Physics 210
Lab 1

Measurements

Introduction and Goals

Today we will discuss how to make and understand scientific measurements, how to calculate using significant figures, and how to use calipers to measure length. To do this we will calculate the volume of various objects and try to understand how significant figures relate to measurement devices we choose to utilize. Our goals for this exercise are to determine the volume of several objects, and familiarize ourselves with the concepts of base units, measurement, and error.

In general, we can model materials around us as uniform. If I take a slice of putty and weigh it, I can determine the volume that putty takes up. I can do this for many other materials: metals, liquids, plastics, etc. For some shapes, we can have a mathematical formula that allows us to estimate the volume. Specifically, for cubes we can calculate the volume via

$$V = length \times width \times height$$

But we can have the volume for more complex objects, like cylinders, spheres, and so on. In fact, we can describe other volumes by adding and subtracting these basic geometric shapes to approximate the more complex object. For today, we will just calculate the volume of a cylinder with a diameter D, and height H

$$V = \frac{\pi D^2 h}{4}$$

Where $\pi = 3.14159\ldots$ is the infamous "pi."

For a sphere, this volume is

$$V = \frac{\pi\ D^3}{6}$$

The Instruments

Today we will be using a Vernier calipers simulation found at this external link: Virtual Calipers. This should work on mobile, though closing the calipers on the object can be tricky. When you open the link, the center of the page should show this set of simulated calipers (shown below).

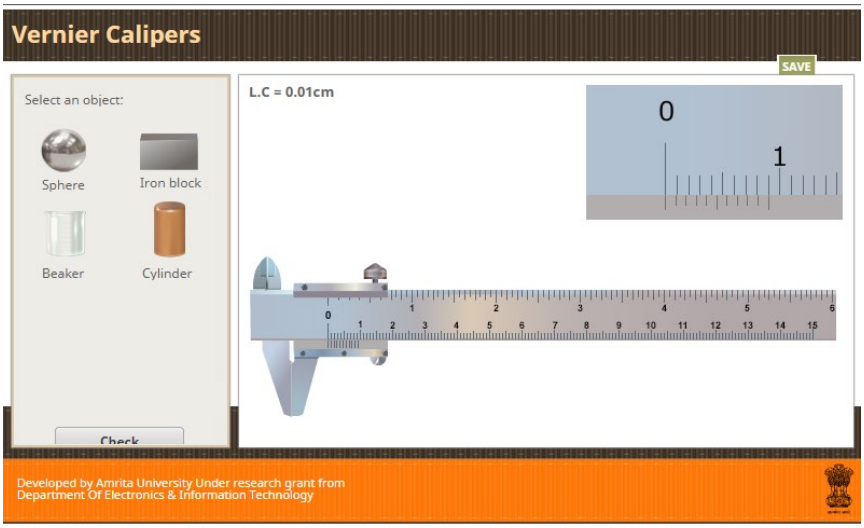

Figure 1. A screenshot of the website for the exercise. Four objects that can be measured are in the top right panel (a sphere, an iron block, a beaker, and a cylinder) and the calipers are in the center, with the Vernier scale in the upper right corner.

While many are familiar with the digital scale (to measure weight/mass), as well as rulers to measure length (in centimeters or inches), fewer people have everyday experiences with Vernier calipers. However, the calipers have something in common with the ruler: they are both what we call ruled instruments. Measurements are made by comparing a physical object to predetermined hash marks on the measurement instrument. A digital device still has error, but it has different types of error compared to a rule instrument. As sophisticated as these new instruments we will use today can be, they ultimately still compare the length of a physical object to a hash mark visually. The parts of the Vernier calipers are shown below, with labels.

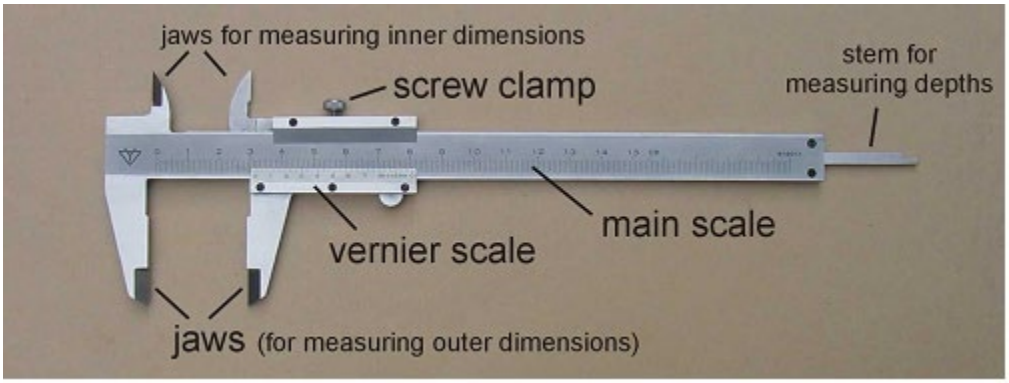

Figure 2. A picture of Vernier calipers with the components labeled.

The main difference, and why the calipers are more accurate and precise than a ruler, is the existence of the Vernier scale. To make a proper measurement, you look to where the zero on the Vernier scale crosses the main scale, like with a ruler, but then again look at where the Vernier scale has alignment with the main scale (see instructions and accompanying slides for more detail).

