M4b: Measurements

Introduction:

Precise and accurate measurements are the cornerstone not just of physics experiments, but also of physics itself, and the sciences in general. In order to make accurate measurements, it is necessary to take those measurements using the proper instrument. Being familiar with the appropriate use of the equipment is also important. If the correct equipment is being used incorrectly or inaccurately, then the measurements will be flawed. In either case, with incorrect measurements, the results of any experiments will be inaccurate, and the experiment may need to be repeated, resulting in more time spent in the lab.

The focus of this current experiment is on learning how to use the different tools of measurement properly, and also on learning how to select the correct measuring tool for the task. By taking several different measurements of mass, length, and time for different objects in different situations, it becomes possible to familiarize one's self with the West Campus Physics Laboratory's measuring apparatuses. This familiarity will prove to be extremely important for all future physics experiments performed throughout the semester.

After collecting the different measurements, those values will be used to calculate volume, density and velocity. Remember, when collecting data and taking measurements, and also when performing calculations, to pay careful attention the units of measurement; units of measurement must be consistent. Also, all measurements used for experiments performed here in the lab should be made in **MKS** (meters, kilograms, and seconds), unless explicitly stated otherwise. Finally, once all calculations have been completed, some simple statistical analysis will be performed on the collected data.

Apparatus:

- 2 cubes of similar volume
- 1 long cylinder
- 5 different lengths of wire cut from the same spool
- 1 small metric ruler
- 1 meter stick
- 1 digital caliper
- 2 different laboratory balances
- 1 standard clock with second hand
- 1 stop watch
- 1 computer photogate & range finder timing system
- 1 air track & aux. equipment

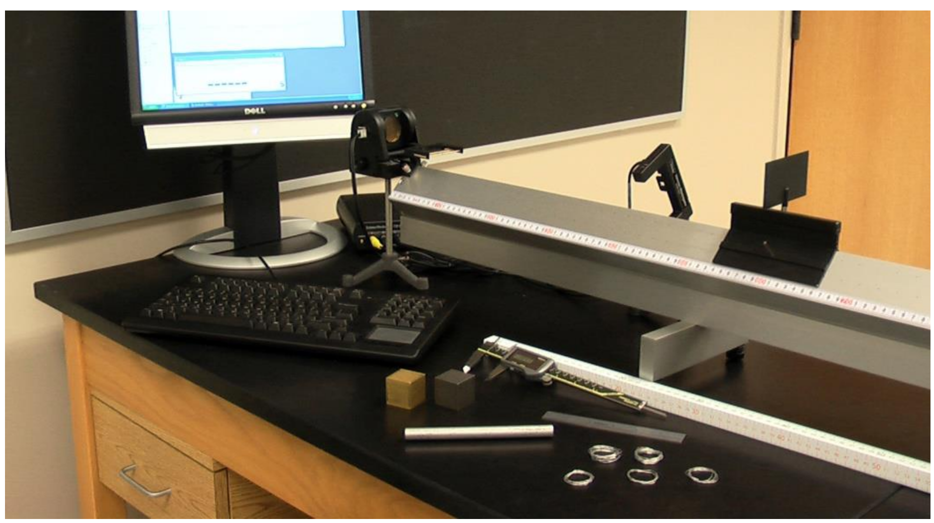

Figure 1

Procedures:

This lab consists of four small sub-experiments, all of which are related to the central concept of measurement, and all of which are geared to providing the understanding necessary to operate the different measuring apparatuses in the physics laboratory. Be sure to follow the instructions to each of the four different parts of this experiment exactly. **In general, please be sure to seek assistance from a lab instructor before starting any experiment this semester.**

PART I

1. There are multiple laboratory balances located throughout the Physics Lab. The mass of the two cubes should be measured on all these balances, in order to gain familiarity with their different accuracies. Keep in mind that if a mass is too heavy for a balance, it will not give a reading.
2. Record only 2 of the mass measurements: one of the measurements of mass should be from the most precise balance in the lab, and the other measurement should be taken from the least precise balance in the lab. Record this information in the provided **Data Table**. Take careful note of any variations in the mass between these two balances, and be prepared to offer possible explanations for any discrepancies observed within the final lab report write up.
3. Measure the length, width, and height of both of the cubes. Do so first with the provided metric ruler, and then with the digital caliper. Record these measurements as well; again, being sure to take note of any variations, paying attention to any difference in precision between the two measuring tools. Please be aware that measuring only one side of the cube will not suffice.
4. Calculate the volume and the density of each cube using the measurements obtained with the digital caliper and the most precise electronic balance. In general, unless otherwise specified, one should always use the most accurate measurement available when calculating experimental results. The following formulas might prove useful:

$$\text{Volume}_{\text{parallelepiped}} = \text{Length} \times \text{Width} \times \text{Height} \qquad \text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

5. To demonstrate how the precision of the equipment used to take measurements might affect experimental results, please calculate out the volume and the density again, this time using the measurements of the least precise balance and the ruler.
6. Now that the density has been calculated using both the more and less precise measurements, it becomes necessary to compare the results. To compare these two densities, utilize one of the error-checking formulas. Provided below are two different error-checking formulas that will be used throughout the semester; it would be beneficial to become familiar with both formulas. Calculate the percent difference between the densities.

$$\text{percent error} = \left|\frac{x_{\text{experimental}} - x_{\text{theoretical}}}{x_{\text{theoretical}}}\right| * 100\% \qquad \text{percent difference} = \left|\frac{x_{\text{experiment 1}} - x_{\text{experiment 2}}}{x_{\text{experiment 1 \& 2 average}}}\right| * 100\%$$

Part I (cont.)

