PHYSICS 130 LABORATORY
EXPERIMENT 1

MEASUREMENT AND PRECISION

NAME: __________________ DATE: ________ SECTION: _____
PARTNERS: __________________ _______________ _______________

OBJECTIVE

Laboratory investigations involve taking measurements of physical quantities, and the process of taking Any measurement involves some uncertainty or experimental error. Therefore, questions will arise such as:

1. How does one estimate and express the degree of uncertainty in the collection of physical data?

2. How do you record data and answers to calculations with the correct number of significant digits in order to relate the proper precision?

3. How do you calculate the mean and standard deviation of a series of repeated measurements, and how do you compare an experimental result to an accepted value?

In addition, once measurements have been taken, how does one graphically analyze and report such data?

This experiment will address all of these questions.

DISCUSSION:

_A. *TYPES OF UNCERTAlN11ES*

Statistical uncertainties (sometimes called indeterminate or random errors) are present in all experimental measurements. There is no way to determine the size or sign of the uncertainty in any individual measurement. Statistical uncertainties show up as variability in the size of a particular measurement when that measurement is repeated many times. These types of uncertainties may have many causes, including operator errors or biases, fluctuating conditions, and inherent variability of measuring instruments. The effects of these uncertainties can be minimized by taking a number of repeated measurements and then taking their average. The average is generally better than any single measurement.

Systematic uncertainties (or determinate errors) can be more serious because their effects cannot be reduced by averaging repeated measurements. Causes of systematic uncertainties include defective or miscalibrated apparatus, a constant bias in observation or procedure, or even blunders.

B. *ACCURACY AND PRECISION*

The accuracy of an experiment is a measure of how close the result comes to the true value. That is, it is a measure of the correctness of the result.

The precision of an experiment is a measure of its reliability, or how reproducible the result is. That is, it is a measure of the magnitude of uncertainty of the result without reference to what the result means.

A measurement with relatively small statistical uncertainty is said to have high precision. A measurement which has a small systematic uncertainty is said to have high accuracy.

C. *EXPRESSING UNCERTAINlIES*

The estimated uncertainity, called "limit of error", is recorded as a plus or minus following the measured value (example, 2.0 ± 0.2 m). This quantity, sometimes called absolute uncertainty or error, is always expressed in the same units as the measured quantity and usually has only one significant digit.

The uncertainity in a measurement can also be expressed as a percent. For the above example, the percent uncertainty would be 10%. This is sometimes called the relative uncertainty or error.

There is,sometimes a need to compare two measurements. This is usually done by finding the percent difference between two measurements. For example, if you measure a distance to be 5.0. while some other person measures it to be 4.8 m, then the percent difference would be (5.0 - 4.8)/5.0 X 100% = 4%.

D. *GRAPHING*

It is often convenient to represent experimental data in graphical form, not only for reporting, but also to obtain information.

Graphing Procedures:

1. Choose axis scales which are convenient to read. Use scale units of 1,2, or 5, and make their size so as to use all of the graph paper. This will allow your data points to spread out making them easy to identify.

2. When the data points are plotted, draw a smooth line connecting the points. "Smooth" suggests that the line does not have to pass exactly through each point but connects the general areas of significance for the data points with approximately an equal number of points on each side of the line, that is, the "curve of best fit."

3. If the limits of errors have been determined, each experimental quantity plotted should have error bars attached. A smooth curve is drawn within the error bars.

4. Be certain each graph has:

   a) each axis labeled with the quantity plotted.
   b) the units of the quantities plotted.
   c) the title of the graph on the graph paper.
   d) your name and date on the graph.

5. When graphing on the computer, you are given a choice of connecting each data point with a straight line or having the computer draw a regression line for your set of data points. If you think the relationship between the two variables is linear, then you should use the regression line. Otherwise, have the computer draw the graph by "connecting points."

EQUIPMENT

Meter stick
Cent-o-gram balance
100-g weight
Circular objects (5)
Vernier caliper
Electronic timer
Coin

PROCEDURE:

1. For each of the measuring instruments (meter stick, vernier caliper, balance, timer), determine the unit of measurement, the smallest scale division, and the uncertainty in reading the instrument. Record this information in the table below.

TABLE I

	Unit	**Smallest Scale Division**	**Uncertainty**
Meter Stick			
Vernier Caliper			
Balance			
Timer			

2. Use the meter stick to measure the length and width of this piece of paper in centimeters. Record your measurements to the precision you determined was possible in Step 1 and record the uncertainty in your measurement, for example, 8.7 ± 0.1 cm. Calculate the length of the : perimeter of the paper and its area. Record the answers with the correct number of digits (significant figures). Refer to pages 16 - 20 of your textbook for an explanation of significant figures.

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Length =___________________________

Width =___________________________

Perimeter = =___________________________

Area = =___________________________

3. Use the metric scales on the meter stick and the vernier caliper to measure the thickness of the 100-g weight. Record the uncertainties for each measurement. The thickness measured with the vernier caliper should fall within the range of uncertainty for the thickness measured with the meter stick. If not, don't panic, just ask the instructor for assistance.

Thickness (meter stick) = ____

Thickness (vernier caliper) = ____

4. Use the balance to measure the mass of the 100-g weight. Record its mass along with the uncertainty.

Mass = ___________________________

5. Use the electronic timer to measure the time required for a coin to drop from the ceiling to the floor. Do this twenty times, and record your results with the correct uncertainties and units. Note that the variation in the results of your time measurements is probably greater than the reading uncertainty of the timer. Find the mean and standard deviation for your twenty measurements.

Trial	Time
1	
2	
3	
4	
5	
6	
7	

Trial	Time
8	
9	
10	
11	
12	
13	
14	

Trial	Time
15	
16	
17	
18	
19	
20	

Average time with standard deviation = ______________________________________

NOTE: For a large random sampling of events, 68 % of those events should fall within one standard deyiation of the mean. Did your data tend to follow this rule? Comment:

6. Measure the circumference and diameter of each of the five circular objects making certain to obtain as many significant digits for each determination as your measuring device will allow. Record all measurements along with their uncertainties in the table below.

Object Number	**Circumference (cm)**	**Diameter (cm)**
1		
2		
3		
4		
5		

Make a graph of circumference versus diameter and determine the slope of the curve showing your calculation below. Compare your slope with the accepted value of 3.1416 by calculating the percent difference.

Slope =____________________ Percent difference = __________________