

Lab 1 - Introduction to Measurement and Error Analysis

Part 1

Name _____

Partner's Name _____

I. Introduction

In this lab you will measure three types of physics quantities: length, time, and mass. You will also get an introduction to measurement errors associated with these measurements.

II. Equipment

Cardboard Box

Meter Stick

Triple Beam Scale with Additional Weight Set (scale may be shared with other groups)

Burette with stand

Beaker with water

Stopwatch

III. Procedure

A. Length

1. Measure the width, depth, and height of the cardboard box. Record the values in Table 1.
2. Record your best estimate of the uncertainty in each measurement of width, depth, and height in Table 1.
3. Repeat measurements of the width, depth, and height of the cardboard box until a total of five independent values of each are recorded. Remember to exchange rolls with your lab partner several times during this step. **DO NOT MEASURE THE LENGTH FIVE TIMES CONSECUTIVELY FOLLOWED BY THE WIDTH AND THEN THE HEIGHT.**

B. Mass/Weight (Yes, I know they are not the same!!!)

1. Verify/set the triple scale to read 0.0 grams when no mass is on the scale. Using the appropriate additional weights, weigh the cardboard box and record the weight/mass in Table 2.
2. Repeat the previous step until a total of five independent weights are recorded. Remember to re-zero the scale before each weighing and exchange rolls with your lab partner.

C. Time

1. Set up the burette with water and beaker as demonstrated by your instructor. While draining the water from the burette to the beaker, record the time it takes for the water level to fall from 0 ml to 10 ml. Record the time in Table 3.
2. Repeat the previous step until a total of five independent values of time are recorded. Remember to exchange rolls with your lab partner several times during this step.

D. Cleanup/organize your lab setup.

IV. Data (include units!)

<u>Width</u>	<u>Depth</u>	<u>Height</u>
±	±	±
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Table 1.

<u>Weight/mass</u>	<u>Time</u>
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Table 2.

Table 3.

V. Analysis

Definitions:

Average/mean - $\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$

Standard Deviation - $S_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2}$, estimates how well a typical single measurement of x is likely to estimate the 'true' value.

Standard Error - $S_{\bar{x}} = \frac{S_x}{\sqrt{n}}$, estimates how precisely the mean of the n trials is likely to estimate the 'true' value.

In the example below n = 5.

Example: If we have five independent measurements of x : $x_1, x_2, x_3, x_4,$ and x_5 , the average is

$$\bar{x} = \frac{1}{5} \sum_{i=1}^5 x_i = \frac{1}{5} (x_1 + x_2 + x_3 + x_4 + x_5). \text{ The standard deviation is}$$

$$S_x = \sqrt{\frac{1}{5-1} \sum_{i=1}^5 (x_i - \bar{x})^2} = \sqrt{\frac{1}{5-1} ((x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2 + (x_4 - \bar{x})^2 + (x_5 - \bar{x})^2)}$$
 and the

standard error is $S_{\bar{x}} = \frac{S_x}{\sqrt{5}}$. The standard deviation and standard error are associated with the independent

measurements (x_i) and average \bar{x} respectively as follows: $x_i \pm S_x$ and $\bar{x} \pm S_{\bar{x}}$.

- A. Calculate the average, standard deviation, and standard error of the five quantities recorded in this lab. Record the data below in *tabular form*.

- B. What are the best values with uncertainties of the five quantities measured?

- C. Comment on how your estimated uncertainty in step III-A-2 compares with the standard deviation and standard errors calculated.
- D. Although we have not discussed this in class, calculate *with uncertainty* the volume of the cardboard box. Comment/explain your motivation for the uncertainty you record. Remember the uncertainty in the volume must have units of volume, not length!
- E. Assume your average value of the box's width and depth are exact (have no uncertainty) but the height has an uncertainty given by your calculated standard error of the height. With this assumption, what would the uncertainty in the box's volume be? Comment/explain your motivation for the uncertainty you record.

VI. Conclusions and Comments