Archimedes' Principle

Equipment

Qty	Description	Part #
1	Density Set	ME-8569A
1	Overflow Can	SE-8568A
1	Large Rod Base	ME-8735
1	45 cm Steel Rod	ME-8736
1	Physics String	ME-8050
1	Ohaus Triple beam Balance	SE-8707
1	Stainless Steel Caliper	SF-8711
1	1000 ml beaker	
1	100 ml beaker	
1	50 ml graduated cylinder	

Introduction

The buoyant force on several objects is measured by weighing the water displaced by the object as it is submerged. The buoyant force is also determined by measuring the difference between the object's weight in air and its apparent weight in water.

Some of the objects have the same density, some have the same volume, and some have the same mass. The density of each object is measured and the dependence of the buoyant force on density, mass, and volume is explored.

Part I: Mass, Volume, and Density

Theory

The density (ρ) of an object depends on its mass (m) and volume (V):

$$\rho = \frac{m}{V}$$

Procedure

1.   Using the triple-beam balance, find the mass of each of the six objects in Figure 1. List the objects in order from least to greatest mass. Are any of the masses nearly the same?

Figure 1: Set of Objects

2.   Using the calipers, measure the dimensions of the 3 cylinders and the 2 blocks. Remember to divide the diameter by 2 to get the radius, r. Calculate the volume of these objects.
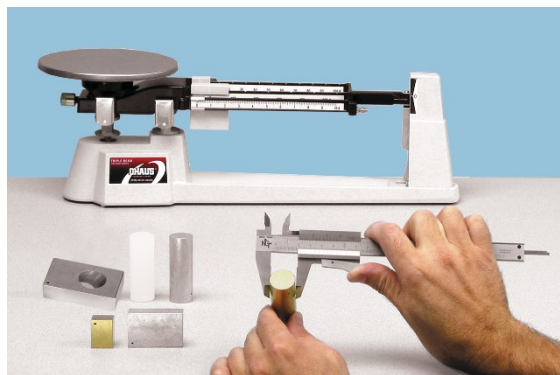
3.   There is no simple formula for the volume of the irregularly shaped object so it is necessary to find the volume by measuring the volume of water it displaces:

   A.   Put the beaker under the overflow can spout as shown in Figure 2.

   B.   Pour water into the overflow can until it overflows into the beaker. Allow the water to stop overflowing on its own and empty the beaker into the sink and return it to its position under the overflow can spout without jarring the overflow can.
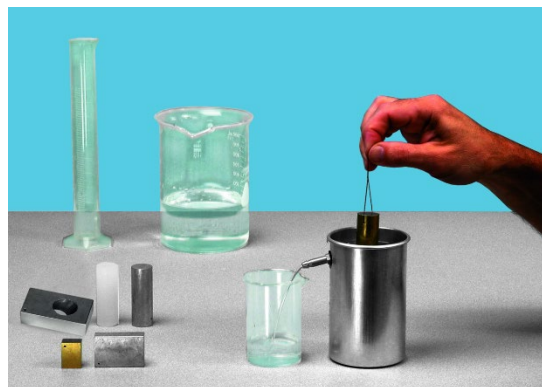
   C.   Tie a string on the irregular object.   Figure 2: Overflow Can

   D.   Gently lower the irregular object into the overflow can until it is completely submerged. Allow the water to stop overflowing and then pour the water from the beaker into the graduated cylinder. Measure the volume of water that was displaced by reading the water level in the graduated cylinder in milliliters (1 ml = 1 cm^3).

4.   List the 6 objects in order from least to greatest volume. Is this the same order as the mass list? Are any of the volumes nearly the same?

5.   Calculate the density of each object. List the 6 objects in order from least to greatest density? Is this list in the same order as either the mass list or the volume list? Do any of the objects have densities that are nearly the same?

6.   Group the objects according to the type of material of which they are made. In which list (mass, volume, or density) are the objects grouped similarly?

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Part II: Finding the Buoyant Force Using Archimedes' Principle

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

For each of the objects, find the weight of the water displaced by each one:

1.   Find the mass of the beaker. Put the beaker under the overflow can spout as shown in Figure 2.

2.   Pour water into the overflow can until it overflows into the beaker. Allow the water to stop overflowing on its own and empty the beaker into the sink and return it to its position under the overflow can spout without jarring the overflow can.

3.   Tie a string onto each of the objects.

4.   Gently lower the first object into the overflow can until it is completely submerged. Allow the water to stop overflowing. Find the mass of the water plus beaker. Subtract the mass of the beaker to determine the mass of the water alone. Multiply the mass by the acceleration due to gravity to find the weight of the displaced water.

5.   Repeat this procedure for the other objects. Note that the plastic cylinder will float so don't try to completely submerge it in the water. Also find the weight of the displaced water when only half the brass cylinder is submerged.

6.   List the objects in order from least buoyant force to greatest buoyant force. Is this in the same order as the mass list, the volume list, or the density list? Are any of the buoyant forces nearly the same? Why or why not?

Part III: Finding the Buoyant Force by Finding the Upward Force

Theory

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 (see Figure 3). 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.
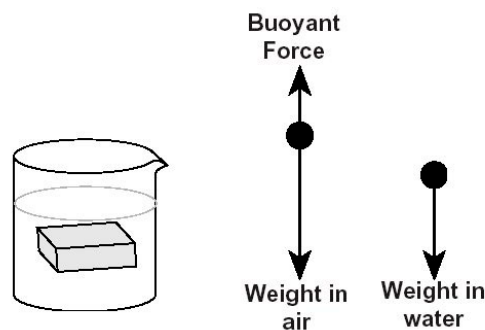

Figure 3: Force Diagram

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Procedure

1.   Put the triple-beam balance on top of a stand as shown in Figure 4. Tie a string to the bottom of the pan and put a paperclip hook on the end of the string. Zero the balance.

2.   Hang the first object from the string. The balance will read the same as when the object is placed on top of the pan. Multiply the mass by the acceleration due to gravity.

3.   While the object is still hanging from the balance, submerge the object in a beaker of water so that the entire object is under water but it is not touching the sides or bottom of the beaker. Record the reading on the scale and multiply by gravity to get the apparent weight. The scale reads in units of mass: Does the mass of the object change when it is submerged in the water? What actually changes?

Figure 4: Weighing in Water

4.   Calculate the buoyant force by taking the difference between the weight in air and the weight in water.

5.   Repeat these steps for all the objects. Note that the plastic cylinder will float so don't try to completely submerge it in the water. Also, for the half-submerged brass cylinder, find the apparent weight in the water when only half the cylinder is submerged. NOTE: The weight in air of the brass cylinder is still the whole weight.

6.   Compare the buoyant forces found by this method to those found using Archimedes' Principle.

Questions

1.   In each case, is the buoyant force that was determined using the upward force equal to the weight of the water displaced?

2.   Which objects had the same buoyant force when submerged? Why?

3.   For the plastic cylinder, what was the apparent weight in water?

4.   How was the buoyant force for the totally submerged brass cylinder related to the buoyant force for the half-submerged brass cylinder?

5.   What does the buoyant force depend on: The mass of the object, or its volume, or its density, or the material from which it is made?

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