

## 4C Lab: Archimedes's Principle and the Buoyant Force

**Goal:** To verify Archimedes's Principle by comparing the density of a metal cylinder obtained by two methods.

### Equipment List:

Graduated cylinder  
Beaker  
Vernier calipers  
Metal cylinder  
String  
Pan balance with rod underneath  
Paper towels

**Pre-lab exercise:** none

### Background/Theory:

*Archimedes's Principle states that an object wholly or partially submerged is buoyed up by a force equal to the weight of the displaced fluid.*

The pressure at any point in a volume of fluid is due to the weight of the column of fluid above it. In an incompressible liquid, the pressure is a linear function of depth:

$$P = \rho gh$$

Where  $\rho$  is the density of the fluid,  $g$  is the acceleration due to gravity and  $h$  is the depth. This pressure is independent of the horizontal cross-sectional area of the liquid or of the object submerged in it. Since the pressure,  $P$ , increases with depth, there is a higher pressure on the bottom of the object than on the top. Thus, there is a greater force up on the object than down. The net force, called the buoyant force, is equal to the weight of the fluid displaced by the object. If the object is less dense than the fluid, it sinks until the buoyant force is equal to its own weight and then floats, partially submerged, at equilibrium. If the object is more dense, the buoyant force is less than the weight of the object, but equal to the weight of the fluid displaced. Plus, since the object is completely submerged, the volume of the fluid displaced is equal to the volume of the object. AND! If you try to measure the weight of the submerged object, a scale would measure its apparent weight, which is smaller by the amount of the buoyant force.

Note the following relationships:

$$\text{Specific gravity} = \frac{\text{weight of the object in air}}{\text{Wt of an equal volume of water}} = \frac{\rho_o g V}{\rho_w g V} = \frac{F_g}{F_b} = \frac{\text{weight of object in air}}{\text{Apparent weight loss}}$$

**Procedure:**

**Part 1: Direct calculation of the density of water:**

- Measure and record the mass of the graduated cylinder with uncertainty
- Partially fill the graduated cylinder with water. Record the volume and estimate the uncertainty in the volume.
- Measure the mass of the cylinder and water, with uncertainty.
- Determine the density of water with uncertainty. Is your value within uncertainty of the accepted value of  $1.0 \text{ g/cm}^3$ ?

**Part 2: Direct calculation of the density of the metal block:**

- Measure and record the mass of the metal block, with uncertainty
- Partially fill the graduated cylinder with water. Record the volume of water (yes, with uncertainty). Completely immerse the metal block in the water and determine the volume of the block. (Uncertainty here too)
- Using the vernier calipers, determine the volume of the block.
- Determine the density and the uncertainty in the density with each volume measurement.

**Part 3: Archimedes's Principle method to determine density**

- With the small metal rod, raise the pan balance off the table. Tie a string to your block and measure the mass from the underside of the balance. Verify that your reading is the same as the reading of the block on the pan.
- Fill the small beaker with water. Completely submerge the metal block attached to the underside of the pan balance filled with water. Record the new "apparent" mass (certainly uncertainty!).
- Using Archimedes's Principle, determine the specific gravity of the metal block. With your value of the density of water from part 1, find the density of the object. Then, use the accepted value for the density of water and find the density of the object.

**Conclusion:** Compare your value of the density of the object by the four methods. Do your values agree within uncertainty?