Experiment 1
MEASUREMENT

EQUIPMENT

3 discs of different diameters	*Computer Software: Sphere Volume*
3 spheres of different diameters	*Circle Area*
3 unknown masses	*Calculator*
1 set of standard masses	*Percent Error Program*
1 metric ruler	
1 vernier caliper	*1 250g spring scale*
1 electronic balance	*1 stopwatch*
1 reflex strip	*1 wristwatch or wall clock*

INTRODUCTION

The purpose of this experiment is to become familiar with methods of measurement and error. In the study of physical objects it is very important to be able to systematically measure the quantities of length, mass, and time. In this experiment you will investigate methods of making these measurements. Then you will use the computer to calculate the area and volume of several objects.

Although you are probably more familiar with measuring things in units of pounds, feet, miles, etc., the international community of scientists have adopted a system using kilograms, meters, and for time, seconds. These units form the basis of the SI (Système International) or the MKS (meter, kilogram, second) measurement system. These are metric units. One advantage of the metric system is that it is based on the decimal system. One tenth of a meter is called a decimeter, one hundredth of a meter is called a centimeter, and one thousandth of a meter is called a millimeter. Similarly, 1000 meters is called a kilometer (about 0.62 miles). You will find more information about the metric system and conversions in the appendix.

Every measurement that you make is a comparison. The characteristic you wish to quantify must be measured in comparison to a standard. The first international standard of length was a bar called *The Standard Meter* kept in the *Bureau of Weights and Measures* in Paris. Historically, the meter was intended to be a convenient fraction (1/10,000,000) of the distance between the North Pole and the equator traveling along a line through Paris. There are copies of this standard meter in the laboratory and you will use these as your first technique for measuring length.

The standard unit for mass is the kilogram. *You will use scales that measure mass in grams.* Mass is a property of an object that is related to the gravitational force acting on it, in other words, its weight. **Mass and weight are not the same, and should not be confused.** Mass can also be considered a measure of an object's inertia or resistance to change in motion. Mass is an important property of an object as it can be used in determining the acceleration and momentum of the object. There is, of course, a standard kilogram mass in the Bureau of Weights and Measures. Copies are available in the laboratory.

The standard unit of time is the second, and it was defined as 1/86,400 of a mean solar day. It is a bit difficult to keep a copy of the standard clock around since the standard clock is based on the vibrations of a cesium atom. However, there are electronic stopwatches available for your use in the laboratory.

Measurement of Length

There are a number of different ways to measure length. Some you are familiar with, such as simple estimation, the use of rulers, tape measures, and such. Others you may not be so familiar with, such as the use of micrometers, calipers, and electronic rangers. The method chosen to make a linear measurement depends upon the accuracy desired and the distance involved. You can easily estimate the distance from your seat to the door, say three or four meters, but it would not probably be so easy to estimate the diameter of a coin. In the first instance it would be unnecessary to use a ruler graduated in tenths of a centimeter to find the distance, while in the second case it may be very necessary to use calipers graduated in tenths of a millimeter. In this experiment you will try different techniques on several small objects to discover the relative merits of each.

To measure the length of an object, place the object on the ruler exactly on a millimeter mark. Then determine the length by measuring the difference between the two scale positions. That is, the length of the object is the difference in the right and left scale readings. Note that it may be difficult to accurately place the object on the ruler so that you are measuring the exact length. For this reason it is wise to make several measurements of the length and average the results.

A more precise method of measuring length is achieved by the use of a caliper. The object whose length is to be measured is placed between the two jaws of the caliper and held lightly, but firmly. The caliper you will use is designed to measure tenths or hundredths of a main scale division. In this way measurements can be made to tenths of a millimeter while measurements with your ruler can be accurate only to within an estimated 1/2 millimeter.

Measurement of Mass

Mass is usually measured on some type of scale. This scale may be mechanical or electronic. In either case, the gravitational force on the object causes a displacement of the scale mechanism that is then measured. In this laboratory you will use a simple spring scale, then a triple beam balance then a digital balance to find the masses of some objects.

