Buoyancy
Apparatus and Setup

Materials

- Force probe
- 1000 mL beaker
- Vernier Calipers
- Plastic cylinder
- String or 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"
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.
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

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 end of the cylinder.

Also calculate and record the experimental uncertainty for the area.

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.

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.
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.

- 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.
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.
- Record the submerged depth and average force in Table 2.
- 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.
QUESTION 1: Draw the free body diagram for the cylinder when it is partially submerged. Label all forces clearly.

QUESTION 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 $\rho$, distance submerged $h$, tension in the paper clip $T$, and gravity $g$.

QUESTION 3:

a) What would a plot of $T$ vs $h$ look like? Explain.

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

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

Have an instructor check your work and initial your lab report.
Prepare Your Plot

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

- 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**.
- Print the graph, making sure to include regression statistics.
- Enter the values of the slope and intercept of the regression line, and their associated experimental uncertainties, into **Table 3** of your Laboratory workbook.
What does it all mean?

**QUESTION 4:** Calculate the density of water, \( \rho \), from your fit to the \( T \) vs. \( h \) graph. Also calculate the uncertainty. Write your answer in the form \( \rho \pm \delta \rho \).

**QUESTION 5:** Does the value of \( \rho \) calculated from your data agree with the accepted value of 1000 kg/m\(^3\)? Comment.

**QUESTION 6:**

a) What is the physical meaning of the intercept on your \( T \) vs. \( h \) graph?

b) Does it agree with your answer in Question 3? If not, why not?

**QUESTION 7:**

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