Buoyancy

Introduction

A fluid exerts an upward force on any object it surrounds. This is referred to as a **buoyant force**. Archimedes' Principle states that the buoyant force exerted on a body is equal to the weight of fluid that is displaced by that body. In general, if a volume V of an object is immersed in a fluid of density ρ, the buoyant force can be expressed as

$$F_B = \rho g V$$

The volume immersed V, may be the total volume of the object, or any fraction of the total volume.

Knowing the buoyant force on an object, and its physical size we can easily determine the density of the surrounding fluid. Similarly, if we know the density of the fluid we immerse an object in, and the volume of fluid it displaces, we can determine the weight of the object. It is also possible to use Archimedes' principle to determine the volume of irregular shapes that would otherwise be difficult to measure, by simply knowing the density of the fluid and the weight of the object.

Objectives

In this lab, you will be investigating the buoyant force exerted on a cylinder submerged in water.

You will use force probe to collect the average tension for the submerged cylinder at different depth.

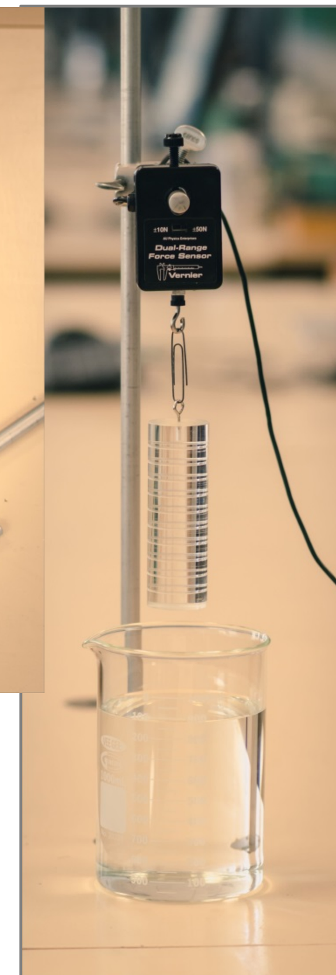
By analyzing the plot of Tension vs submerged depth, you can determine the density of water.

Apparatus and Setup

Materials

- Force probe
- $1000\ mL$ beaker
- Vernier Calipers
- Plastic cylinder
- Paper clips
- Assorted bars and clamps
- Water

Attach the force probe to one of the support bars as shown and connect it to CH 1 of the LabPro. Make sure that the force probe is set to "**5 N**" or “**10 N**” rather than to "50 N“.



Back to Basics

Q

QUESTION 1: Refer to Prelab 2, write the net force equation in terms of the mass of the cylinder m, its cross sectional area A, the density of the fluid ρ, distance submerged h, tension in the paper clip T, and gravity g.

Q

QUESTION 2: **a)** Sketch what a plot of T vs h would look like?

b) Write the equation for the slope of this graph.

c) Determine the expected y-intercept of this graph.

Measuring with Vernier Calipers

Vernier calipers are commonly used in laboratories for the precise measurements of dimensions.

Turn on the calipers with the OFF/ON switch.

Make sure the calipers are set to measure in $millimetres$ by pressing the $mm/inch$ button until the display shows mm.

Close the jaws of the calipers completely and press ZERO to zero the calipers.

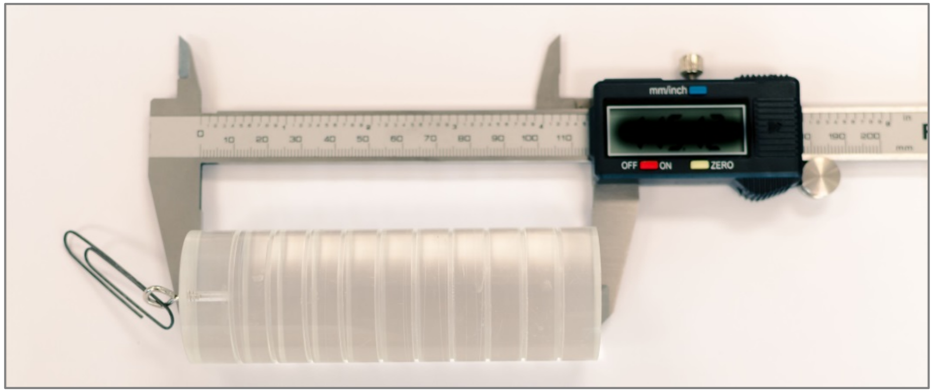
Be sure to turn off your calipers when you are finished.

