Name EVAN Hamilton Date_____ Period_____

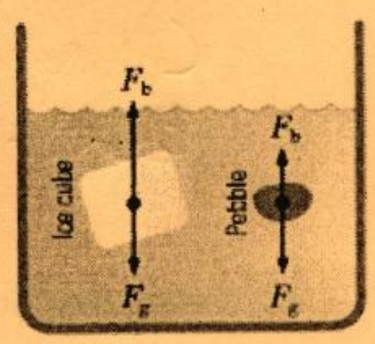
Buoyant Force Lab

Driving Question

What are the relationships between the buoyant force on an object submerged in a fluid and a) the volume of the submerged object, and b) the weight of the fluid displaced by the submerged object?

Background

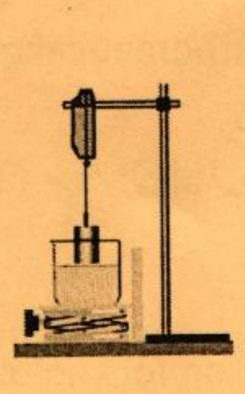
Have you ever noticed that it is easier to lift an object that is submerged in water? Or wondered why injured athletes may be prescribed aqua therapy to regain their strength? When an object is submerged in a fluid (which includes both liquids and gases), it experiences an upward buoyant force F_b that opposes gravitational force F_g. This is the reason ice floats on the top of water, and a balloon filled with helium rises in air. If we define F_g in the negative direction, a submerged object will rise in the fluid if the net force is positive (the condition of ice rising in water, or a helium balloon rising in air), and sink if it is negative (the condition of a rock sinking in a pond).

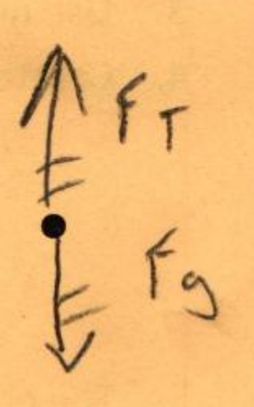


The magnitude of the gravitational force acting on an object is proportional to its mass, but it is easily observable that the buoyant force acting on a submerged object is not proportional to the object's mass: a small rock may have the same mass as a tennis ball, but a tennis ball floats in water and the rock does not. So, what is different between these two objects? Their masses may be the same but their volumes are different, and so is the volume of water displaced by each once submerged.

Pre-Lab Questions

1. The dot at the right represents a cylinder suspended by a string and partially submerged in water. Draw and label arrows that represent the forces that are exerted on the block. Each force must be represented by a distinct arrow starting on and pointing away from the dot. The length of the arrows reflect the magnitude of the forces.
2. Using your sum of the forces equation for the FBD, state an expression for the force of the water (Buoyant Force, F_B) in terms of the F_T, m and known physical constants.





3. What do you expect to happen to the force measured by the sensor, F_T, as more of the object is submerged in water?

The Force will lessen as it is submerged!

$F_B = mg - F_T$

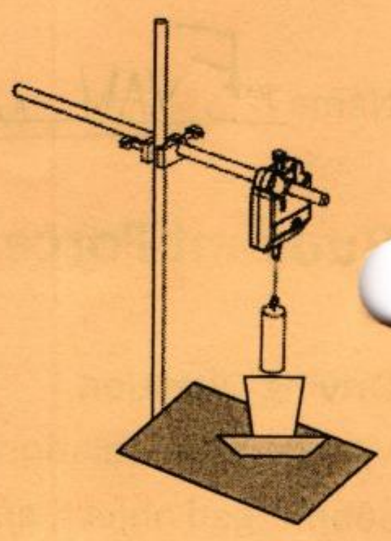
$\Sigma F_y = F_T + F_B - F_g = 0$

Data Collection

1. Measure the dimensions of your object and calculate the volume and record in the data table below. Measured dimension(s) 3.98 cm r=.625 h=3.25cm
2. Make small marks along the side of your object that represent $\frac{1}{4}$, $\frac{2}{4}$, and $\frac{3}{4}$ of the volume of your object submerged in water. Calculate the volume and record in the data table below.
3. Place the overflow container on the balance and tare the balance.

