Archimedes Principle

Introduction

According to Archimedes Principle when an object is immersed in a fluid, the fluid exerts on the object a force whose magnitude is equal to the weight of the displaced fluid and whose direction is opposite the force of gravity. [1] Consider the specific case of an object suspended from a string while being immersed in a container of water, as depicted in Figure 1. Because the object is in static equilibrium, the net force on the object is zero so that

$$W_a + B - W = 0\,, \tag{1}$$

where W_a is the tension in the string (the apparent weight of the object), and W is the weight of the object. The buoyant force B is

$$B = \rho_{\text{water}} V g\,. \tag{2}$$

In Equation 2 V is the volume of the object, ρ_{water} is the density of water, and g is the acceleration of gravity. It can be shown using Equations 1 and 2 that the density of the object ρ satisfies the relationship

$$\rho = \frac{M}{M - M_a}\rho_{\text{water}}\,. \tag{3}$$

Here M is the mass of the object, and M_a is its apparent mass, i.e. $M_a = W_a/g$.

The purpose of this experiment is to obtain precise values of the density of a brass cylinder and an irregularly shaped lead weight, using equation 3. The values obtained are then compared to those obtained by the less precise method of calculating the density directly using the relationship

$$\rho = \frac{M}{V}\,, \tag{4}$$

M and V being the mass and volume of the object. In addition, the precise value of the density of a cork is also obtained. This case is distinguished from the previous cases in that the cork floats so that equation 3 seems not applicable, in a practical sense, for determining the density of the cork.

Procedure

The equipment used in performing the experiment is shown in Figure 2. Record all measurements and calculations in the appropriate table.

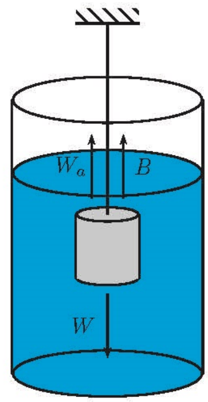

Figure 1: Archimedes Principle.

1. Determining precise values of the densities using equation 3 requires having a precise value of the density of water. The density of the water depends on its salinity and temperature. We assume the salinity of the water to be 0.00 mg/L. The temperature of the water is measured, directly, to three significant figures using a digital thermometer. The density of water can then be obtained by linking to the website density calculator and using the density calculator with appropriate values of salinity and temperature. Since the temperature and salinity are accurate to three significant figures, the density should be reported to three significant figures.

2. Measure the mass of the brass cylinder. Measure its diameter and length using the vernier calipers. Measure the apparent mass of the brass cylinder by suspending it from a string attached to a balance and submerging the cylinder completely in a container of water.

3. Measure the mass of the lead weight. Determine the volume of the lead weight by measuring the water displaced when the lead weight is immersed in a graduated cylinder filled with water to the 50 cm^3 graduation. Measure the apparent mass of the lead weight in the same manner as that of the brass cylinder.

4. Measure the mass of the cork. Because the cork floats, its apparent mass is negative so that Archimedes Principle cannot be directly applied to the determination of its density. In order to circumvent this problem, tie the lead weight to the cork, and measure the apparent mass of both the cork and the lead weight. The apparent mass of the cork equals the apparent mass of the lead/cork combination less the apparent mass of the lead obtained, previously. Note: the combination of cork and lead weight should be totally submerged when the apparent mass is measured.

Analysis

Numerical results should be reported to the correct number of significant figures.

1. Calculate the volume V of the brass cylinder, using the formula $V = \pi \frac{D^2}{4} L$, where D is the diameter of the cylinder, and L is its length.

2. Calculate the density of the brass cylinder using equation 3. Calculate the density of the brass cylinder directly using equation 4.

3. Calculate the density of the lead weight using equation 3 and equation 4.

4. Calculate the density of the cork ρ_c using equation 3. In this case the apparent mass of the cork M_a, which is a negative value, is given by,

$$M_a = M_{\text{c,Pb},a} - M_{\text{Pb},a} \, , \tag{5}$$

   where $M_{\text{c,Pb},a}$ is the apparent mass of the combined cork and lead weight, and $M_{\text{Pb},a}$ is the apparent mass of the lead weight recorded in Table 2.

5. Comment on the consistency of the two methods of measuring density for the cases of the brass cylinder and lead weight. Which method should be more accurate, and why should it be?

6. Comment on the reason for attaching the lead weight to the cork in order to determine its density.

Figure 2: Equipment used in measuring density.

References

[1] Wikipedia. Buoyancy. `http://en.wikipedia.org/wiki/Buoyancy`, 2007. [Online; accessed 1-November-2007].

	Temperature (°C)	Density (gm/cm^3)
Water		

Table 1: Data

	Mass (gm)	Apparent Mass (gm)	Diameter (cm)	Length (cm)	Volume (cm^3)
Brass					
Lead					
Cork					

Table 2: Data and Calculations I

	Density (gm/cm^3) Archimedes	Density (gm/cm^3) direct
Brass		
Lead		
Cork		

Table 3: Data and Calculations II