CHEM 1215 LAB NOTES

EXPT #1: MEASUREMENTS & SIGNIFICANT FIGURES: LENGTH, MASS, VOLUME

TECHNIQUES: measurements, significant figures

READING: Measurements, Precision & Accuracy, Significant Figures
e.g. Burns chapter 3, Tro chapter 1

SAFETY: Safety Goggles are required when conducting volume measurements.

Introduction

In any scientific field, it is important that experimental investigations be conducted in a manner so that essential facts and relationships can be organized in order to evaluate the results and make reasonable conclusions. Therefore, it is necessary to gather information using methods that provide accurate results. Common laboratory measurements involve the determination of the fundamental properties of mass and length. Most people are familiar with the use of scales and rulers or meter sticks. The objective of this experiment is learn the correct methods for using lab equipment to make length, mass, and volume measurements. Measurements will be made with a variety of tools, and several calculations will be conducted to compare the experimental results with the expected results. The concepts of accuracy, precision, and uncertainty will be used to evaluate your results.

When making a measurement it is important to report your answer with the appropriate number of significant figures. This is especially important when using a measuring tool with a graduated scale. When using such a device, it is the responsibility of the person conducting the measurement to make any appropriate estimations between the lines on the scale in order to make the measurement with the greatest amount of precision. When carrying out any arithmetic manipulations of measurements, the rules for significant figures should be followed.

After performing this experiment and analyzing the data, you should be able to do the following:

1. Explain how the number of significant figures in a measured value depends on the least count of the measurement instrument.
2. Correctly use an instrument with a scale for measurements.
3. Understand the difference between devices that make the same kind of measurement, and know how to select the appropriate device for the experiment being conducted.

Theory

A. Least Count of an Instrument Scale

The least count of an instrument is the smallest subdivision marked on its scale. This is the unit of the smallest reading that can be made without estimating. For example, the least count or smallest subdivision of a meter stick is usually the millimeter (mm). We commonly say "the instrument is calibrated in centimeters (numbered major divisions) with a millimeter least count" (see Fig. 1).

A measurement reading generally has one more significant figure than the least count reading of the instrument scale. This is the estimated fractional part (doubtful figure) of the smallest subdivision. In the case of a meter stick with the least count of 1 mm, a reading can be estimated to a fraction of a millimeter, usually 0.1 mm (or 0.01 cm or 0.0001 m).

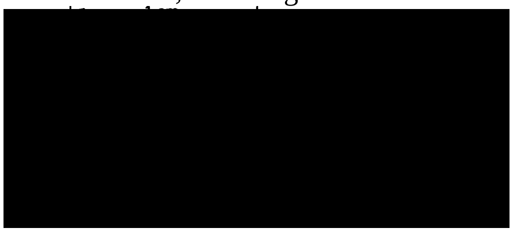

Figure 1.1. Least count. Meter sticks are commonly calibrated in centimeters (the numbered major divisions) with a least count, or smallest subdivision, of millimeters.

B. Laboratory Balances

Some common types of laboratory balances are shown in Fig. 2.2. Mechanical balances or "scales" are used to balance the weight of an unknown mass *m* against that of a known mass m_l (i.e., $mg = m_l g$ or $m = m_l$), and the mass of the unknown is read directly in mass units, usually grams. The weight w of an object is its mass *m* times a constant g, the acceleration due to gravity; g= 9.80 m/s^2 = 980 cm/s^2 (i.e., w= mg or m= w/g). Some scales, such as bathroom scales, are calibrated in weight (force) units (pounds) rather than in mass units.

A set of known masses is used to balance an unknown mass on a pan balance (Fig. 2a). On a beam balance the riders on the beams are used to balance the unknown mass on the platform 1(Fig. 2b). The common laboratory beam balance is calibrated in grams. In this case, the least count is 0.1 g and a reading can be estimated to 0.01 g.*

Figure 1.2 Laboratory balances. (a) A double-beam, double platform (pan) Harvard trip balance, which is also called an *equal-arm balance.* (b) A single platform, triple-beam balance. (c) A digital electronic balance.

Before making a mass determination, check to see if the balance is zeroed. Adjustments can be made by various means on different scales.

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* The official abbreviation of the gram unit is g (in roman type). The standard symbol for acceleration due to gravity is *g* (in italic type), where weight is given by mg. Look closely so as to avoid confusion with these symbols.

