

Experiment 1

Measurement

Advanced Reading

(Serway) Chapter 1

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 $1 \text{ N} = 1 \text{ kg m/s}^2$. In terms of fundamental quantities, a Newton is $[\text{mass}][\text{length}]/[\text{time}]^2$.

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 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 several different masses. 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. Estimate to a tenth of the smallest scale on the ruler. These measurements should be done by *each* lab partner. Calculate the block's volume using the *average* values of the length, width, and height. Your results should have the appropriate significant figures and include the propagated uncertainties. See section of text on significant figures.

6. Each lab partner should measure the mass of the wooden block with the Dial-o-gram balance. (zero the balance before you start). Calculate the average mass. 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. Each lab partner should make their own separate set of measurements. Calculate the volume of the object using the *average* values.

8. Measure the mass of the metal object with the Dial-o-gram balance. Repeat three times and calculate the average. 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."

Questions/Conclusions

1. Why is it important for you to have a "feel" for mass, length and time (or more specifically, kilograms, meters, and seconds)?

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. It is important to know how to convert various quantities in the metric system. In your lab report, make a table containing the masses of the metal object and the wooden block in both grams and kilograms. On the same chart, record the volume of the same objects in both cubic centimeters (cm^3) and cubic meters (m^3). Be sure to include the uncertainties of these values in the table.

4. What is the value of the slope of the graph in step 11 of the procedure? What is the significance of this number? Recall that the equation of a line is given by $y = mx + b$, where m is the slope and b is the y intercept. Calculate the percentage error of your value from the true value. What could be responsible for the discrepancy?

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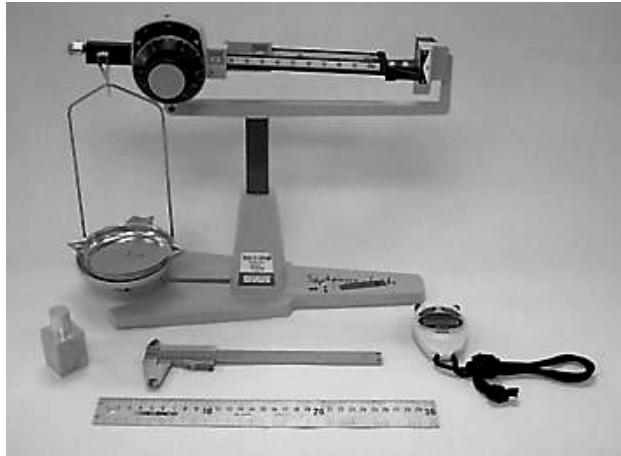


Figure 1-1

Dial-o-gram balance, metal object, ruler, stopwatch and Vernier caliper.