ARCHIMEDES' PRINCIPLE

Objective

To determine the densities of irregularly shaped objects using Archimedes' Principle.

Equipment

Balance on a ring stand, beaker (600ml), string, metric ruler, aluminum cube, unknown cylinder, distilled water.

Introduction

A body at rest in a fluid experiences a upward pushing force called the buoyant force, which is equal to the weight of the fluid displaced by that body. This is known as **Archimedes' principle**.

If we have an object of mass m and volume V, its density ρ is given by:

$$\rho = \frac{m}{V} \tag{1}$$

In this lab, the units of density will be g/cm^3.

If the object is weighed when submerged in a fluid, it will have an apparent weight, $w' = m'g$, where m' is its apparent mass and g is the acceleration due to gravity. Using Archimedes' principle, we can obtain the equation:

$$mg - m'g = m_f g \tag{2}$$

which can be read as "the weight of the object minus the apparent weight of the object equals the weight of the fluid displaced by the object." In equation 2, the term m_f is the mass of the fluid displaced.

If the fluid has a density, $\rho_f = (m_f/V_f)$, the substitution $\rho_f V_f$ can be made for m_f in equation 2 and we get:

$$mg - m'g = \rho_f V_f g \tag{3}$$

Remember that the volume of the fluid displaced is equal to the volume of the submerged object. Now, if we use equation 1, and substitute (m/ρ) for V_f in equation 2, and divide both sides by g, we get:

$$m - m' = \rho_f(\frac{m}{\rho}) \tag{4}$$

Solving for the density of the object, ρ, we get:

$$\rho = \rho_f(\frac{m}{m - m'}) \tag{5}$$

Equation 5 means that if we have a fluid of known density, ρ_f, and we can measure the mass of the object, m, and the apparent mass while submerged, m', we can determine the density of the object with no regard to its shape.

Activity 1.

1) Using the triple beam balance, measure the mass of the aluminum cube and the unknown cylinder. These measurements should be in units of grams (g). Record the masses in the appropriate table on the data sheet.

Activity 2.

2) Fill the beaker one-half to two-thirds full with distilled water. Place the balance on the ring stand.

3) Cut a length of string approximately the length from the bottom of the balance to the table top. Tie one end of the string to the aluminum cube. There is a small clip directly under the balance pan. Tie the other end of the string to this clip, with the cube next to the beaker. Make sure the cube can be fully submerged in the beaker of water.

4) Suspend the cube from the string and measure the mass on the balance. Record this measurement in the table on your data sheet. Place the cube in the water so that it is totally submerged but not touching the side or bottom of the container. Balance the system and record this new mass measurement in the table on your data sheet.

5) Using equation 5, calculate the density, ρ, for the aluminum cube. Use $\rho_f = 1$. Record this value for density on your data sheet.

Activity 3.

6) Measure the length of the sides of the aluminum cube in centimeters.
Calculate the volume of the cube by (l x w x h) and record the value on your data sheet.

7) Using equation 1, calculate the density of the aluminum cube using the volume of the aluminum cube and the mass from activity 1. Record this density value on your data sheet.

Activity 4.

8) Using the density values from activity 2 and activity 3, compare your experimental values for the aluminum cube by computing the percent difference. The percent difference is given by:

$$\text{percent difference} = \frac{|1^{st} measurement - 2^{nd} measurement|}{(\frac{1^{st} measurement + 2^{nd} measurement}{2})} * 100 \qquad (6)$$

9) Record the percent difference on your data sheet.

Activity 5.

10) Repeat activity 2 for the unknown cylinder and calculate the objects density. Record all measured and calculated values on your data sheet.

Summary.

Answer the following questions and include with your data sheet:

Using the density of the unknown object, make a guess of its composition.

If there was a bubble of air trapped in one of your objects, how would it affect the density measurements? Would the density go up, down or not change at all? Explain.

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DATA SHEET

Activity 1.

Table 1: Record the mass of the objects.

Object	Mass (g)
Aluminum Cube	
Unknown Cylinder	

Activity 2.

Table 2: Record the masses for the aluminum cube.

Mass in air (g)	
Mass in water (g)	

Density of aluminum cube (g/cm^3): ______________________________

Activity 3.

Table 3: Record the length of the sides of the aluminum cube.

Length (cm)	
Width (cm)	
Height (cm)	

Volume of aluminum cube (cm^3): ______________________________

Density of aluminum cube (g/cm^3): ______________________________

Activity 4.

Using the density values from activity 2 and activity 3, compare your experimental values for the aluminum cube by computing the percent difference.

Percent Difference: ______________________________

Activity 5.

Table 4: Record the masses for the unknown cylinder.

Mass in air (g)	
Mass in water (g)	

Density of unknown cylinder (g/cm^3): ______________________________

Answer the questions from the summary.