7. Finally, to confirm that the results garnered from this Part of the experiment are reasonable, compare the more precise calculate densities against the accepted values for the densities of the materials of the cubes. Provided below is a table that gives the accepted densities for the cubes. Please calculate the percent error for the most precise density measurement and the accepted value for the density of each cube.

Density of Steel: Plain Carbon Steel 7.86 g/cm^3
Density of Brass: Yellow Brass 8.47 g/cm^3

PART II

1. Select the longest cylinder from the **M4** lab materials. Gradually moving along the length of the cylinder, measure its diameter in ten different places using the caliper. Record these measurements in the provided **Data Table**.
2. Calculate the mean (average) diameter of the longest cylinder and its standard deviation. Standard deviation provides insight into the variance among the different measurements collected as compared to the mean value. Also calculate the standard deviation as a percentage of the mean. These values can be calculated by using the following formulas. *(*They also may be calculated using a graphing calculator or Excel).*

$$\text{Mean} = \frac{\sum \chi}{n}$$

χ = *a measured value*
n = *the number of measured values*

$$\text{Standard Deviation} = \sqrt{\frac{\sum(\chi^2) - \frac{(\sum \chi)^2}{n}}{n-1}}$$

$$\%\ Dev/Mean = \frac{Standard\ Deviation}{Mean} * 100\%$$

Why are there discrepancies in the different measurements of the cube and of the Cylinder?

PART III

1. Estimate the length of each piece of wire as accurately as possible without directly using a measuring tool. When asked to estimate, it is assumed that the student will make use of both their own previous experiences with units of measurement, as well as their earlier experiences in the lab, in order to provide them with a benchmark to base their estimations upon. Be sure to record all of the data in the appropriate **Data Table**.
2. Now measure the length of each piece of wire as accurately as possible by using the most precise tools of measurement available.
3. Measure the mass of each piece of wire using the most precise electronic balance available.

4. Make a graph of the data collected, placing the mass measurements on the y-axis and the corresponding length measurements on the x-axis. Find the slope of the best-fit straight line through the data on the graph, as well as the standard deviation of the slope. The best fit straight line refers to the statistical slope using the method of least square regression. All of the lab computers have Excel available for you to use to create the graph and complete the statistical calculations. This slope will give the linear density of the wire. Also calculate the deviation as a percentage of the slope.

PART IV

This set of procedures uses the air track and side bumper to launch a cart with a consistently constant velocity. To launch the cart it is necessary to pull the cart back so that it is creating tension in the rubber bands on one end of the track, releasing it to launch the cart down the air track. As a suggestion, try to compress the rubber band to a similar degree each trial of the experiment in order to better maintain a more constant velocity.

1. Ask a Lab instructor for assistance to set up the air track and the photogate timing system.
2. Measure the length of time the cart takes to travel one meter. Conduct five trials using the analog clock with a second hand to measure the time. Try to be as accurate as possible Record all of the information in the appropriate **Data Table**.
3. Repeat the above procedure (2), still conducting 5 trials, but using the hand held stop watch instead.
4. Calculate the mean and the standard deviation of the time measured with the analog clock and the stop watch systems. Also calculate the velocity of the cart for each timing system. This may be done by making use of the mean time and the measured distance of travel.
5. Repeat the procedure (2) now using the computer photogate timer to determine the time for five trials.
6. Calculate the velocity for each of the photogate trials.
7. Calculate the mean velocity and standard deviation for the photogate trials.
8. Ask a Lab instructor for assistance to set up the range finder timing system.
9. Repeat the procedure (2), this time using the computer range finder to determine the time for the five trials.
10. For each of the trials using the range finder, find the slope of the graph "Position vs Time" to determine the velocity.
11. Calculate the mean velocity and standard deviation for the range finder trials.

Experiment M4b: Measurements

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

Physics Course____

Physics Professor______________________________________

Experiment Start Date___________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheets: M4b: Measurements

NAME: ____________________________ DATE: _________________

PART I -- MASS AND DIMENSIONS

	Measured Mass *Via Least Precise Balance* (g)	Dimensions *Measured with ruler* (mm)		Measured Mass *Via Most Precise Balance* (g)	Dimensions *Measured with caliper* (mm)	
Cube 1		**L:**			**L:**	
		W:			**W:**	
		H:			**H:**	
Cube 2		**L:**			**L:**	
		W:			**W:**	
		H:			**H:**	

	Least Precise Volume (cm^3)	Least Precise Density (g/cm^3)	Most Precise Volume (cm^3)	Most Precise Density (g/cm^3)
Cube 1				
Cube 2				

	% Diff. between Most and Least Precise Densities	% Error for Most Precise and Accepted Density
Cube 1		
Cube 2		

Data Sheets: M4b: Measurements

NAME: ____________________________ DATE: _________________

PART II -- DIAMETER MEASUREMENTS

Trial #	Measured Diameter (mm)	Trial #	Measured Diameter (mm)
1		6	
2		7	
3		8	
4		9	
5		10	

Mean of Diameter: ____________ Standard Deviation of Diameter: ____________

% Dev/Mean: ____________

PART III -- LINEAR DENSITY

Trial #	Estimated Length (cm)	Measured Length (cm)	Measured Mass (g)
1			
2			
3			
4			
5			

Slope of the Regression Line (Linear Density): ______________

Std. Dev.:________________

% Dev/Slope: ____________

Data Sheets: M4b: Measurements

NAME: ______________________________ DATE: __________________

PART IV -- TIME AND VELOCITY

Distance:_________________________(m)

Trials	Clock Time(s)	Stop Watch Time (s)
1		
2		
3		
4		
5		
Mean		
Standard Deviation		
Velocity (m/s)		

Trials	Photogate Time (s)	Photogate Velocity (m/s)	Range Finder Time (s)	Range Finder Velocity (m/s)
1				
2				
3				
4				
5				
			← Mean →	
			Standard Deviation	