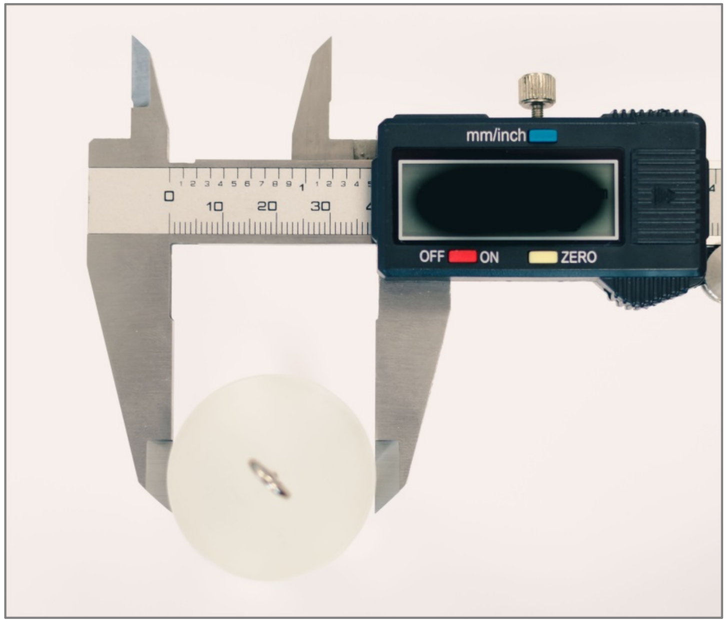
The experimental uncertainty associated with the Vernier calipers is 0.01 mm.

Preliminary Measurements

LW

Use the Vernier calipers to measure the length and diameter of the plastic cylinder and record it in **Table 1** of your Laboratory workbook, along with the associated experimental uncertainties.





Preliminary Measurements

LW

Calculate the cross-sectional area of the cylinder and record it in **Table 1** of your Laboratory Workbook.

Note: This is the circular cross-section of the bottom end of the cylinder. This value will need to be expressed in m^2.

LW

Also calculate and record the experimental uncertainty for the area.

LW

Use a balance to obtain the mass of the cylinder and record it in **Table 1** of your Laboratory workbook.

Click on the icon below to launch *LoggerPro.*

CLICK HERE CLICK HERE

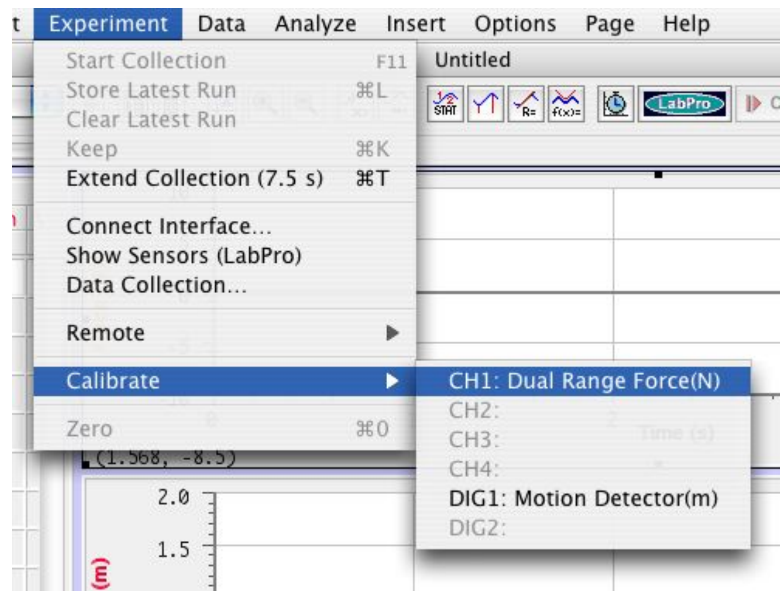
LoggerPro will display a graph of force vs time.