Adapted from Pasco Scientific

4. Assemble the apparatus as shown at right. Connect the force sensor as instructed by your teacher. Record the values in the data table for a submerged depth of 0.
5. Slowly fill the cup with the water until it reaches the top of the cup. Use a pipette to add water to the cup dropwise until the extra drop spills over the edge.
6. Slowly lower the crossbar with the force sensor so that ¼ of the object is submerged. Record the force measured by the sensor, F_T and the mass of the water that was displaced.
7. Repeat step 3, 5 and 6 for the remaining depths in the data table.



Data and Analysis

1. Use your FBD to determine the buoyant force at each depth. Show your work for one calculation and record the remaining values in the table.

Calculation Work
0.28 - 0.26 = 0.02 ...
↳ $m_{displaced}$

2. Calculate the weight of the water displaced ($F_{g\ displaced}$). Show your work for one calculation and record the remaining values in the table.

$\left(\frac{m_{disp}}{1{,}000}\right) \times 9.8$

$\left(\frac{2}{1{,}000}\right) \times 9.8 = 0.0196\ N$

Depth	$V_{submerged}$ (cm_3)	F_T (N)	$m_{displaced}$ (g)	F_B (N)	$F_{g\ displaced\ water}$ (N)
0 V	0	.28	0	0	0
1/4 V	0.997	.26	2	.02	0.0196
1/2 V	1.994	.25	3	.03	0.0294
3/4 V	2.991	.24	4	.04	0.0392
V	3.998	.22	5	.05	0.0496

↳ Divide by 1,000,000 for graphing

3. Use n-Plot to create a graph of submerged volume on the horizontal axis and buoyant force on the vertical axis.
4. Create mathematical models for your graph, including the 5% rule.

Buoyant Force = (12009.96)(Submerged Volume) + 0.004

$\frac{0.0004}{0.05} \cdot 100 = 8\% =$ 1 Significant

5. The equation for the buoyant force is:

$$F_B = \rho V g$$

Where ρ is the density of the fluid and *V* is the volume of fluid displaced. Circle and label the variable plotted on the vertical axis. Circle and label the variable plotted on the horizontal axis. What does the slope of your line represent? P × G

6. Use n-Plot to create a graph of $F_{g\ displaced}$ on the horizontal axis and buoyant force on the vertical axis. Get teacher approval before printing. Archimedes' principle states that an object completely or partially submerged in a fluid experiences an upward buoyant force equal in magnitude to the weight of the fluid displaced by the object. Does your data support this statement? If yes, explain how it supports it; if no, identify which data do not support it, and what may have caused this disagreement.

No. There has been too many errors either procedural, equipment, or poor measurment to where our data reflects a poor representation of this principle, not to mention using soapy water.

nPlot

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Sheet 1 | Sheet 2 | Sheet 3 | Sheet 4 | Sheet 5

	x data	y data	± x	± y	skip
1	0	0			
2	9.97e-7	0.02			
3	0.00000	0.03			
4	0.00000	0.04			
5	0.00000	0.05			
6					
7					
8					
9					
10					
11					
12					

Settings | Swap x & y | Clear Data

X label: Submerged Volume X units: cm

Y label: Buoyant Force Y units: N

Title: Submerged Volume v Buoyant Force (Evan & Noam)

Save graph as: 0.03

Save Graph | Recall Graph | Graph to Clipboard

Models:

- None
- No Relation
- Exactly Proportional: $y = x$
- Proportional: $y = Ax$
- Linear: $y = Ax + B$
- Square Law: $y = Ax^2$
- Quadratic: $y = Ax^2 + Bx + C$
- Inverse: $y = A/x$
- Inverse Square: $y = A/x^2$
- Square Root: $y = A\sqrt{x}$

Advanced Models

- Power Law: $y = Ax^B$
- Exponential: $y = Ae^{x/B} + C$
- Inverse Square Root: $y = A/\sqrt{x}$