Instructions

Measurements

1. Click on one of the follow three objects:
    a. Sphere

Figure 3. A silver sphere from the simulation.

    b. Iron block

Figure 4. An iron block from the simulation.

    c. Cylinder

Figure 5. A brassy cylinder from the simulation.

2. When you selection an object, it should appear in the jaws of the Vernier caliper, along with options to measure different dimensions:
    a. For the sphere, you can only measure the diameter.
    b. For the iron block, you can measure length, breadth, or thickness.
    c. For the cylinder, you can measure the diameter, or the length.
3. To use the calipers to make a measurement, click on the simulation and move the jaws until they clamp down on the object.
4. To read the measurement of length from the calipers, follow these steps:
    a. Close the jaws on the object (**step 3**).
    b. Read the first two (or three) digits from the position where the Vernier scale 0 intersects with the main scale.

c. Read the last two digits where the Vernier scale has a near perfect alignment with the main scale.

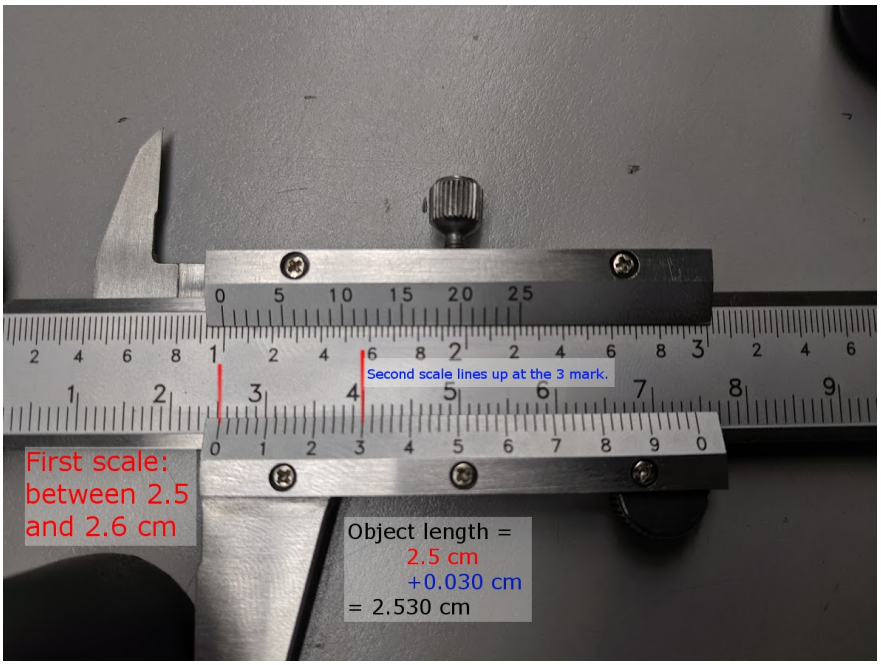

Figure 6. A picture illustrating the steps to read a Vernier caliper. See lecture materials for more details.

5. Measure all the dimensions of the sphere, iron block, and cylinder.
6. If the length falls between hash marks, do you best to estimate this to the nearest ½.
7. Given your measurements, create a **Data Table** in your lab report to indicate the measurements you made using these calipers, and then use the formulas from the theory section to *calculate the volume* of each object in cm^3.

Analysis

Each week we will have some analysis of the data we collect. As the semester goes on, this analysis will become increasingly open ended. Follow the analysis steps, if any, and then answer the questions as part of your lab report.

[Q1] Suppose instead we had used a ruler for these calculations and measurements. How many significant figures does a ruler measure? How many significant figures does a caliper measure?

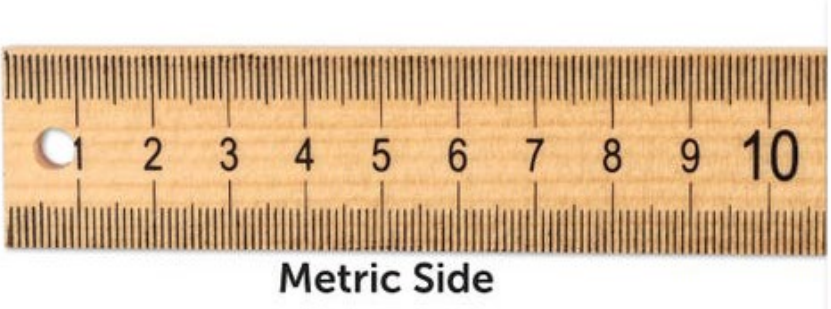

Figure 7. A picture of a metric ruler.

[Q2] Given your answer to **[Q1]**, round your results from **step 7** to the number of significant figures that you would have if you used a ruler to measure the dimensions of the three objects (sphere, iron block, cylinder).

[Q3] Calculate the relative percent error of between the volumes in **[Q2]** and the volumes you calculated as part of the instructions (**step 7**).

[Q4] Given your answer to **[Q3]**, which of the devices would you consider to be more accurate: the ruler, or the calipers?

[Q5] What are limitations of calipers that, say, a ruler or meter stick do not have? Give a few examples where calipers would be important to use, and a few where a meter stick is the right tool.