Experiment 1
Measurement

Advanced Reading
Lab Appendices, pages A2 to A9

Equipment

- Vernier caliper
- stopwatch
- 30 cm ruler
- meter stick
- wooden block
- metal object
- Dial-o-gram balance
- masses of various values
- 5 circular objects of various sizes

Objectives

In this experiment you will: (1) learn the proper usage of a ruler, meter stick, Vernier caliper, stopwatch, and Dial-o-gram balance, (2) determine the volume and density of an object while following the rules of uncertainty propagation, and (3) learn to use graphics software by determining the relationship between the circumference of a circle and its diameter.

Theory

The fundamental quantities of mechanics are length, mass, and time. The SI units for these quantities are the meter (m), kilogram (kg), and second (s), respectively. All other mechanical quantities can be stated in terms of these quantities. For example, the unit for force in the SI system is the Newton which is 1 N = 1 kg m/s^2. In terms of fundamental quantities, a Newton is [mass][length]/[time]^2.

In the physics laboratory it is important to know how to measure these quantities with precision and accuracy, and also to know when to do so. For example, it is sometimes appropriate to do a "back-of-the-envelope" calculation based on crude measurements to test a hypothesis.

In this experiment, you will use a variety of methods to measure the fundamental quantities of length, mass, and time (Fig. 1-1). You will then examine the inherent uncertainty of the different measurement methods and learn to propagate these uncertainties

Procedure

Part A. Estimation of Fundamental Quantities

Time

1. Estimate a 30 second time interval while your lab partner uses the stopwatch to time you. (A good way to do this is to tap your foot, trying to establish a 1 second rhythm.) Repeat this process for your lab partner. Next, estimate a one minute interval.

2. Calculate the percent error of the estimated times from the actual times. See the "General Laboratory Introduction" for a discussion of percent error.

Length (distance)

3. Close your eyes and hold out your hands to estimate one meter. Have your lab partner measure this length with the meter stick. Repeat the process for your lab partner. Calculate the percent error of your estimated meter from the actual meter.

Mass

4. With your eyes closed, have your lab partner place a known mass in your hands. Guess the mass in grams (1/1000 of a kilogram). Do the same for your lab

partner. Repeat this process with a different masse. Calculate percent error.

Part B. Measurement of fundamental quantities using more sophisticated techniques

5. Using the 30 cm ruler, measure the length, width, and height of the wooden block. Include uncertainty on ach measurement. Measurements should be done by *each* lab partner. If your values are different, calculate the block's volume using the *average* values of the length, width, and height. Your results should have the appropriate significant figures.

6. Measure the mass of the wooden block with the Triple Beam balance. (zero the balance before you start). Calculate the density of the block using the volume from part 5.

7. Using the Vernier calipers, measure all the dimensions needed to calculate the volume of the metal object (without holes). Each lab partner should make their own separate set of measurements. Calculate the volume of the object using the *average* values if measurements are different.

8. Measure the mass of the metal object with the Triple Beam balance. Use this value and the volume obtained in part 7 to calculate the object's density. Be sure to record this density in your notebook because it will be needed for one of the questions.

Determination of π

9. Using the Vernier caliper measure the diameter D, in centimeters, of each of the five circular objects.

10. Using the ruler measure the circumference C, in centimeters, of each object. To do this, wrap a piece of string around each object and measure the length of string required to encircle the object.

11. Graph C vs. D from parts 9 and 10. Use the graphics software on the computers. Use the linear fit command from the menu to plot a best-fit line. Label both axes properly, including the units. Refer to the "General Laboratory Introduction."

Post lab Questions

1. Assume you are given a population of the United States as 325,768, 935 people. Since the number of significant figures (sig figs) is determined by the precision of a measurement, **the number above implies a precision that is not realistic**. *The number above has too many sig figs.*

You are to rewrite the population above (with correct number of sig figs) assuming the following percent uncertainties (i.e., precision) of **0.1%, 1% & 10%, respectively.** Your 3 answers should be written in terms of absolute uncertainty (i.e., population $\pm\delta$population).
Absolute uncertainty should be rounded to one sig fig. SHOW ALL WORK.

2. Based upon the density values found in a table of element properties, from what material is the metal object made? Calculate the percentage error of your density from the standard density. What could be responsible for the discrepancy?

3. Assume you measured the mass of a cell phone to be 201g. Determine the weight of the cell phone in both newtons and pounds. Assume the acceleration of gravity is 9.80 m/s/s. What are the weight(s) of the cell phone on the moon? What is the mass of the cell phone on the moon? Show all work.

Question 4 is on next page.

Notes on Propagation of Uncertainties

"Most physical quantities cannot be measured in a single direct measurement but are instead found in two distinct steps. **First, measure** one or more quantities…. **Second**,… use measured quantities to **calculate** the quantity of interest….

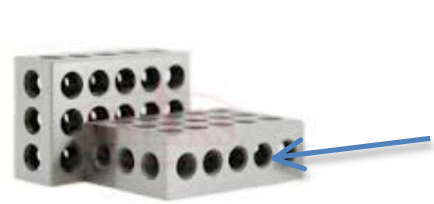
When a measurement involves these two steps, the estimation of uncertainties also involves two steps. First we must estimate the uncertainties in the quantities directly measured and then determine **how these uncertainties "propagate" through the calculations** to **produce an uncertainty in the final answer**."

Notes above taken **from An Introduction of Error Analysis,** 2nd Edition, by John Taylor

4. Using page A-6 through A-9 **of on-line Appendix** complete the following exercise on uncertainty propagation.

The true measurements of the calibration blocks pictured below are as follows:

$2.540 \pm 0.005 cm$, $5.080 \pm 0.005 cm$ &
$7.620 \pm 0.005 cm$



Using the dimensions above, **determine both the perimeter and area and their uncertainties** of the **one side** of the block indicated by the arrow. Be sure and show all uncertainty calculations. Answers should be given in both absolute & Percent uncertainty.