Calibrating the Force Probe

Use a $200\ g$ mass for calibration.

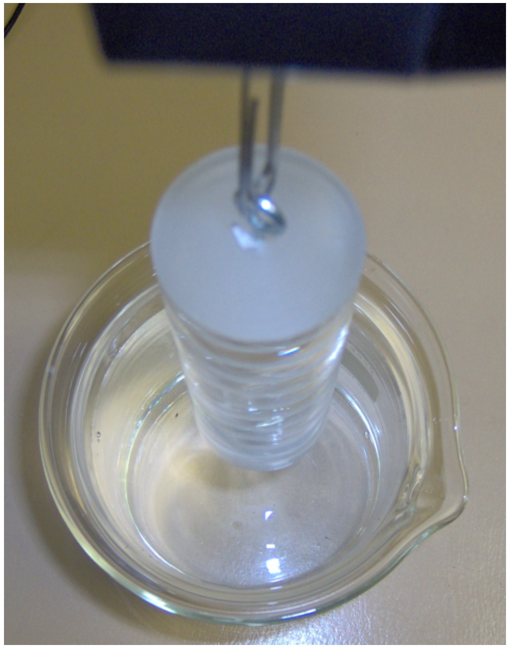
Remember that a $1\ kg$ mass weighs $9.81\ newtons$. You need to determine the weight of the $200\ g$ mass.

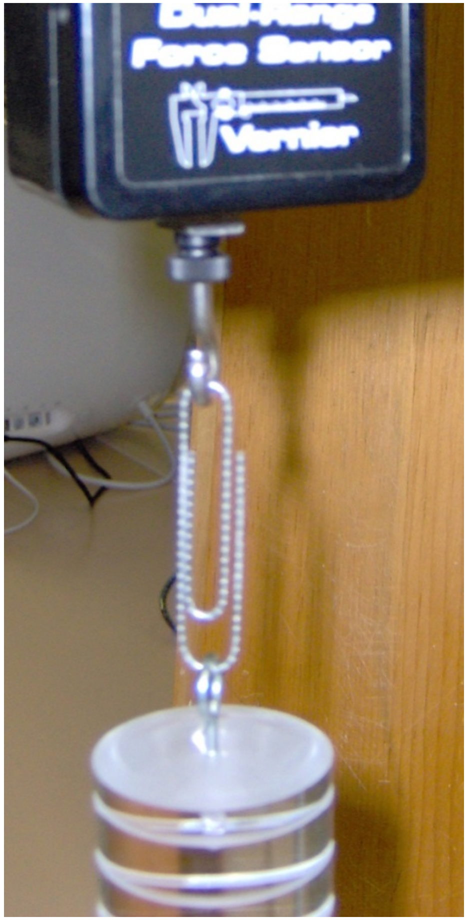
- Click **Experiment**, then **Calibrate**.
- Click **Dual Range Force**.
- Click the **Calibrate now** button.
- With nothing hanging from the force probe enter 0 in the Value box and click **Keep**.
- Now hang the $200\ g$ mass from the force probe and enter its weight in the Value box and click **Keep**.
- Click **Done**.



Setup

- Carefully hang your cylinder from the force probe using a paper clip.
- Position the filled beaker so that the cylinder that is hung from the force probe is directly above its center.
- Return to *LoggerPro*.
- Press Collect.
- When collection is finished you should get a straight, flat line.
- Click **Analyze** then **Statistics**.
- The weight of the mass is the average value of all the force readings.





