Archimedes' Principle

Equipment

1	Smart Cart (Blue)	ME-1241
1	Smart Cart Rod Stand Adapter	ME-1244
1	Density Set	ME-8569
1	Braided String	SE-8050
1	90 cm Rod	ME-8738
1	45 cm Rod	ME-8736
1	Multi-Clamp	ME-9507
1	Large Rod Base	ME-8735
1	String	SE-8050
Required but not included:		
1	PASCO Capstone Software	
1	Calipers	SE-8710
1	1000 ml Beaker (for water)	SE-7288

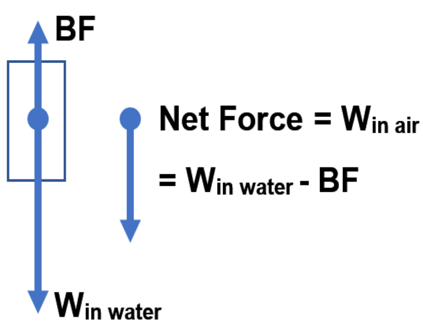
Figure 1: Measuring the Buoyant Force

Introduction

Archimedes' Principle states: "When an object is submerged in a fluid, the fluid exerts an upwards buoyant force equal to the weight of the fluid displaced by the object".

In this lab, the buoyant force on an object is measured by taking the difference between the object's weight in air, and its apparent weight in water. This measured buoyant force is compared to the theoretical value calculated using the object's volume, and Archimedes' Principle.

Several objects of different shapes are examined: Some of the objects have the same density, some have the same volume, and some have the same mass. The dependence of the buoyant force on density, mass, volume and shape is explored.



When an object is submerged in a fluid, the apparent weight of the object is less than the weight in air because of the upward buoyant force. Thus, the buoyant force can be calculated by finding the difference between the weight of the object in air and the apparent weight of the object when it is submerged in water.

Setup

1. Mount the rod on the large rod base.

2. Mount the Rod Stand Adapter into the top of the Smart Cart.

3. Screw the hook into the force sensor of the Smart Cart.

4. Attach the Rod Stand Adapter to the top of the rod stand with the hook end of the Smart Cart pointed down.

5. Tie a piece of string onto each of the masses. Tie a loop on the other end of the string so that it can be hooked onto the sensor.

6. Put 1000 ml of water in the beaker, but don't submerge the samples yet!

7. In PASCO Capstone, leave the sample rate on the default sample rate. Change the Sampling Mode to Fast Monitor.

8. Create a table as shown below. Create a User-Entered Data set called "Object" and fill in the types of objects. Create User-Entered Data sets called "W air" (Weight in air) and "W water" (Weight in water), both with units of N. The last column contains a calculation.

   Table I: Buoyant Force = Weight in Air – Weight in Water

Object	W air (N)	W water (N)	Wair – Wwater (N)
Brass Cylinder			
Aluminum Cylinder			
Brass Cube			
Aluminum Cube			
Aluminum Shape			

   In the Capstone calculator, create the following calculations:

   Wair - Wwater = [W air (N)]-[W water (N)] with units of N
   Weight = [Force (N)] with units of N
   Buoyant Force = ρ*[Volume (cc)]*g/1000 with units of N
   ρ = 1.00 with units of g/cm^3
   g = 9.81 with units of m/s^2

9. Create a Digits display with the calculation "Weight".

Procedure: Using Weight

1. Without anything hanging from the hook, zero the Smart Cart Force Sensor in Capstone.

2. Hang the brass cylinder on the Force Sensor with the beaker moved out of the way, so that the sample hangs in air.

3. Record the weight in the "W air" column of Table I.

   Note that you don't need to start and stop recording. The program is in "Monitor" mode, where it continually updates the display, but doesn't actually record any data.

4. Move the beaker with water under the Force Sensor, and hang the sample completely submerged as shown in Figure 1. Adjust the height if necessary.

5. Record the weight in the "W water" column. Note that the buoyant force = "weight in air - weight in water" is automatically calculated in the last column.

6. Repeat for the other listed samples, including the irregularly shaped aluminum piece. Always check to make sure that the weight reads zero with the sample removed, and that the sample is completely submerged but not touching the bottom when measuring in water.

7. When you have made all your measurements, click on Stop.

Procedure: Using Volume

8. Create a table as shown below. Select "Object" in the first column. Create a User-Entered Data set called "Volume" with units of cc. Select the calculation "Buoyant Force" in the third column.

   Table II: Buoyant Force = Weight of Fluid Displaced

Object	Volume (cc)	Buoyant Force (N)
Brass Cylinder		
Aluminum Cylinder		
Brass Cube		
Aluminum Cube		
Aluminum Shape		

9. Use calipers to measure the radius and height of the brass cylinder, and record your measurements.

10. Calculate the volume of the cylinder and record the value in Table II.

11. Note that the Buoyant Force = "weight of water displaced" is automatically calculated in the last column. Calculate the value yourself to confirm that it is correct. Pay attention to the units! Remember that the relationship between mass (m), density (ρ) and volume (V) is

    $$m = \rho V$$

    Hint: To calculate the weight of water displaced, you must use the density of water!
    ρ_{water} = 1.00 g/cc
    Finally, remember that the buoyant force is the weight of the displaced fluid, not just the mass. You can look at the equation used in the Calculator for help.

12. Use calipers to measure the dimensions of the other samples and record their volumes in the table. To calculate the volume of the irregularly shaped object, use its weight and assume it has the same density as the other aluminum shapes.

Analysis

13. Create a table as shown below. Select "Object" in the first column, "Wair – Wwater" in the second column, and "Buoyant Force" in the third column. Create a User-Entered Data set called "% Difference" in the fourth column.

    Table III: Weight Method vs. Volume Method

Object	Wair – Wwater (N)	Buoyant Force (N)	% Difference
Brass Cylinder			
Aluminum Cylinder			
Brass Cube			
Aluminum Cube			
Aluminum Shape			

14. Table III shows the results for the buoyant force calculated using the apparent weight (weighing method) and directly using Archimedes' Principle (volume method). What do you conclude?

15. Calculate the % difference for each sample.

16. Which other samples have approximately the same volume as the aluminum cylinder? How do their values for the buoyant force compare? Explain how this can be, even when the other sample doesn't have the same mass, density, size or shape?

17. If you re-did this experiment with the brass mass only half submerged, what would change? Would the "weight method" still give you the same answer for the buoyant force as the "volume method"? Try it!

18. The plastic cylinder that comes with the Density Set floats in water. What does it tell you about its density? What is its apparent weight when floating? What is the buoyant force acting on it while floating? What would be the buoyant force if it was completely submerged?

19. If you added salt to the water in the beaker, it would change its density. How could you use the apparent weight of the brass cylinder hanging in the salt water to find this new density? Try it!