

Physics 215 - Experiment 1

Measurement, Random Error & Error analysis

Advanced reading- from [Physics](#) by Giancoli, 6th Edition
(Sections 1-4, 1-5 & 1-6)

Part A-Measurement of Length and Error Analysis

Equipment:

1 Ruler
1 Vernier Caliper
1 Micrometer Caliper
Several Coins.

Objective:

The object of this experiment is twofold:

1. To learn to measure lengths using a ruler, vernier caliper, and micrometer caliper.
2. To become acquainted with types of error and statistical methods for analyzing one's data and for estimating its accuracy.
3. To determine the density of a block of metal.

Theory:

In using a ruler three things must be remembered: (1) the reading should be estimated to **one half** of the smallest division; (2) the ends of the ruler should not be used since the ends may have become damaged and no

longer be square; (3) errors of parallax should be avoided by placing the scale against the object to be measured.

In using a vernier caliper tenths of a division are not estimated; they are read off the vernier scale. Notice that 10 divisions on the vernier scale corresponds to 9 divisions on the main scale. Therefore, the mark on the vernier scale which best lines up with a mark on the main scale gives the reading of a tenth of the smallest division on the main scale (see fig. 1. 1).

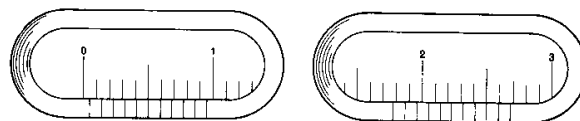


Figure 1-1

In using a micrometer caliper, centimeters and tenths of a centimeter are read from the scale on the barrel. Then thousandths of a centimeter are read from the scale on the thimble. Since this scale only goes from 0 to 50 thousandths the thimble must be turned twice to move one-tenth of

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a centimeter. If the scale is over halfway between the marks on the barrel, then 50 thousandths must be added to the reading. Ten-thousandths of a centimeter should be estimated. (See fig. 1.2.) A zero correction for the micrometer caliper should be determined and recorded. For example, if the micrometer caliper reads 0.002 cm when closed, then

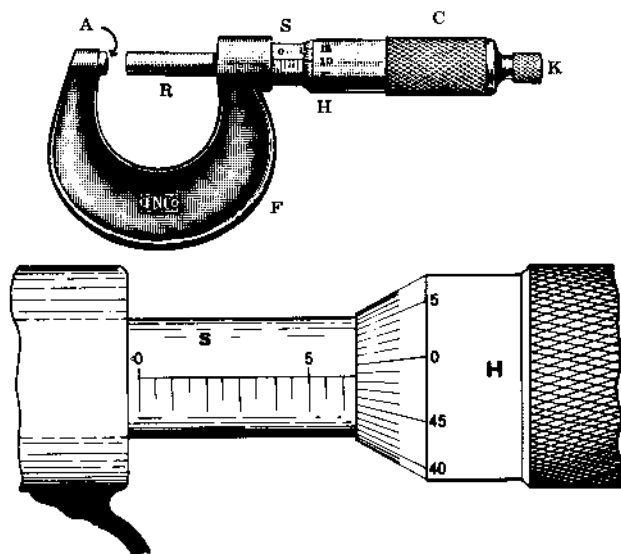


Figure 1-2

Statistical Analysis Of Data and Errors

Mean

If one makes a series of n measurements with results x_1, x_2, \dots, x_n , the mean, or average value, \bar{x} , of the measurements is defined

every reading will be too large by this amount and the zero correction must be subtracted from each reading. When closing the micrometer caliper the small knurled knob must be used so

that the caliper will not be damaged by overtightening.

as

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i = \frac{1}{n} (x_1 + x_2 + \dots + x_n)$$

\bar{x} will be the most probable value for the quantity being measured. By itself, however \bar{x} gives no indication of the reliability of the results, that is, of what statistical error there may be in the results. To analyze this facet of the problem one needs the standard deviation or root mean square of the data.

Standard Deviation Or Root Mean Square

The standard deviation (or root mean square) of the above n measurements is defined as

$$\sigma = \left[\frac{\sum (x_i - \bar{x})^2}{(n-1)} \right]^{\frac{1}{2}}$$

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σ is a measure of the scatter to be expected in the measurements. If one measured a large number of values x_i , then statistically about 67% of the x_i 's would lie between $\bar{x} - \sigma$ and $\bar{x} + \sigma$ and about 97% of the x_i 's would lie between $\bar{x} - 2\sigma$ and $\bar{x} + 2\sigma$.

The error discussed here is experimental, or random error which results because one does not always get the same result in making a series of measurements. This type of error is unavoidable because, no matter how accurately one makes one's measurements, there will always be some uncertainty in the measurements.

The above error is not the only type of error which may be present, however. Systematic errors may be present, and if they are present they may be difficult to account for unless one is aware of them. A few examples will explain what systematic error is. The speedometer in most automobiles reads too high so that one's speed is systematically lower than the indicated speed, and the speedometer introduces a systematic error into any calculations of the speed of the auto. A second example is using a steel

tape measure in cold weather; the tape must have contracted due to thermal effects so that its length is shorter than the length indicated on the rule. A final example is presented by most electrical meters which have an indicated accuracy stamped on the meter. If the accuracy is indicated as 5% then one's measurements made with the meter may be too large or too small by up to 5%. One way of compensating for systematic errors is to calibrate one's instruments if more accurate results are desired.

Personal or human error is a third type of error. Often the person taking data is biased by the first result obtained. In taking measurements one should not try to make them all come out the same, but should merely make each measurement as accurately as possible. Another type of human error is to be sloppy in one's experimental technique; for example, if one allows parallax errors to occur in making a measurement, this is an avoidable human error. In the present experiment, one must be careful to avoid parallax errors.

