Lab #9 Archimedes' Principle

Purpose: To gain an understanding of the upward buoyant force exerted on objects immersed in a fluid, and use this knowledge to determine the density and specific gravity of various objects and fluids.

Equipment: Triple beam balace
Vernier Calipers
Plastic Cups
Fluids of varying densities (water, antifreeze, vegetable oil)
Cylinders/spheres of various metals

Discussion:
A common observation when an object is immersed in a fluid is that it either floats or it sinks. When it floats there must be some upward force acting upon it (otherwise it would sink). This upward force is referred to as the buoyant force. When the object sinks, this same upward buoyant force still acts on the object, but it is not as great as the downward force due to gravity (the object's weight). This idea was first recognized by Archimedes (287-212 BC), who had been assigned the task of determining the real composition of the King of Syracuse's crown, without destroying it any way. Pondering this one day as he stepped into his tub, he noticed that the water level rose as he immersed more of his body into it. He became so excited about his discovery that he immediately hopped out of the tub and ran outside (sans towel) and down the street shouting "Eureka!" ("I found it!")

As a result of this upward buoyant force, an object's apparent weight, when immersed in a fluid, is LESS than its actual weight when not immersed. Most of us have observed this phenomenon in a swimming pool or in the bay/gulf, holding a son or daughter while he or she is partially submerged takes less effort that doing so on dry land. One fact that we usually don't think about, however, is the fact that this upward buoyant force is different for fluids of different density.

ARCHIMEDES' PRINCIPLE states that when an object is immersed in a fluid, it is acted upon by an upward buoyant force that is EQUAL to the weight of the fluid displaced. This is always true, whether the object is more dense or less dense than the fluid in which it is immersed. In the case of an object that is LESS dense than the fluid, this upward buoyant force equals the weight of the fluid displace and ALSO EQUALS THE WEIGHT OF THE OBJECT.

Archimedes' Principle applies to objects immersed in ANY fluid. Not all fluids are liquids: gases are also considered fluids. A lighter-than-air craft such as the Goodyear Blimp is a good example of Archimedes' Principle: it is acted upon by an upward buoyant FORCE that = the weight of fluid (air) displaced.

Recall that the DENSITY of an object represents its mass per unit volume. (Typical density units in the metric system are grams per cubic centimeter or kilograms per cubic meter.) A property of materials closely related to density is the SPECIFIC GRAVITY of the material. The specific gravity of a substance is the ration of the weight a given volume of the substance to the weight of an equal volume of water. That is, a material's specific gravity is the ratio of its density to that of water. In other words, the specific gravity of material tells HOW MANY TIMES MORE DENSE THE OBJECT IS THAN WATER. Note that since specific gravity is dimensionless; since it is the ratio of two thins that have identical units. For example, the density of water is 1.0 g/cm^3, and the density of mercury is 13.6 g/cm^3. So the specific gravity of mercury is therefore simple 13.6.

One way to find the specific gravity of the fluid used is:

$$\text{Specific gravity (oil)} = \left(\frac{(object's\ \ mass\ \ in\ \ air) - (its\ \ mass\ \ in\ \ oil)}{(object's\ \ mass\ \ in\ \ air) - (its\ \ mass\ \ in\ \ H_2O)}\right)$$

(Note: The denominator in the equation above happens to be numerically equal to the VOLUME of the object, only because exactly 1.00 cu. cm. of water has a mass of exactly 1.00 grams.)

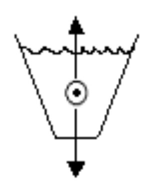
In today's lab, we will be immersing metal objects of varying shapes into different fluids. If the object is suspended from a scale, we can measure its mass in grams in air (not immersed) as well as its mass in grams while submerged. There will be a difference, due to the upward buoyant force (B. F.). For metal objects that are clearly more dense than the fluids into which they are immersed, the picture looks like this:

Wt. submerged = (Wt. in air) – (B.F.)

or, $\quad$ B.F. = $Wt._{air} - Wt._{subm.}$

So $\quad$ B.F. = $(m \cdot g)_{air} - (m \cdot g)_{subm.}$

or, $\quad$ B.F. = $(m_{air} - m_{subm.}) \cdot g$



Procedure:

1. Measure and record the dimensions of one of the metal objects.
2. Measure and record the mass of the metal object.
3. Determine the volume, and then the density of the object.
4. Measure and record the (apparent) mass of the object while immersed in water, then antifreeze, then vegetable oil. Make sure the object is completely submerged (with as little as possible of the metal hook submerged). The apparent loss of weight of the object is due to the B.F. and is also = to the weight of fluid displaced.
5. Repeat steps 1-4 using an object of different material.
6. From your results, determine the following:
    a. The buoyant force on both objects in each of the three liquids.
    b. The specific gravity of antifreeze and vegetable oil, based on the average of the 2 values found using the 2 objects.

Archimedes' Principle – Data Table

Sample	D (cm)	H (cm)	V (cm^3)	m_{air} (g)	ρ (g/cm^3)	m_{H2O} (g)	m_{oil} (g)	m_{AF} (g)	$\uparrow BF_{H2O}$ (N)	$\uparrow BF_{OIL}$ (N)	$\uparrow BF_{AF}$ (N)	SP. Gravity of oil	Sp. Gravity of Antifreeze
Al													
Cu													
Zn													
											Average:		

Calculations: