PHYS 1401

General Physics I

EXPERIMENT 1

MEASUREMENT and UNITS

I. OBJECTIVE

The objective of this experiment is to become familiar with the measurement of the basic quantities of mechanics and to become familiar with the recording of experimental data including paying special attention to units and significant figures.

II. INTRODUCTION

The basic concepts of mechanics are **Length, Mass** and **Time**. Every other concept in mechanics is derivable from these three. The SI units of these concepts are the **meter, m**, the **kilogram, kg** and the **second, s**. Definitions of these basic units can be found in any college physics textbook. You can also find these definitions in the SI units booklet publised by the National Institute of Standards and Technology (NIST).

For the purposes of this and future experiments, let us define the **precision** of the measuring instrument to be **the size of the smallest division of the instrument.** For the meter stick and the ruler, the smallest division is the millimeter. Therefore their precision is $1\,\text{mm} = 0.1\,\text{cm} = 0.001\,\text{m}$. Measurements using either the meter stick or the ruler should be recorded to the nearest millimeter.

A **vernier caliper** has a precision of $0.1\,\text{mm}$. This means that the vernier caliper gives one extra significant figure over the ruler and the meter stick and should be used to measure dimensions around $5\,\text{cm}$ or smaller.

For a digital instrument, the precision is also the size of the smallest division. Most digital instruments have several scales and the precision of each scale is different from the others. If you use the digital scale in the lab to measure the mass of an object, you will get a reading like $74.5\,\text{g}$. The precision of this scale is a tenth of a gram $0.1\,\text{g}$.

Significant figures are all the numbers which can be read from an instrument. Please refer to the separate handout on significant figures for a discussion of the rules governing the number of significant figures which should be retained in calculations.

III. APPARATUS

Ruler, vernier caliper, micrometer, pendulum, stop watch, digital balance and spring balance.

III. EXPERIMENTAL PROCEDURE

Procedure (1): Lab Table

If the dimensions of the object being measured are much larger than the precision of the measuring instrument (100 times or more), the instrument is considered very adequate for the measurement and will give fairly "precise" results.

1. Using a meter stick, measure the length and the width of the lab table and record them (in meters) to the nearest mm (the least significant figure has units of mm). The spacing between the millimeter marks on the meter stick is small, therefore do not estimate fractions of millimeters. Just read the dimensions to the nearest millimeter. Record your data in data table (1) in units of meters (m), centimeters (cm) and millimeters (mm). Use scientific notation when needed.
2. Calculate the area of the table top and enter it in the data table. Remember the units. When you multiply the numbers, you also must multiply the units.

Procedure (2): Rectangular Block

1. Using a ruler, measure the dimensions of the rectangular block and record your measurement in data table (2). Remember the units and use scientific notation when needed. The precision of the ruler is the millimeter (mm), the same as the meter stick.
2. Calculate the surface area of the block $A = 2LW + 2LH + 2WH$ and enter it in your data table in m^2, cm^2 and mm^2. Note: $1\,\mathrm{cm} = 0.01\,\mathrm{m} = 1 \times 10^{-2}\,\mathrm{m}$ and $1\,\mathrm{mm} = 0.001\,\mathrm{m} = 1 \times 10^{-3}\,\mathrm{m}$.
3. Calculate the volume of the block, $V = LWH$, and enter it in your data table. Remember the units!
4. Using a digital scale (or triple beam balance), measure the mass of the block and record it in data table (2) in grams (g) and kilograms (kg). $1\,\mathrm{g} = 0.001\,\mathrm{kg}$.

5. Calculate the density of the block of wood $\rho = M/V$ in $\mathrm{kg/m^3}$ and $\mathrm{g/cm^3}$.

Procedure (3): Cylindrical Block

1. Here we will repeat procedure (2) using a cylindrical block instead of rectangular and using a **vernier caliper** instead of the ruler. The precision of the caliper is $0.1\,\mathrm{mm}$ which is 10 times smaller than the precision of the ruler which is $1.0\,\mathrm{mm}$. The vernier caliper has a main scale and a movable scale (the vernier). The main scale is a ruler and its smallest division is, therefore, the mm. The vernier has 10 divisions that cover $9\,\mathrm{mm}$ on the main scale. When making a measurement using the caliper, read the position of the zero mark of the vernier on the main scale. Then find a mark on the verneir which coincides with (or is very close to) a mark on the main scale. This mark gives the extra significant figure in the measurement. If you use a digital caliper, then you will get a digital reading which includes the extra significant figure.
2. Using a vernier caliper, measure the diameter and the height of the cylindrical block and record them in data table (3).
3. Calculate the surface area (including the top and the bottom) and the volume of the block. $A = 2(\pi r^2) + 2\pi r H$ and $V = \pi r^2 H$. Remember the units!
4. Measure the mass of the cylindrical block and calculate its density as you did with the rectangular block. Enter the values in the data table.
5. Inspect the measurements and calculations of the last two procedures and make a comment on the improved precision in the latter procedure.

Precedure (4): Time Measurement

1. In this procedure, we will measure the period of a pendulum. The period of a pendulum is the time it takes the pendulum bob to swing back and forth once returning to its starting point. If the period of the pendulum is around one second, then we need to use a clock which has a precision which is much less than $1\,\mathrm{s}$.
2. Make a pendulum where the length of the string is about $1\,\mathrm{m}$. Pull the bob to the side until the angle with the vertical is $20°$. Using a digital stop watch, measure the time it takes the

pendulum to make 10 oscillations and record this time in data table (4).

3. Calculate the period of the pendulum, T. Remember the units.
4. It should be noted here that a source of error in this procedure is the reaction time of the person handling the stop watch. This is the time difference between the actual release of the pendulum bob and the start of the stop watch. Also at the end of the measurement, generally there will be a difference between the end of the last oscillation and the stopping of the stop watch. Based on this observation, do you think it is wise to measure the time for just one oscillation?
5. If your answer to the above questions is "yes", then you should try measruing just one oscillation 10 different times and see how much variation there is among the 10 readings.

Table (1): The Lab Table

Length, L			
Width, W			
Area, A			

Table (2): Rectangular Block

Length, L			
Width, W			
Height, H			
Surface Area, A			
Volume, V			
Mass, M			
Density, (rho)			

Table (3): Cylindrical Block

Diameter, d			
Radius, r=d/2			
Height, H			
Surface Area, A			
Volume, V			
Mass, M			
Density, (rho)			

Table (4): Pendulum

Time for 10 Oscillations, t	
Period, T	