SMS-204, 2014: Integrative marine sciences, physics. Lab 1

Knowledge: mass, volume, and density; no-slip condition; sinking in a highly viscous fluid.

Skills: basic statistics, propagation of errors, graphing of data.

The lab is performed in groups of 3-4 students. Choose a name for your group. By the end of the lab you will take a quiz (as individuals first and then as a group) to assess your understanding of the class and lab exercises. The quiz will ***not*** affect your grade but may result in your group all getting a pizza dinner.

Station 1: Density rods.

In this station you have 8 rods.

Measure the mass of each, and estimate the uncertainty of the mass (see Appendix). Measure the diameter and length of each rod and their uncertainties (See Appendix).

Rod #	1	2	3	4	5	6	7	8
mass								
length								
diameter								

Uncertainty in measuring length or diameter _______

Uncertainty in measuring mass_________

Discuss with your group and agree on how you would compute the uncertainty in the volume of the rods and the uncertainty in their density (you will need to do it for your homework). To do it you will need to **propagate** the uncertainties (see appendix).

Be sure to enter your data in the class data spreadsheet + uncertainties. You will need them to complete the homework.

Station 2: No slip condition

You are about to turn on a rotating table over which a tank full of water is set.

a. What do you expect will happen to the water in the tank as it starts rotating? Will the water rotate as well? Will there be a difference between fluid right next to the boundary vs. in the center of the tank?

b. Put some sawdust or dye next to the rim of the tank and some further towards the center. Start the rotation of the tank and observe the motion. How would you explain it? How is it related to the no-slip condition?

c. You will soon stop the tanks rotation. What do you expect will happen in the fluid when you do it?

d. Stop the tank's rotation and watch the sawdust to investigate the fluid's response.

<u>Station 3:</u> Sinking in a viscous fluid

Measure the mass and diameters of 5 different size beads. Then measure their sinking speeds in Glycerin using a stopwatch and a ruler. Measure the sinking speed three times to establish some confidence in the sinking speeds you are getting (You will need it for the homework). Start measuring after the beads have attained a constant settling speed (denoted by a tape). Make sure to have input the units into the table below. Note the uncertainties in mass, distance and time and add them to the table below. Discuss within your group the balance of the forces acting on the bead when it reaches constant settling velocity. Why does it keep sinking and why doesn't it sink faster with time?

Distance bead falls each time_________ (remember: sinking speed=distance/time)

Bead Size	Bead diameter	Bead Mass	Sinking time (1)	Sinking time (2)	Sinking time (3)	Sinking speed (1)	Sinking speed (2)	Sinking speed (3)
Size 1								
Size 2								
Size 3								
Size 4								
Size 5								

Uncertainty in measurements: diameter______ mass______ time________

Copy the data from this table to the laptop in the lab. I will aggregate the data so that you can use them in your homework. Use the data collected at station 1 and 3 (including the data from other groups that will be posted shortly on the WWW) in the homework assignment.

Station 4: Densities of oceanic and continental crust.

a. Determine the densities of the two rock samples (basalt and granite) with the materials provided to you. How do they compare?

b. The average elevation of land *above* sea level is 875m (average density of rocks is about 2.8g cm^{-3}). The average depth of the ocean floor is 3795m *below* sea level and water density is about 1.02g cm^{-3}. Given that, which crust (oceanic or continental) would you expect to be denser? Is it consistent with what you found?

Appendix:

Uncertainties of a measurement:

In measuring lengths of rods or their weights, an uncertainty due to finite digitization of the measurement device is associated with the measurement. This uncertainty is ± 0.5 times the smallest unit that we can resolve. This uncertainty provides the <u>precision</u> of the measurement. We assume that the measurements are unbiased, that is, that our measuring devices are <u>accurate</u>. Our only assurance that this assumption is true is that the scale and meter that we use are regularly calibrated. Often uncertainties are termed "errors," and the two terms are used interchangeably.

Uncertainties in multiple *independent* measurements of the same quantity:
Each measurement (*e.g.,* of settling velocity) has an uncertainty (*e.g.,* due to the precision of the stopwatch and length-measuring device) that is most often smaller than the uncertainty of the group of measurements (due to variability in measurement techniques between different individuals and between groups). These sources of variability are separated in the uncertainty analysis into uncertainties within and among groups and can be nested to any arbitrary degree (*e.g.,* multiple observations by a single individual within a group are pooled to produce the group's measurements, which in turn are pooled to produce the class' measurements). In a normal distribution, spread is quantified by the standard deviation; 68 % of data lie within one standard deviation from the mean; 95.5 % of the lie within 2 standard deviations. Uncertainty of the estimate of the mean (the standard error of the mean) is reduced by a factor of $1/\sqrt{n}$ when making *n independent* measurements. This outcome reflects the way that *n* independent measurements increase confidence in the outcome. Notice that when $n = 2$ a few more replicates decrease uncertainty a lot, whereas once you reach about 20 or so replicates, it takes a good many more replicates to improve matters much further.
While the standard deviation of a measurement does not necessarily change as we add more measurements, the standard error of the mean, that is the uncertainty in the mean value, equals the standard deviation divided by $\sqrt{n}$, and decreases the more measuremnts we have.

Uncertainty in a derived quantity (propagation of errors):

The absolute (*dz*) or relative (*dz/z*) uncertainties of a sum, difference, product or the ratio (*z*) of two independent variables (*x, y*) with uncertainties (*dx*, *dy*) are computed as follows. (You can derive it yourself from the chain rule in differentiation or see it in Taylor J., 1997, *An Introduction to Error Analysis,* 2nd, Ed., University Science Books, Herndon, VA). Here *dz, dx* and *dy* denote the uncertainties in *z, x* and *y,* respectively.

$$z = x + y \rightarrow dz = \sqrt{(dx)^2 + (dy)^2}$$

$$z = x - y \rightarrow dz = \sqrt{(dx)^2 + (dy)^2}$$

$$z = x \cdot y \rightarrow \frac{dz}{z} = \sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2}$$

$$z = \frac{x}{y} \rightarrow \frac{dz}{z} = \sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2}$$

For example from measurements of three sides of a cube (say, x+/-dx, y+/-dy, z+/-dz) we would like to compute the volume of a cube and the uncertainty. The volume is computed from:

$$Volume = x \cdot y \cdot z \rightarrow \frac{dVolume}{Volume} = \sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2 + \left(\frac{dz}{z}\right)^2}$$

$$\rightarrow dVolume = Volume\sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2 + \left(\frac{dz}{z}\right)^2}$$

$$density = \frac{Mass}{Volume} \rightarrow \frac{d\_density}{density} = \sqrt{\left(\frac{dMass}{Mass}\right)^2 + \left(\frac{dVolume}{Volume}\right)^2}$$

 This page was last edited on 1/2/2017