To use the spring scale, simply attach the object whose mass is to be measured to the spring hook and read the value adjacent to the scale pointer. This is a fast but not particularly precise method. A better method is measurement by the triple beam balance. Here the mass to be measured is placed on the weight pan and the sliding masses on the balance beams are adjusted to give a zero reading at the pointer. The mass of the object is then read as the sum of the values at which the sliding masses are aligned. The most accurate method we will use is the electronic balance. Simply place the object on the pan and read the measurement.

Measurement of Time

Time is the easiest physical quantity to measure. Most everyone wears a wristwatch these days, and some hand calculators have a clock function. In laboratory exercises you may sometimes keep track of time with wristwatches or wall clocks. However, for more accurate measurements you will use a stopwatch. This timepiece measures time to a hundredth of a second and will serve as the time standard in this experiment.

Calculation of Area

It is quite often necessary to calculate the area of an object. To help you make such mathematical calculations you are going to use a computer program.

Remember that *the area of a rectangular surface is equal to its length times its width*, so that the surface area of an object 1-cm high and 1 cm wide is 1 cm^2 (one square centimeter). An object 2-cm high and 4 cm wide would have an area of 8 cm^2 (eight square centimeters).

The area of a circle is equal to pi (π) times the radius of the circle squared (πr^2). Since the radius is one half the diameter, you can remember that the area of a circle is equal to pi times one half the diameter squared. In one part of the experiment you will calculate the surface areas of several discs whose diameters you have measured.

Calculation of Volume

Sometimes it is necessary to calculate the volume of an object. For instance, *the volume of a rectangular object is equal to its length times its width times its height or L*W*H.* For example, an object 2m high, 3m wide, and 4m deep has a volume of 24m^3 (24 cubic meters).
The objects that we will measure in this lab are more common than cubes and rectangles. They are spheres. Thus it is necessary to know how to calculate the volume of a sphere. The formula is:

$$Volume = \left(\frac{4}{3}\right)\pi R^3$$

or using R = D/2

$$Volume = \left(\frac{1}{6}\right)\pi D^3$$

where D is the diameter of the sphere.

Use the computer and the appropriate program to make this calculation. By using the correct program, it is only necessary to enter the diameter of the object that you have measured. From this, the volume of the object will be determined. In this way, you are able to complete the same calculations for various objects very quickly. This illustrates that computers are very useful in doing repetitive computations.

Calculation of Error

It is important to recognize that any measurement you make is subject to error regardless of the care with which you make the measurement. To indicate how precise or reliable a given measurement is, it is often convenient to determine the percentage error.

The percent error can be calculated using the following formula:

$$\% \ error = \frac{|true \ value - measured \ value|}{true \ value} x100$$

Whenever the true value of the quantity is known, you can calculate percent error and determine the accuracy of your experiments. In some

experiments this will be possible, in others it will not. But, whenever you are given the correct value for a quantity, you should calculate the percent error of your measurement. The sign of the percent error is not significant. Record the absolute value (% error without a sign) on your data sheet. Make certain you understand the number of significant figures to report.
 See Appendix F of lab notebook.

PROCEDURE

(Experiment data is located on the website below). Go to this webpage to get lab data.

https://relativity.phy.olemiss.edu/~thomas/weblab/107_webpage_upload/1_107_COVID_web_items/Folder_107_Measurement_Data/1_Measurement_data_index.html

A. Measurement of Length

1. Make a best guess estimate of the diameters of 3 different discs.

    To see data: click on 'Estimation of diameters'.

2. Your answer should be in metric units. Record your best guess to the 1/2 cm in the space provided in the data table.

    Now use the ruler to measure the diameters of the 3 disks. The ruler can measure length to 1 mm (0.1 cm). Record the measurements on the data chart.

    To see data: click on 'Diameter of circular objects using ruler'.

3. Repeat the measurements using a caliper. The caliper can measure lengths to a resolution of 0.01 mm or 0.001cm. Record the results.

    To see data: click on 'Diameter of circular objects using caliper'.

