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Activity P13: Buoyant Force
(Force Sensor)

Equipment Needed	Qty	Equipment Needed	Qty
Economy Force Sensor (CI-6746)	1	**Mass and Hanger Set (ME-9348)**	1
Base and Support Rod (ME-9355)	1	Ruler, metric	1
Beaker, 1000 mL	1	**String (SE-8050)**	1 m
Calipers (SF-8711)	1	**Support rod (ME-8736)**	1
Clamp, right-angle (SE-9444)	1		
Cylinder, w/ hook (from ME-8569)	1	**Other**	**Qty**
Graduated cylinder	1	Water	800 mL
Lab Jack (SE-9373)	1	*Vegetable oil (optional)*	800 mL

What Do You Think?

Why is it easy to float in the ocean? In which would you feel a stronger buoyant force: a swimming pool filled with oil or with syrup?

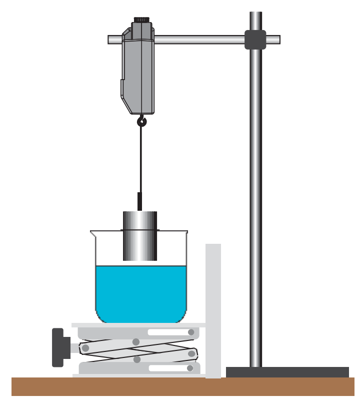
Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Archimedes' Principle states that the buoyant upward force on an object entirely or partially submerged in a fluid is equal to the weight of the fluid displaced by the object.

$$F_b = m_f g = \rho_f V g$$

where ρ_f is the density of the fluid, V is the submerged volume of the object, and g is the acceleration due to gravity.



The submerged volume is equal to the cross-sectional area, A, multiplied by the submerged height, h. So the buoyant force can be written as:

$$F_b = \rho_f (Ah) g$$

If the object is lowered into the fluid while the buoyant force is measured, the slope of the graph of F_b versus h is proportional to the density of the fluid.

SAFETY REMINDER

- Follow the directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

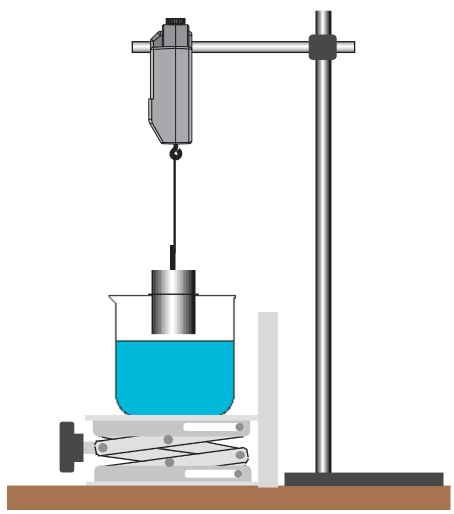
PART I: Sensor Calibration and Equipment Setup

• To calibrate the Force Sensor, refer to the description in the Force Sensor Manual.

1. Mount the Force Sensor on a horizontal rod with the hook end down.
2. Using the calipers, measure the diameter of the metal cylinder. From the diameter, calculate the radius and the cross-section area. Record the cross-section area in the Data Table in the Lab Report section. Recall:

$$A = \pi R^2$$

3. Hang the metal cylinder from the Force Sensor hook with a string.
4. Put about 800 mL of water into the beaker and place the beaker on the lab jack below the hanging cylinder. The bottom of the cylinder should be touching the water.
5. Position the metric ruler next to the edge of the lab jack. Note the initial height of the top of the lab jack.



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PART III: Data Recording

- Before recording data for later analysis, you may wish to practice using keyboard sampling to collect data.

1. With the cylinder attached to the Force Sensor hook, press the <u>tare</u> button on the Force Sensor to zero the sensor.
2. Record Force vs. Depth data as you submerge the cylinder.

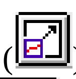
<u>In *DataStudio*</u>, move the Table display so you can see it clearly.

- Click on the 'Start' button to start recording data. The 'Start' button changes to a 'Keep' and a 'Stop' button (

). The Force will appear in the first cell in the Table display. Click the 'Keep' button to record the force value.
- Immerse the cylinder 5 millimeters (5 mm or 0.005 m) by <u>raising</u> the beaker of water 5 mm with the lab jack. Use the metric ruler to measure the distance that you raise the lab jack.
- Click the Keep button to record the next Force value at the depth of **0.005** m.
- Increase the depth of submersion by increments of 5 mm. After each increase in the submersion, wait for the force reading in the display to stabilize, then click the Keep button to record a Force value at the appropriate depth.
- Repeat the data recording procedure until the top of the cylinder is submerged. Stop data recording by clicking on the 'Stop' button. Run #1 will appear in the Summary window.

Analyzing the Data

1. Determine the slope of the Force vs. Depth Graph.

- In *DataStudio*, click the 'Scale to Fit' button () to rescale the Graph axes to fit the data. Next, click the 'Fit' menu button (

). Select 'Linear'.

2. Record the slope of the linear fit in the Data Table in the Lab Report section.
3. Calculate the density of water by setting the slope equal to $\rho A g$ and solving for ρ. Record the value for the density in the Data Table in the Lab Report section.
4. Compare the calculated value to the accepted value by calculating the percent difference.

Record your results in the Lab Report section.

Lab Report - Activity P13: Buoyant Force

What Do You Think?

Why is it easy to float in the ocean? In which would you feel a stronger buoyant force: a swimming pool filled with oil or with syrup?

Data Table

Item	Value
Area of Cylinder	
Slope (from graph)	
Density of water (calculated)	
Density of water (accepted)	

Questions

1. How does your experimental value compare to the accepted value for the density of water? What is the percent difference?

2. Why was the Force Sensor zeroed after the cylinder was attached to the hook?

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Optional

Substitute vegetable oil for the water in the beaker and repeat the experiment. Compare the result for the density of oil to a value calculated by weighing a known volume of oil.

Data Table

Item	Value
Area of Cylinder	
Slope (from graph)	
Density of oil (from slope)	
Mass of beaker	
Mass of beaker and oil	
Volume of oil	
Density of oil (mass/volume)	

Optional Questions

1. How does the experimental value for the density of oil compare to the value determined by the mass/volume method? What is the percent difference?

2. Is vegetable oil less, more, or equally as dense as water?