# Physics 215 - Experiment 6

# Archimedes' Principle

### Advance Reading
Urone, Chapter 10, sections 10.1 through 10.4 & 10.7

### Objective
The objective of this lab is to measure the buoyant force on a variety of objects.

### Theory
Archimedes' principle states that a body wholly or partially submerged in a fluid is buoyed up by a force equal in magnitude to the weight of the fluid displaced by the body. It is important to remember that fluids include both *liquids and gases*. The buoyant force is given by:

$$F_B = \rho g V \qquad \text{(Eq. 6-1)}$$

where ρ (rho) is the density of the fluid, V is the volume of fluid displaced by the object, and g is acceleration due to gravity. It is the buoyant force that keeps ships afloat and hot air balloons aloft.

In this experiment, the buoyant force will be measured using three methods. The three methods are as follows:

- Direct Measurement of Mass
- Displacement Method
- Direct Measurement of Volume

The **direct measurement of mass** requires measuring the mass of an object first in air, then in water. Though the mass of the object does not change, its apparent weight will change when measured while immersed in a fluid that is denser than air.

$$F_B = F_A - F_W \qquad \text{(Eq. 6-2)}$$

The **displacement method** requires measurement of the volume of fluid displaced by the object. The weight of the fluid displaced is equal to the buoyant force exerted on the object.

$$F_B = \rho_{fluid} g \Delta V \qquad \text{(Eq. 6-3)}$$

The **direct measurement of volume** method (for an object that sinks) requires measuring the dimensions of an object and calculating the volume. This volume is equal to the volume of fluid that would be displaced if the object were immersed.

$$F_B = \rho_{fluid} g V \qquad \text{(Eq. 6-4)}$$

As you read the *advance reading* sections of *Urone*, consider the third method on an object that floats.

### *Procedure*
### *Direct Measurement - Mass*
1. Measure the mass of one of the metal cylinders in air. Calculate its weight ($F_g$=mg). Suspend the object by a string tied to the pan of the Dial-O-Gram balance. Partially fill the overflow container with water, then completely submerge the cylinder. Do not allow the cylinder to touch the container. Its *effective mass*, "m", while submerged can be used to calculate its "weight" in the fluid ($F_W$ = "m"g). The difference between the objects weight in air and its weight in fluid is due to the buoyant force acting on the object, Eq. 6-2.

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2. Your partner will repeat the procedure. Calculate $F_{B\text{-}avg}$.
3. Repeat Step 1 and Step 2 for the other metal cylinder.

*Displacement Method - Volume*

4. Partially fill the graduated cylinder with water. Use the pipette to fine-tune the meniscus (i.e., fill to where the meniscus is not between markings). Record this initial volume, $V_i$.
5. Gently immerse one of the metal cylinders into the water. Record the new water level, $V_f$. Calculate $\Delta V$. Calculate the weight of displaced water, $F_B$, using Eq. 6-3 ($\rho_{water}$ =1000 kg/m$^3$).
6. Repeat for the other metal cylinder.

Direct Measurement - Volume

7. Measure the dimensions (height and diameter) of each metal cylinder; calculate their volumes. Using this information and the density of water, calculate the respective buoyant forces.
8. Compare $F_B$ values obtained from the three methods for each cylinder.
9. Calculate the density of each object.
10. Compare to accepted values.

*Buoyant Force - Floating Object*

11. Measure the mass and volume of the wood cylinder.
12. Partially fill the graduated cylinder with water. Record $V_i$.
13. Gently lower the wood cylinder into the water. Record $V_f$ and calculate $\Delta V$. This is the volume of displaced fluid.
14. Calculate the weight of the displaced water. Compare this buoyant force to the weight of the wood cylinder. Are they the same?
15. Draw a free-body diagram for this system. Calculate the density.

*Questions* *(Refer to Table 10-1)*

1. Air is a fluid. Why is the buoyant force due to the displaced air not included in our calculations during this experiment? Explain carefully.
2. Consider the situation of A and B below. Does one tub weigh more than the other, or do they weigh the same? Draw a free-body diagram for each case.

A. A tub filled to the brim with water.

B. A tub filled to the brim with water with a boat floating in it.

3. A 1000 cm$^3$ gold brick and a 1000 cm$^3$ aluminum brick are immersed in water. Which brick experiences the greater buoyant force? Why?
4. How can a ship made of steel float in water ($\rho_{steel}$ = 7.8 x 10$^3$ kg/m$^3$)?
5. Explain how a hot air balloon is able to fly. (Hint: Does not involve helium!)
6. Calculate the buoyant force that would be exerted on the wood cylinder if you held it under water. How much force must you exert?