PHY 221 LAB 04-5 – Buoyant force

Objective

In this activity, you will investigate the force by a fluid on an object that is partially or completely submerged in a the fluid. This force is called a *buoyant* force.

Materials

1. a force sensor
2. a graduated cylinder
3. water
4. a cylinder with a hook
5. string

Background

A cylinder hangs by a string and it is completely immersed in water.

Sketch a picture, and sketch a free-body diagram for the cylinder.

Apply Newton's second law and solve for the buoyant force by the water on the cylinder.

As you can see, by measuring the tension in the string and the weight of the cyilinder, we can calculate the buoyant force by the water on the cylinder. We will use this technique in this experiment to determine: (1) how the buoyant force depends on the % volume of the cylinder that is immersed in the fluid and (2) how the buoyant force depends on depth in the fluid for a cylinder completely immersed in the fluid.

Procedure

1. Connect a force probe to Channel 1 on the LabPro interface.
2. Start the Logger Pro software.
3. Hold the force sensor vertically with the hook facing downward.
4. Zero the force sensor by clicking the Zero button in Logger Pro (next to the Collect button).
5. Use a cloth or paper towel to dry the cylinder if it is wet. Hang the cylinder from the force sensor using a string.

6. Click Collect while holding the cylinder steady, and measure the force on the force sensor by the string for a five to ten seconds.
7. Highlight a few seconds of data where the force is constant, and click the STAT icon to display statistics.
8. Record the average force on the force sensor in the first row of the data table below. This reading is equal to the tension in the string.
9. In this case, since there are no other forces acting on the cylinder, the tension should be equal to the weight of the cylinder.

Sketch a free-body diagram for the cylinder. Apply Newton's second law to calculate the weight of the cylinder.

weight =

10. Lower the cylinder until it is about 25% submerged, meaning about 25% of the cylinder is under water. Hold it steady and click Collect.
11. Again, use the STAT button to measure the tension in the string. Record the result in the table below.

Sketch a free-body diagram for the cylinder. Apply Newton's second law to calculate the buoyant force by the water on the cylinder.

F_B =

Record your result in the data table below.

12. Repeat for each of the positions described in the data table.
13. After collecting all of your data, take additional readings with the cylinder at various heights in the water, but be sure that for each reading, it is completely submerged. Record the depth beneath the surface, using a meterstick, and record the tension in the string.

Cylinder Position	Tension (N)	Buoyant force (N)
Cylinder completely in air		0
25% of cylinder under water		
50% of cylinder under water		
75% of cylinder under water		
Cylinder completely under water near the surface of the water		
Cylinder completely under water and near the bottom of the container		
depth beneath surface =		
depth beneath surface =		
depth beneath surface =		
depth beneath surface =		

Analysis

1. Based on your observations, does the buoyant force on the cylinder depend on the percentage of the volume of the cylinder that is submerged, for a partially submerged cylinder?

2. If half of the cylinder is submerged, how does the buoyant force on the cylinder compare to the buoyant force when 100% of the cylinder is submerged?

3. Though you only have a few data points, is the buoyant force on the cylinder proportional to the volume of the cylinder submerged?

4. **For a completely submerged cylinder**, does the buoyant force on the cylinder depend on depth in the fluid?

Application

1. Obtain a test tube (with stopper) and a set of BBs or paperclips.

2. Measure the mass of a BB or paperclip. Note: think about you experimental technique. Due to uncertainty in the balance, you should not attempt to measure the mass of one BB or paperclip. Instead measure the mass of many (25, 50, 100?) and calculate the mass of just one.

3. Measure the volume of the test tube (with stopper) using the water displacement method.

4. Suppose that you want the test tube (with BBs or paperclips inside) to just barely float in equilibrium (without sinking to the bottom nor emerging above the surface).

   (a) Sketch a free-body diagram for the system.

   (b) Apply Newton's second law and substitute for the buoyant force from Archimedes' Principle.

   (c) Calculate the density of the system in terms of the density of water. (No substitution of numbers are necessary.)

   (d) What must be the density of the system in this case? (Give a numerical answer.)

   (e) What must be the mass of the system in this case? (Give a numerical answer.)

   (f) How many BBs or paperclips must be added to the system in order to have the correct density to float in equilibrium while completely submerged, as in this case?

5. Add the appropriate number of BBs or paperclips to the system and test your calculation. Record the number of BBs or paperclips required for the test tube to just barely float in equilibrium (without sinking to the bottom nor emerging above the surface).