Electronic balances with digital readouts are becoming increasingly common (Fig. 2c). They have the advantage of accuracy and ease of operation. However, electronic balances are much more delicate. The mass value is displayed automatically, with the accuracy or number of significant figures depending on the particular balance. Some electronic balances have auto calibration and others have a keypad for calibration by the user.†

Because of the wide variety of electronic balances available, if you are using one in this experiment you should first familiarize yourself with its operation. Your instructor may brief you, or an operation manual should be available. (When first using an electronic instrument, it is always advisable to read the operation manual supplied by the manufacturer.)

Materials

Calculator, meter stick, triple beam balance, pan balance, analytical balance, measuring cup, test tube, pipette, graduated cylinder, and burette.

Procedure

In this lab, make sure that you record all results with the appropriate number of significant figures. The results of any calculations should also be recorded with the appropriate number of significant figures.

Part A

Make the following measurements of length.

Part A1. Length Measurements

- Using a meter stick, measure the length of the long side of this lab manual or handout with the side of the meter stick marked in inches. Record that value on your report sheet.
- Measure the same length of this lab manual or handout with the side of the meter stick marked in centimeters. Record that value.
- Divide the number of centimeters in your measurement by the number of inches to calculate your experimental number of centimeters per inch. Record the value with the appropriate number of significant figures.

Part A2. Length Measurements

- Using a meter stick, measure the length of the long side of a dollar bill with the side of the meter stick marked in inches. Record that value on your report sheet.
- Measure the same length of a dollar bill with the side of the meter stick marked in centimeters. Record that value.
- Divide the number of centimeters in your measurement by the number of inches to calculate your experimental number of centimeters per inch. Record the value with the appropriate number of significant figures.

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† In general, an electronic balance has a suspended beam, and the balancing force on the end of the beam opposite the weighing pan is electromagnetic. The force is supplied by a current-carrying coil of wire in the field of a permanent magnet The force is directly proportional to the current, which is controlled automatically by a photosensitive diode whose resistance is a function of the light incident on it.

Any tilting of the beam increases the light from a source on the diode, and a feedback circuit calls for more current in the coil. The increase in current (and hence in force) is adjusted so as to keep the beam in horizontal equilibrium. The current that balances the beam is read out on a digital ammeter calibrated in grams or milligrams.

Part A3. Length Measurements

- Using a meter stick, measure the length of your forearm (or your lab partner's forearm) from elbow to the tip of your middle finger with the side of the meter stick marked in inches. Record that value on your report sheet.
- Measure the same length with the side of the meter stick marked in centimeters. Record that value.
- Divide the number of centimeters in your measurement by the number of inches to calculate your experimental number of centimeters per inch. Record the value with the appropriate number of significant figures.

Part A4. Length Measurements

- How do the results of your cm/in. ratios in parts A1, A2, and A3 compare to the accepted value.
- Calculate the percent error (accuracy) between your ratios and the standard value (2.54 cm/inch) for parts A1, A2, and A3.

$$\text{Percent error} = \frac{(\text{Experimental value} - \text{Standard value})}{\text{Standard value}} \times 100\ \%$$

- Calculate the percent difference (precision) between your ratios and the accepted value for parts A1, A2, and A3.

$$\text{Percent difference} = \frac{(\text{Largest value} - \text{Smallest value})}{\text{Average value}} \times 100\ \%$$

- What do you conclude? Are your measurements in parts A1, A2, and A3 accurate? Are your measurements in parts A1, A2, and A3 precise?

Part B

Make the following measurements of mass.

Part B1. Mass Measurements

- Use a triple beam balance to determine the mass of a coin (penny, nickel, dime, quarter, etc.) with the appropriate number of significant figures. Record the type of coin, it's mint date, and the mass of the coin.
- Remove the coin from the balance and zero the balance.
- Repeat the mass measurement again and record the mass.
- Remove the coin from the balance and zero the balance.
- Repeat the mass measurement a third time and record the mass.
- Calculate the average of these three measurements.

Part B2. Mass Measurements

- Use a **pan** balance to determine the mass of a coin (penny, nickel, dime, quarter, etc.) with the appropriate number of significant figures. Record the mass of the coin.

Part B3. Mass Measurements

- Use an **analytical** balance to determine the mass of a coin (penny, nickel, dime, quarter, etc.) with the appropriate number of significant figures. Record the mass of the coin.

