1 Background

1.1 Density

The *density* (or, more precisely, the *volume mass density*) of a substance tells you how much mass there is in a given volume of the substance:

$$\rho = \frac{m}{V}$$

Density is an example of an *intensive* property (also known as a bulk property or material property): it does not depend on the quantity of substance you have. Since intensive properties do not depend on a specific sample, they are useful in characterizing a system or material. (There are also *extensive* properties, which *do* depend on the specific sample. Mass and volume are examples.)

1.2 Measurement uncertainty

Unfortunately, no measurement is perfect. Every instrument you ever use will have some margin of error.

For example, say you have a ruler with centimeter markings and you are measuring the diameter of a cylindrical object that is around 5 or 6 cm. You can probably see when a measurement lies between two markings, but you cannot precisely measure how far it is between marks. Your measurement could be 5.25 cm, 5.49 cm, 5.7 cm ... or *anything* between 5 cm and 6 cm—you just know that it's somewhere between the two! In this case, you could report your measurement as 5.5 ± 0.5 cm, or $5.5\,\text{cm} \pm 9.1\,\%$ (note that ${}^{0.5}/_{5.5} = 0.091$).

In general, a measurement is reported as $r \pm \delta r$, though sometimes relative uncertainties (given as percents) are more useful: $r \pm {}^{\delta r}/_{r}$.

Part of being an honest experimenter is knowing and reporting the experimental uncertainties in your equipment. For analog instruments, a good rule of thumb is to take the smallest increment and divide by two to find the uncertainty.

For digital instruments, you do no estimating yourself, so you cannot interpolate between two values. Because of this, your uncertainty is the smallest increment of the digital readout. For example, if a digital scale gives you precision to the tenth of a gram, the uncertainty would be ± 0.1 g.

2 Tools

The length measurement tools available in our laboratory are rulers, metersticks, tape measures, and Vernier calipers. For mass measurement, we have digital scales, spring scales, and pan balances (borrowed from our friends in chemistry). For volume measurements, we have the length measurement tools listed above, as well as beakers and graduated cylinders.

If you think of another tool you would like to use, or another measurement you would like to make, discuss it with your professor. A suitable tool may or may not be available. (Part of scientific practice is working within your limitations.)

3 Task

Determine two different methods of calculating the density of an object. Then, take five stoppers of each material and use both methods to determine the density of each stopper. (This is a total of 10 calculations for the rubber stopper, and 10 calculations for the cork stopper.) Use a variety of measurement tools (for example, do not use a ruler for every single length measurement). Report uncertainty for each individual measurement you do.

Each group will turn in a table of measurements and calculated densities for each stopper in class on Monday. This information is to be clearly organized in a data table. The class's results will be used in the next lab.