# Archimedes Principle

## Learning Objectives

- Apply Archimedes' principle
- Calculate percent uncertainty
- Reflect on the source of differences in experimental results
- (Use a spreadsheet for repetitive calculations)

## Overview

In this lab, you will measure the density of 4 unknown metals in two different ways. You will compare these densities to one another and to the known densities of metals in order to identify the unknown metals and to account for experimental discrepancies.

## Stop and Think

1) **Write an expression for the density of an object in terms of its mass $m$, and volume $V$.**

2) **Derive an expression for the apparent weight $W_f$ of the object as read by a spring scale if the object is attached by a light string to the scale and is completely immersed in the fluid. Your answer should be in terms of the buoyant force $F_B$, the mass of the object $m$, and $g$.**

3) **Write an expression for the buoyant force acting on the object in terms of its volume $V$, $g$, and the density of the fluid $\rho_f$.**

*4)* **Using your answer to all the previous answers, write an expression for the density of the object in terms of $W_f$, $\rho_f$, $g$, $V$ only.**

## Materials and Apparatus

1. PC with Capstone
2. Pasco force sensor
3. 4 unknown masses
4. string

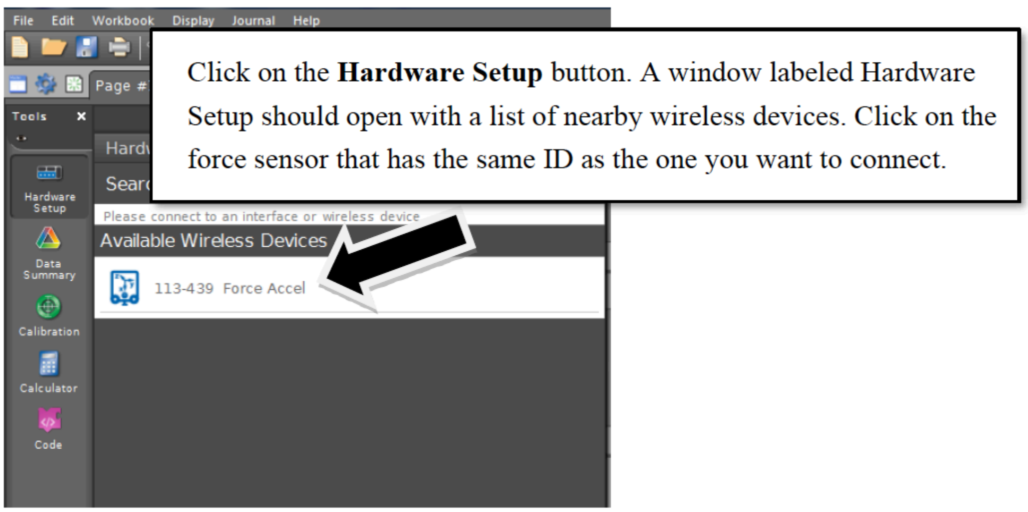
5. calipers
6. beaker of water

# Experiment

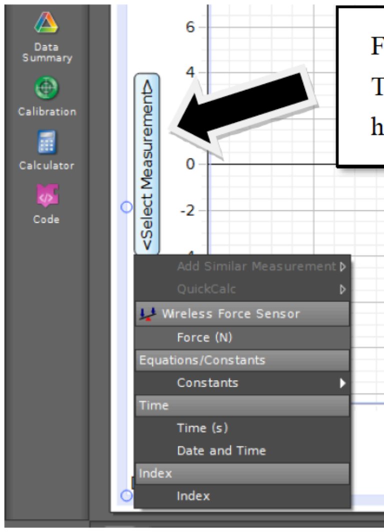
Create a table (spreadsheet or paper). I recommend a spreadsheet since there will be repetitive calculations and mistakes can be more easily corrected in spreadsheets.

1) Starting with Unknown Metal #1, **measure its mass using a scale and record it in the table.**
2) **Using the calipers, record the dimensions of the object and calculate its volume. Record the volume in the table in SI as V1.**
3) **Calculate the density from the mass and volume and record it in the table as $\rho_{measured1}$.**

Press the power button located on the side of the wireless force sensor at your station to turn it on. When the Bluetooth indicator light is flashing red, it means the sensor is waiting to be connected to a laptop.
Boot a laptop up into Windows and open the Capstone software (an icon should be on the desktop). Click on the Hardware Setup button located on the left side of the screen. This will open a window displaying nearby wireless devices.

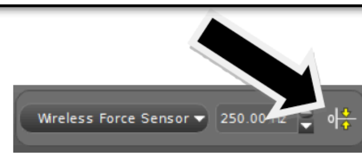



After connecting the force sensor, click on the sliders located next to **Wireless Acceleration Sensor** and **Wireless Gyro Sensor** to disable them. The force sensor will only be used to measure force in this experiment. Click on the **Hardware Setup** button again to close the Hardware Setup window. Double-click on the **Graph** icon to open a graph. On the vertical axis, click on the **<Select Measurement>** button.




From the drop-down menu, click on **Force (N)**. The software will automatically assign the horizontal axis to be the **Time (s)** axis.

Make sure nothing is connected to the force sensor hook and click on the icon with the two yellow arrows to zero the force sensor.




4) Tie a string to $m_1$ and attach it to the force sensor hook. Click on the **Record** button to start collecting data. Note that when the force sensor hook is pulled, it measures force to be negative. When it is pushed, it measures positive values. **Measure the object's weight when it is hanging from the force sensor in the air. Record this in the table as $W_{air}$?**

**5) Measure the apparent weight when the object is completely immersed in water and record it as $W_{water}$.**

6) Using your experimentally determined value for $W_{air}$ and $W_{water}$, **determine the buoyant force acting on the object when it is completely immersed in water and record it as $B_{experimental}$.**

**7) Calculate the predicted buoyant force based on the volume you calculated in Q2 and record it as $B_{predicted}$.**

8) **Calculate the % difference between $B_{predicted}$ and $B_{experimental}$ (%difference1).**

9) **From the experimentally determined value for buoyant force, use your derivation to calculate the volume of the object and record it as $V_2$.**

**10) Calculate the % difference between V1 and V2 (%difference2).**

11) **Calculate the density of the object using the last equation from Stop and Think and V2 just calculated and record it as $\rho_{measured2}$.**

12) **Calculate and record the % difference in densities of between $\rho_{measured1}$ and $\rho_{measured2}$ (%difference3).**

13) Repeat the previous steps for each unknown metal.

Do not keep any of your materials and apparatuses away as you may need them for the reflection.

# Reflect

**How do the measured volumes V1 and V2 compare? What equation did you use to calculate the volume of your objects in Q2? How close to the ideal shape are your objects (any nicks, grooves, holes, hooks)? Do you think each object has a similar error or are some objects further from the ideal shape?**

**How do you predicted and measured buoyant forces compare? Can you explain any discrepancies? Which value do you trust more? Why?**

**For each object, how do your measured densities compare? Can you explain any discrepancies? Which value do you trust more? Why?**

**Based on the density you trust more and using this table, identify the metal of each object.**

**Google each of these metals and compare them with the visual aspect of your objects. Do you think you identified the metals correctly?**

**Which object has the largest %difference in volume? Which object has the largest %difference in density? Which object has the largest %difference in buoyant force? Is it always the same object? Look at the shape of that object; how close to the ideal shape is it? How big is the hook compared to the object? Does it make sense? Why?**