**Archimedes’ Principle**

**(One week, In-Person)**

# Notes:

1. This lab will be done in-person with your lab partner(s), in LD011.
2. You will prepare a short summary on what you did and submit to your TA on (or before) the due date. Summaries are not as detailed as lab reports. Your TA might (not always) provide feedback which you should incorporate into your later lab reports and/or lab summaries. The short summary should discuss some (not all) elements mentioned in the handout “How will this lab be conducted?”
   1. When working in a group, turn in only one summary and make sure it lists all group members as authors.
   2. Summaries should be uploaded to Canvas in .pdf format by the deadline in the course calendar.
   3. Do not include raw spreadsheets in the Canvas submission or summary. You may want to use figures generated from the spreadsheet(s) in your summary.
3. Getting help:
   1. Your lab TA can answer questions during the lab or after the lab by email or at their office hour (listed in the syllabus).
   2. You can also ask advice from lab partner(s) and/or other students.

# Objectives of this lab:

For this lab, you will design and implement an experiment that first measures the density of water and then the density of an arbitrary solid object. You will be REQUIRED to utilize Archimedes’ Principle as part of doing the experiment when you determine the density of the arbitrary solid object.

These are things you will do:

1. You will use the electronic balance the measure the mass of water in a graduated cylinder filled to various levels (volumes). Repeat for various volumes so that you can obtain an accurate value for the water density.
2. Remember to subtract off the mass of the graduated cylinder.
3. Using Newton’s Laws, free-body diagram(s), and Archimedes’ Principle, develop a method that will allow you to accurately compute the density of an unknown solid object **by measuring only forces**.
4. With the string attached to the object, and the object submerged in a beaker of water (not touching the bottom), think about all the forces that act on the **water**. There are 3 (remember Newton’s 3rd Law: the submerged object will exert a downward force on the water).
5. Knowing two of these forces, you should be able to recover the displaced volume of the object.
6. Identify errors that can occur in your experiment. For example, realize that some water loss in the beaker will/may occur each time that the submerged object is removed.
7. Minimize those errors.

# What you will learn:

Please review the learning goals for the semester in lab in the handout from the first week. In addition, this lab has several specific goals:

1. You will practice keeping lab notes in a paper notebook, computer file, or other format.
2. You will enhance the data analysis skills you learned previously, by applying them to real data.
3. You will learn to distinguish between two types of errors that occur in data: systematic errors and random errors.
4. You will enhance your understanding of how noise arises in data, and how to account for that noise when interpreting experimental results.
5. You will practice scientific communication skills by preparing graphs and writing a formal lab report.

## What goes in my lab notes, and what about my report?

The purpose of lab notes is to enable you or a colleague to reconstruct what was done and why.

* They don’t have to be neat, in complete sentences, etc., but they do have to be useful.
* In a case like this, they should include things like what as the setup for measuring acceleration and what you did while recording data.
* Did you try different setups or take multiple data sets for same setup?
* If you store multiple files, record what filenames correspond to what conditions.
* Pictures of your setup can be useful! Take a few pictures and paste them into your notes.

The purpose of the summary is to explain what you learned and how you learned it. The sorts of things that belong here are

# A description of each step you did as part of Activity 1, Activity 2.

# Any graphs to show to your results.

# Explain how you determined your results.

# Explain differences between calculated (theory) and the actual (measured) forces.

# Your conclusions about any relevant and useful information you were able to extract from the data.

# An analysis of the errors of the in your experiment including an explanation of how calculated average acceleration, found the standard deviation, and determined the standard error.

# EQUIPMENT

For this lab, the following are available for use: large graduated cylinder, electronic balance, plastic beaker, solid object, string, rubber bands, computer, Vernier Go Direct® Force & Acceleration Sensor, Vernier Graphical Analysis™ Software Package.

**DOs & DON’Ts**

* ***Don’t*** break the equipment – Use care w/ electronic balance and force plate sensor.
* ***Do*** consult with your Lab TA about the various techniques you want to consider as you design your particular experiment.
* ***Don’t*** forget to record all the masses involved in the experiment.
* ***Do*** use your imagination and have fun.

# ACTIVITY 1: Determining Water Density and Developing your Method for Accurate Determination of the Density of an Irregular Solid Object by Force Measurements

* Measure the mass of an empty graduated cylinder.
* Fill the cylinder, with water, to various volume levels, record the volume and the total mass for each volume level.
* Use your data (from above) to determine an accurate value for the density of water.
* Remember to save your data (for each volume level) to make graphs, do analysis, etc.
* In preparation of next week, using Newton’s Laws, free-body diagram(s), and Archimedes’ Principle, develop a method that will allow you to accurately compute the density of an unknown irregularly-shaped solid object **by measuring only forces**.
* One way is to think about the forces that act on the water (in the beaker). Imagine the string attached to the object, and the object submerged in the beaker of water (not touching the bottom). What are the forces that act on the **water**?
* Measuring two of these forces, you should be able to recover the displaced volume of the object. From knowing the mass of the object and now the volume of the object, you can compute its density.
* There are multiple ways to obtain two of the forces. You could use the electronic balance (alone) to determine the weight of the water and the normal force when the object is submerged. Another option is to tie the other end of the string to the Vernier Go Direct® Force Sensor to obtain the string’s tension force and from this “back out” the buoyant force (of course, knowing the weight of the object).

# ACTIVITY 2: Implementing Your Method for Accurate Determination of the Density of an Irregular Solid Object by Force Measurements

* Using the technique you described in the draft report to your Lab TA, perform your experiment. Remember to incorporate any changes required/suggested by the TA.
* Repeat your experiment at least three times.
* Save your data for each run in Excel to make graphs, do analysis, etc.
* Think about how you want to analyze your data and present it in your final report. Calculate and discuss the Percent Error.
* Include an analysis of the errors in your experiment including an explanation of standard deviation, and standard error.