4. Use the ERROR formula above to calculate the percent error of your estimates and the measurements made with the ruler. **Use the caliper measurements as the true values.** Record your findings on the data table.

5. Measure the diameters of 3 different spheres by repeating steps 1 through 4. Record the results on the data table.

    To see data: click on

    'Diameter of spheres using ruler'.

    and

    'Diameter of spheres using caliper'.

B. Measurement of Mass

6. Three (3) objects of unknown masses were measured by your laboratory instructor. They were measured by a spring scale, a triple beam balance and a digital balance.

7. To see the data from the spring scale: click on "Mass using spring scale.

     Record the results in the table below.

8. To see the data from the triple beam balance: click on "Mass using triple beam balance'.

    Record the results in the table below.

9. Repeat using the electronic balance.

    To see the data from the electronic balance: click on "Mass using electronic balance'.

10. Use the ERROR program to calculate the the spring measurement, and triple beam balance measurement. **Use the electronic balance as the true value.** Record the results.

C. Measurement of Time

Go to the website below;

https://nrich.maths.org/10629

11. Estimate a 30-second interval by counting (you can tap your foot or use your heartbeat to establish rhythm). Use computer program to record your estimated time. Record the estimate in table below.

12. Estimate a 60-second interval by counting again as before. Use computer program to

record your estimated time. Record the estimate.

13. Use the reaction timer to record at least 3 reaction times. The recorded time is roughly twice your reaction time on starting and stopping a stopwatch. Do you think you can actually measure time to second (0.01 sec.) using this watch? (See Question # 6)

14. Use the %ERROR formula to calculate the error of your estimates and clock watching.

Remember, that the computer recorded time is your true value. Record the results.

D. Calculation of Area and Volume

15. Use the formulas below to find the area of each disk and the volume of each sphere. Record the results in the table below.

$$Area = \frac{1}{4}\pi D^2$$

$$Volume = \left(\frac{1}{6}\right)\pi D^3$$

Experiment 1   *DATA SHEET*

Name: _____   Section: _____

A. Measurement of Length

Object	Estimated Diameter (cm)	Diameter by Ruler (cm)	Diameter by Caliper (cm) (TRUE)	% Error of Estimate	% Error of Ruler Measurement
disc 1					
disc 2					
disc 3					
sphere 1					
sphere 2					
sphere 3					

B. Measurement of Mass

Object	Estimated Mass (g)	Mass by Spring Scale (g)	Mass by Triple Beam Balance(g)	Mass by Electronic Balance (g) [True]	% Error of Estimate	% Error of Spring Scale Measurement	% Error of Triple Beam
unknown 1							
unknown 2							
unknown 3							

C. Measurement of Time

Estimate of Time	Time Using Program (s) [TRUE]	% Error of Estimated Time	Estimate of Time	Time Using Program (s) [TRUE]	% Error of Estimated Time	Reflex Time average (s)
30 sec			60 sec			

Experiment 1
DATA SHEET

D. Calculation of Area and Volume

Object	Calculated Area (cm²)
disc 1	
disc 2	
disc 3	

Object	Calculated Volume (cm³)
sphere 1	
sphere 2	
sphere 3	

QUESTIONS

1. What was the purpose of this experiment?

2. What is the standard unit for length, mass and time in the MKS metric system?

3. Why are units important when reporting the result of a measurement?

4. An object is estimated to be 2.5 cm long. When measured with a Vernier caliper its true length is determined to be 2.47 cm. What is the percent error of the estimated value?

5. Complete the following calculations using the explanation of significant figures given below.
   * When **multiplying and dividing** several quantities, the number of significant figures in the final answer is the same as the number of significant figures in the quantity with the least amount of significant figures that is being multiplied.
   * When **adding and subtracting** several quantities, the number of decimal places in the result should equal the smallest number of decimal places of any term in the sum.

    Given: x = 12.24   y = 5400   z = 11.572

    Determine: x * y * z = _____

                   x + z = _____

6. Consider the results of your reflex time measurement. What precision, in fractions of seconds, can you claim for the stopwatch?

END OF LAB