Part B4. Mass Measurements

- Compare the results of the measurements in part B1 with those in B2 and B3.
- Comment on the results of these three measurements

Part C

Make the following measurements of volume.

Part C1. Volume Measurements – English and Metric Units

- Carefully fill a cook's measuring cup with tap water to the 2.0 ounce mark, record the actual volume used with the appropriate number of significant figures.
- Pour the water carefully into a dry 100 mL graduated cylinder. Carefully read and record this volume of water on the data sheet.
  - When determining the volume of water in milliliters, read the bottom of the meniscus and estimate the volume to tenths of the space between the lines; that is, to tenths of a milliliter.
  - If your measuring cup does not have a mark for 2.0 ounces, fill the measuring cup to the 4.0 ounce mark. When measuring this volume in milliliters, it may be necessary to pour ½ of the volume into the 100 mL graduated cylinder, record the intermediate volume, dump the graduated cylinder out, and measure the remaining water in the measuring cup. Record the total amount of water.
- Obtain the ratio of milliliters to fluid ounces by dividing the volumes of water in milliliters by the corresponding volume in fluid ounces. Give your answer with the appropriate number of significant figures.

Part C2. Volume Measurements – Test tubes

- How many milliliters of liquid will a test tube hold? Choose a test tube and fill it with water. Empty the water from the test tube into a graduate cylinder and record the volume of the test tube.
- Record the approximate length of the test tube.
- Calculate how many milliliters are contained in each centimeter of the tube. Divide the volume of the tube by it’s length.
- Use a pipet to measure out 2.0 mL of water into a small test tube. You may wish to mark this spot on your test tube with tape or a marking pencil for future reference.
  - Compare the “length” of water in the test tube to the “length” of water you would estimate from the step above.
- Repeat for a 4.0 mL and 6.0 mL volume.

Part C3. Volume Measurements – Comparisons of Volume Measuring Devices

- Obtain a 150 or 250 mL beaker from your bench drawer.
  - Make sure that the beaker is clean and dry.
  - Using one of the pan balances in the lab (properly zeroed) record the mass of your beaker.
  - Fill the beaker to some volume and record the volume used.
  - Record the mass of the beaker with the water in it.
  - Assuming that the density of water is 1.00 g/mL, **calculate** the volume of the water in the beaker from the mass of the water.
- Calculate the error for the beaker measurement assuming that the calculated volume from the mass and density is the actual volume.
- Pour the volume of water from the beaker into your 100 mL graduated cylinder and record the volume as indicated by the graduated cylinder.
- Calculate the error for the graduated cylinder measurement assuming that the calculated volume from the mass and density is the actual volume.

- Comment on the results of these measurement. Which one of these two devices is better at measuring volumes? Why? Do either of these devices (beaker or graduated cylinder) indicate their accuracy?

Part C4. Volume Measurements – Pipette

- Obtain **clean and dry** 150 or 250 mL beaker from your bench drawer.
    - Using one of the pan balances in the lab (properly zeroed) record the mass of your beaker.
    - Fill your 10 mL pipette to the indicator line and dispense this volume into your beaker.
    - Record the mass of the beaker with the water in it.
    - Assuming that the density of water is 1.00 g/mL, **calculate** the volume of the water in the beaker from the mass of the water.
- Calculate the error for the pipette measurement assuming that the calculated volume from the mass and density is the actual volume.
- Comment on the results of this measurement. Is the pipette better at measuring volumes than a beaker or a graduated cylinder? Why? Does your pipette have an indication of its accuracy?

Name ____ Lab Instructor ____________________
Partner _______________________________________ Date ____________________

EXPT #1: MEASUREMENTS & SIGNIFICANT FIGURES: LENGTH, MASS, VOLUME

DATA and OBSERVATIONS:

Part A

Part A1. Length Measurements	Measurement	# of Sig. Figs.
1. Length of lab manual or handout in inches	____________________	_____________
2. Length of lab manual or handout in centimeters	____________________	_____________
3. Ratio of centimeters to inches	____________________	_____________

Part A2. Length Measurements	Measurement	# of Sig. Figs.
1. Length of dollar bill in inches	____________________	_____________
2. Length of dollar bill in centimeters	____________________	_____________
3. Ratio of centimeters to inches	____________________	_____________