$A = 12009.960 \pm 1162.85770000$

$B = 0.0040281201 \pm 0.00284366$

$RMSE = 0.0036736090$

Tangent Finder Yes, download

Lock To Data Include fit

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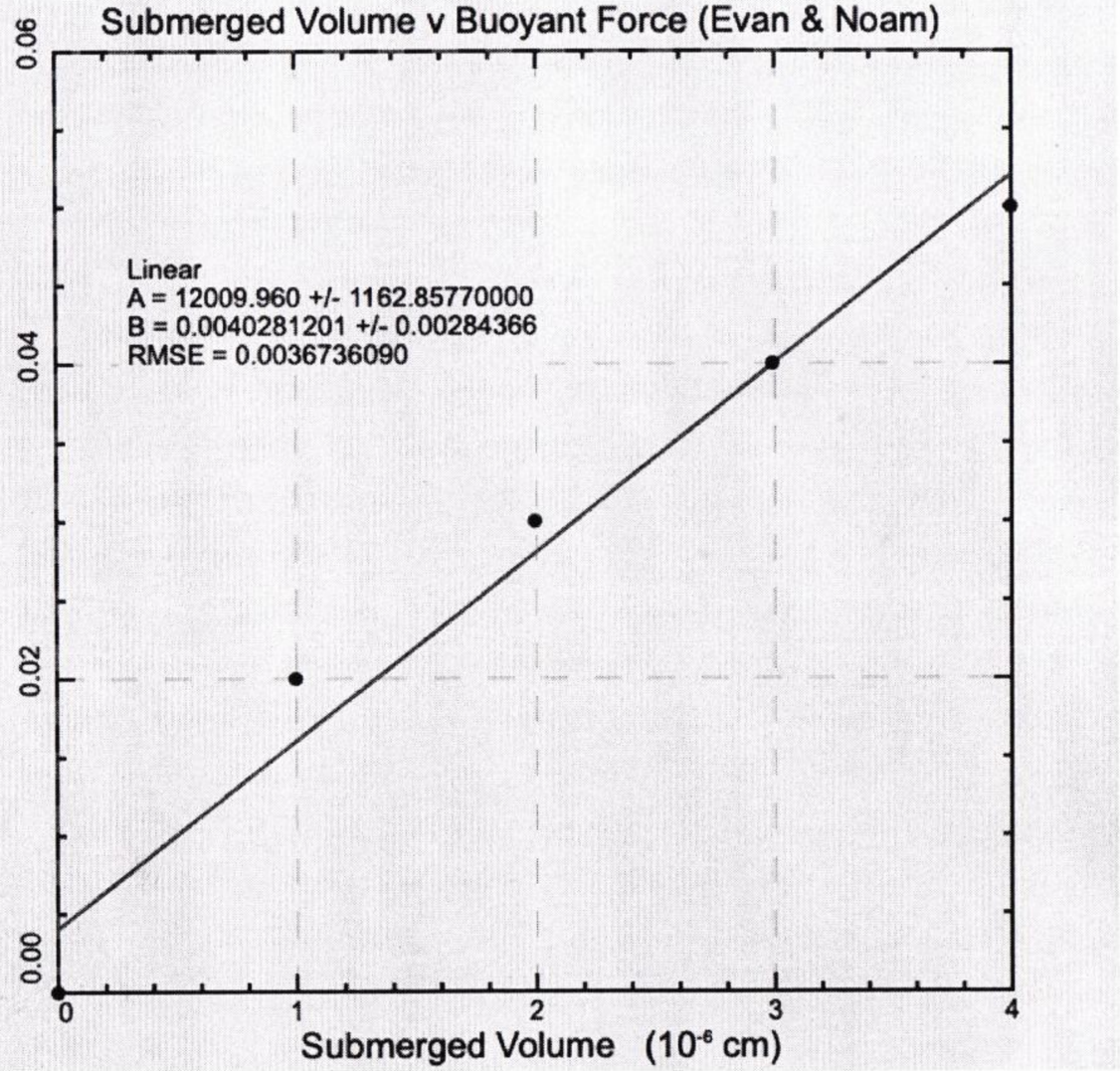

nPlot

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Sheet 1 | Sheet 2 | Sheet 3 | Sheet 4 | Sheet 5

	x data	y data	± x	± y	skip
1	0	0			
2	0.0196	0.02			
3	0.0294	0.03			
4	0.0392	0.04			
5	0.0496	0.05			
6					
7					
8					
9					
10					
11					
12					

Settings | Swap x & y | Clear Data

X label: Fg displaced X units: N

Y label: Buoyant Force Y units: N

Title:

Save graph as:

Save Graph | Recall Graph | Graph to Clipboard

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- Square Root: $y = A\sqrt{x}$

Advanced Models

$A = 1.0110863 \pm 0.00633148$

$B = 0.00013446149 \pm 0.00020507$

$RMSE = 0.00024089210$

Tangent Finder Yes, download

Lock To Data Include fit

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