In analyzing the error in your data try to estimate the magnitudes of the various kinds of error which may be present and discuss

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them in your laboratory report.

Procedure:

A. Ruler

Measure the diameter of a coin three times with the ruler recording the results on your data sheet, then let your partner do the same recording his results. Make your measurements at different points so that a good average dimension will be obtained. You should always be able to estimate the fractional part of the smallest division to get your last significant figure.

Calculate the mean diameter and the standard deviation. Discard any nonsignificant figures before recording the mean diameter.

B. Vernier Caliper

Make three measurements of the diameter of the coin as in part I.A but using the vernier caliper this time. Let your partner do the same. Record the results on your data sheet. Calculate the standard deviation and mean diameter as in part A.

C. Micrometer Caliper

Repeat the measurements and calculations made in parts I.A

and I.B using the micrometer caliper this time. Record the results on your data sheet.

D. Measurement of Density

Density is defined as the ratio of the mass of an object divided by its volume. Using the triple beam balance, determine the mass of your coin, and then assume it is a cylinder and determine its volume. Try to identify the composition of your coin from the density you calculated. Note: Coins are made of various alloys. However, you should be able to determine the most abundant metal used in the minting of the coin. You should be able to find the exact composition on the web.

Questions:

1. Which of the three instruments used in today's lab do you think allowed you to make the most accurate measurement of the diameter of the coin? Why?
2. List and discuss the different types of errors that were present in your measurements

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Part B- Random Error Analysis

Objective

The purpose of this experiment is to make a series of measurements involving a sufficient number of trials to permit the use of a statistical theory of errors to evaluate the results.

Part 1:

Equipment:

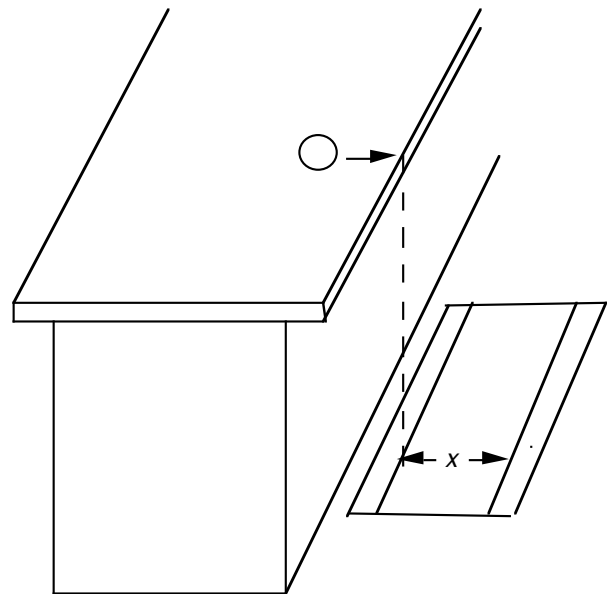
Steel Ball
Carbon Paper
Sheets of Ruled Paper
ruler

Procedure:

Place a sheet of paper over a layer of carbon paper approximately 30 cm from the table on the laboratory floor. Mark a line on the paper which is parallel to the edge of the table. Using a plumb bob, locate the position of the edge of the table on the floor and accurately measure x , the distance from the table and attempt to hit the line on the paper as the ball strikes the floor. Measure the horizontal distance from the position of the edge of the table to the actual impact point, call it x_1 (measure to the nearest cm). Repeat these in a

vertical column. We will now obtain two numbers which will give

a measure of the variability of your skill in this experiment.



Ball shown on table with paper beneath.

1) Calculation of the average value:

$$\bar{x} = \frac{\sum_{i=1}^N x_i}{N}$$

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The x_i 's are simply the measured values for x for the different trials. A comparison of this value with the true distance from the table edge to the line shows whether or not the results are consistently too short or too long.

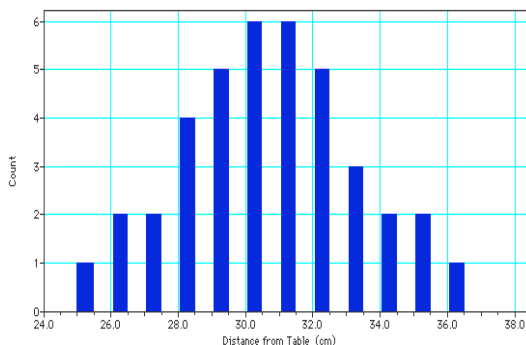
2) Calculation of the standard deviation: This quantity gives an indication of the consistency of the trials.

Write your result as:

$$\sigma^2 = \frac{\sum_{i=1}^N (x_i - \bar{x})^2}{N-1}$$

3) Plot of the distribution of hits versus position (i.e., a histogram):

Draw a graph of the number of times the ball hit within a specified distance from the table versus the distance from the table in centimeter intervals.



Include on the graph:

1) The average value of the measured value of x (the arithmetic average).

2) The true value of x (actual position of the line).

3) The calculated standard deviation.

Part 2

Equipment:

Compressed Pills

Digital Balance (0.001g resolution)

Procedure:

Measure the mass of at least 30 of these compressed pills and calculate:

a) the average value of the mass

b) the standard deviation of this distribution

c) plot the distribution of mass versus number for the pills in your measurement set.

Questions:

1. Compare the graph of your data with the sample graph. Ex-

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plain the differences in the distributions observed. How could you reduce the value of σ if the experiment were repeated?

2. If a die were tossed twice, what can you say about the average value of the number thrown? If the die were tossed 100 times, what would be the average value of the number thrown? Why are your answers different?

3. What can you say about the dose delivered by a pill in your measurement set. How does this experiment help to describe the variability or consistency of the production process producing this medication?