cross section}} h \]

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

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. Note that your density calculation will be very sensitive to the measurements you make, so make them carefully, and average numbers as needed. 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 (baby oil is also mineral oil with fragrance).

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

1) Design an experiment to find out the density of the wood block using only a beaker, water, and a meter stick. Do not use a weighing scale for this part.

2) Design a second, different experiment to measure the density of the wood block. You can use a weighing scale for this part.

NOTE: The order in which you do these two experiments will affect how their results agree with one another; hint – the block is porous.
Assessment and Presentation (Hand-in Sheet/Lab Notebook)

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

1. Did the amount of water on the block that was absorbed by the block of wood affect the results of the experiment? Would that water make your calculated density artificially high or artificially low?

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. How would you explain this in terms of Bernoulli’s Law?

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? 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), what air pressure does the person experience at that depth?