PHYSICS LAB EXPERIMENT – 7

ARCHIMEDES' PRINCIPLE (DENSITY MEASUREMENTS)

OBJECTIVE: To study Archimedes Principle and measure the density of solids and liquids using it. Archimedes, a Greek mathematician, determined that when a body is partially or fully submerged in a fluid, it experiences an upward force called a buoyant force, which is equal to the magnitude of weight of the fluid displaced by the object. Hence buoyancy is the ability of a fluid to support an object by apparently diminishing its weight by the amount which is equal to the weight of the fluid displaced by the object. This principle can be used to explain why ships carrying a heavy cargo are able to float. The purpose of this experiment is to find the density of fluids and various solids using Archimedes' Principle.

APPARATUS: Beam balance with platform, metal cylinders, wooden or cork cylinders, sinkers, pure water, rubbing alcohol, hydrometer, two 400 cm^3 beakers, and fine thread.

THEORY: The density of a body is defined as the mass per unit volume. Many times it is expressed in grams per cubic centimeter. Specific gravity of a body is the ratio of its density to the density of water at the same temperature. Because the density of water at 4ºC is 1 g/cm^3, density in the CGS system is (nearly) numerically equal to specific gravity.

OBSERVATIONS & DATA:

(I) Density of Objects Denser than Water

Archimedes' principle states that the apparent weight loss of a body immersed in a fluid is equal to the weight of the fluid displaced. The specific gravity of a solid that is heavier than water can be determined using this principle. The body is weighed in the water by suspending it by a thread from the arm of a balance so that it is completely immersed in water. The loss of weight is $W - W_1$, where W is the weight of the body in air and W_1 is the weight in water. The loss of weight is then $W - W_1$, which is equal to the weight of the water displaced, which in turn is equal to the weight of the equal volume of water. Because density of water at 4 degrees Celsius is 1 gram per cubic centimeter, we can also determine the volume of the water displaced. Thus the density of the solid under investigation is equal to: ρ= mass/volume (g/cm^3) = specific gravity, $S = W/(W-W_1)$.

Weight of metal cylinder in air (W) _____ x g $g = 9.81\ m/s^2$

Weight of metal cylinder in water (W_1) _____ x g

Weight of the water displaced ($W-W_1$) _____ x g

Specific gravity of the solid $S = W / (W-W_1)$ = _____

Standard value of density for Lead is 11.3 g/cm^3 and Aluminum 2.7 g/cm^3.

Percentage discrepancy _____

Find the volume of the displaced water from your measurements _____

Find the volume of your object by direct measurements _____

Difference between these measurements _____

Next, obtain an unknown, irregularly-shaped solid from your instructor. Following the same procedure as before, determine the density of this solid. In your lab report, use the appearance and density of the unknown solid to determine what material it is (iron, steel, aluminum, titanium, swiss cheese, etc.)

Density of unknown object = _____

(II) Density of solids less dense than water

The density of a solid which is *lighter* than water can be found by using a sinker of sufficient weight and density, so that it can hold the object totally submerged in water. The body as usual is weighed in air (W). Then it is kept in air but the sinker is immersed in water and they weighed together (W_3). Finally, the body and the sinker are tied together and immersed in water and weighed (W_4).

$$S = W/ (W_3 - W_4)$$

Weight of the wooden cylinder in air (W): _____ x g g = 9.81 m/s^2

Weight of the wooden cylinder in air + Sinker in water (W_3) _____x g

Weight of the wooden cylinder and sinker both, inside water (W_4). _____x g

Specific gravity of the wooden cylinder $S = W/ (W_3 - W_4)$. _____

Standard value for *pine* wood is 0.55 g/cm^3.

Percentage discrepancy. _____

(III) Density of a liquid

The specific gravity of an unidentified **liquid** can be found by measuring the loss of weight of a solid when it is immersed in water ($W - W_1$) and also the weight loss for the same solid when immersed in the liquid ($W - W_2$). Where W_1 is the weight of the solid in water while W_2 is the weight in the liquid under investigation. W is the weight in air as usual.

$S = (W - W_2) / (W - W_1)$ = (Weight of liquid)/(Weight of water) = _____

The standard value for pure isopropyl (rubbing) alcohol 0.785 g/cm^3. Check the bottle used in your lab for the alcohol concentration. If it is something other than 100%, calculate the density you should be comparing to and note it in your report.

Percentage discrepancy _____

QUESTIONS:

1. Explain clearly how one can obtain volume of an irregular solid that is insoluble in water.

2. Note that we made an assumption that the density of water is exactly 1 gram per cubic centimeter, but this figure only holds at a very specific temperature.
   (a) Re-calculate the density of your lead (or aluminum) mass using the value of the density of water at 20 °C.
   (b) Is the error introduced by our original assumption significant? Is it a random or systematic error?

3. Why does a block of wood or cork lose *more* weight (when totally immersed in water) than its original (in air) weight? In other words, how can the wood/cork have negative apparent weight?

4. Suppose there are air bubbles around the surface of the solid when it is immersed in water. How would these bubbles affect the results of your experiment?

5. A piece of cork, which has a mass of 50 grams in air, has a specific gravity of 0.25. It is attached to a lead sinker, which has a mass of 2,500 grams. What would be the apparent weight of both solids when they are both immersed in water? The density of the lead sinker is 11.3 g/cm^3.

6. What happens to the water level in a glass of ice water when the floating ice cubes melt? Will the water level rise or fall? Explain clearly.