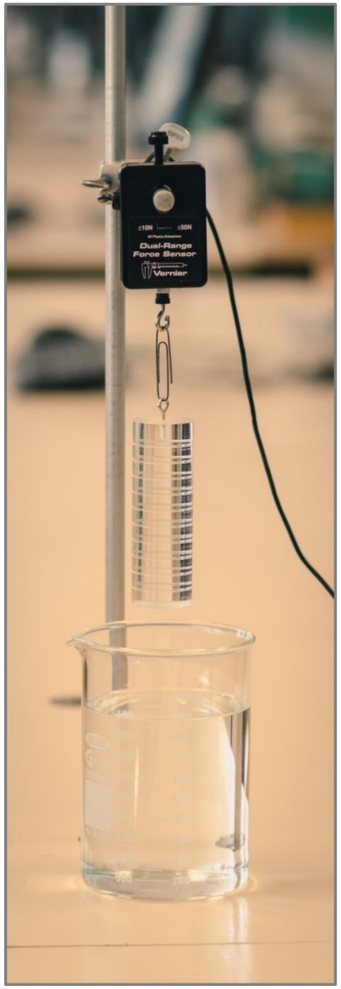
Data Acquisition

Check your value! Using the mass recorded in Table 1, calculate the weight of your cylinder. If your two values of weight are significantly different, check that you have calibrated and zeroed your force probe correctly.

LW

- Record the submerged depth and the average force of tension in **Table 2** of your Laboratory workbook.
- Now lower the force probe and cylinder assembly until the cylinder is submerged by $1.0\ centimeter$.

Note: The calibrated markings on the cylinder are at $1.0\ centimeter$ intervals measured from the bottom.



Data Acquisition (continued)

Be careful with your depth reading! Misjudging the meniscus level of the water may introduce a large uncertainty.

- If possible remove any bubbles from the bottom of your cylinder.
- LW Record the submerged depth and average force in **Table 2**.
- LW Continue to lower the cylinder in $1\ cm$ increments and record the submerged depths and average forces until the cylinder is **completely submerged**.

Be sure to reduce the motion of the cylinder as much as possible before taking a reading.

Once data collection is complete, raise the cylinder to allow it to dry.

Prepare Your Plot

Launch *Graphical Analysis* by clicking on the icon below.

CLICK HERE GA CLICK HERE

- Enter the depths, in *metres*, into the ***x column*** of the data table window.
- Enter the force values, in *newtons*, in the ***y column*.**
- Label the columns in your data table and put in the appropriate units. Title your graph.
- To fit the data to a straight line select **Analyze** and then **Linear Fit**.
- Double click on the pop-up box which appears and check the box for **Show Uncertainties**.
- Enter the values of the fitting data into **Table 3** of your Laboratory workbook.
- Print the graph, making sure to include fit box.

LW

P

CP

Have an instructor check your work and initial your lab report.

What does it all mean?

Q **QUESTION 3:** Calculate the density of water, ρ, from your fit to the *T vs. h* graph. Also calculate the uncertainty. Write your answer in the form $\rho \pm \delta\rho$.

Q **QUESTION 4:** Does the value of ρ calculated from your data agree with the accepted value of $(1000 \pm 50)\ kg/m^3$? Calculate the range of your experimental value and see if the accepted value agrees.

Q **QUESTION 5:** **a)** What is the physical meaning of the intercept on your *T vs. h* graph?

b) Does it agree with your answer in Question 2? If not, why not?

Q **QUESTION 6**: **a)** Give at least two sources of uncertainty in this experiment and classify them as random or systematic.

b) What is the primary source of uncertainty in this experiment?

Wrap it up!

- Check that you have completed all the **Tables** of your Laboratory workbook.
- Make sure that you have answered all the **Questions** completely.
- Attached to your Laboratory workbook should be the following graph: ***Tension vs. Depth Submerged***