Part A3. Length Measurements	Measurement	# of Sig. Figs.
1. Length of forearm in inches	____________________	_____________
2. Length of forearm in centimeters	____________________	_____________
3. Ratio of centimeters to inches	____________________	_____________

Part A4. Length Measurements
1. Accuracy of measurement A1 (percent error between your ratio in part A1 and the accepted value) __________
2. Accuracy of measurement A2 (percent error between your ratio in part A2 and the accepted value) __________
3. Accuracy of measurement A3 (percent error between your ratio in part A3 and the accepted value) __________
3. Precision (percent difference between your largest and smallest ratios in part A) _____________

4. Conclusion:____
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Part B

Part B1. Mass Measurements

1. Type of coin ____________________ Date _____________

	Measurement	# of Sig. Figs.
2. Mass of coin (trial 1)	____________________	_____________
3. Mass of coin (trial 2)	____________________	_____________
4. Mass of coin (trial 3)	____________________	_____________
5. Average mass	____________________	

Part B2. Mass Measurements	Measurement	# of Sig. Figs.
1. Mass of coin	____________________	_____________

Part B3. Mass Measurements	Measurement	# of Sig. Figs.
1. Mass of coin	____________________	_____________

Conclusion:____

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Part C

Part C1. Volume Measurements - English and Metric Units

	Measurement	# of Sig. Figs.
1. Measured volume of water in fluid ounces (measuring cup)	____________________	_____________
2. Measured volume of water in milliters (graduated cylinder)	____________________	_____________
3. Ratio of milliters to fluid ounces	____________________	_____________

Part C2. Volume Measurements – Test Tubes

	Measurement	# of Sig. Figs.
1. Measured volume of water in test tube	____________________	_____________
2. Measured length of test tube	____________________	_____________
3. Ratio of milliters to length	____________________	_____________

Part C3. Volume Measurements - Comparisons of Volume Measuring Devices

	Measurement	# of Sig. Figs.
1. Mass of empty beaker	____________________	_____________
Measured volume of water in beaker	____________________	_____________
Mass of beaker plus water	____________________	_____________
Calculated volume of water using mass and density	____________________	_____________
2. % error in the volume measurement of the beaker	____________________	_____________
3. Measured volume of water in graduated cylinder	____________________	_____________
4. % error in the volume measurement of the grad. cylinder	____________________	_____________

Conclusion:____

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Part C4. Volume Measurements - Pipette

	Measurement	# of Sig. Figs.
1. Mass of empty beaker	____________________	_____________
Volume of pipette used	____________________	
Mass of beaker plus water	____________________	_____________
Calculated volume of water using mass and density	____________________	_____________
2. % error in the volume measurement from the pipette	____________________	_____________

Conclusion:____

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EXPT #1: MEASUREMENTS & SIGNIFICANT FIGURES: LENGTH, MASS, VOLUME

CHEMICAL CONVERSION PROBLEMS:

Include the proper number of significant figures in your answers.

Length:

1. Convert five and one-fourth inches to centimeters. (Given: 1 inch = 2.54 cm.)

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2. Convert 125 mm to inches.

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Volume:

1. What is the volume of a rectangular object with measured dimensions of 14.3 cm by 12.2 cm by 1.50 cm?

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2. Given that 29.6 mL is equivalent to one fluid ounce, calculate the number of milliliters in a 12.0 oz can of soda.

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Mass:

1. A medicine tablet contains 2.5 mg of an antihistamine. Express this mass in grams.

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2. An adult should limit dietary intake of sodium to 2.40 g/day. Express this as mg/day.

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Name ______________________________________ Lab Instructor ___________________

Partner _____________________________________ Date ___________________

EXPT #1: MEASUREMENTS & SIGNIFICANT FIGURES: LENGTH, MASS, VOLUME

PRE-LAB PROBLEMS:

Indicate whether each measurement is of length, volume, or mass.

1. 11.4 cm is a measurement of ___________________
2. 8.0 cm^3 is a measurement of ___________________
3. 24.7 mL is a measurement of ___________________
4. 725 mg is a measurement of ___________________

Work the following problems:

5. The sum of 6.0 cm + 2.00 mm + 5.00 mm = _________________________ cm.
6. 25 mg = ______________________________ g
7. A marathon race of 26.2 miles =_______________________ km.

Given: 1 mile (mi) = 1760 yd
1 m = 1.094 yd
1 km = 1000 m