M4a: Measurements

Introduction:

Precise and accurate measurements are the cornerstone not just of physics experiments, but also of physics itself, and science in general. In order to make accurate measurements, it is necessary to take the measurement using the proper instrument. Being familiar with the appropriate use of the equipment is also important. If the correct equipment is used incorrectly or inaccurately, then the measurements will be flawed. 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 necessary 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; which must stay consistent. Finally, some simple statistical analysis will be performed on the collected data.

Apparatus:

- 4 cylinders with different volumes and masses
- 2 cubes of similar volume
- 1 small metric ruler
- 1 digital caliper
- 2 different laboratory balances
- 1 analog clock with second hand
- 1 stop watch
- 1 computer photogate & range finder timing system
- 1 air track & auxiliary 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 in order 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. **Also, be sure to seek assistance from a lab instructor before starting any experiment this semester.**

PART I

1. Measure the mass of each cube first with the most precise laboratory balance available, and then with the least precise laboratory balance. Record this information in the provided **Data Table**. Take note of any variations in the mass and offer possible explanations for any discrepancies observed.
2. Measure the length, width, and height of both of the cubes. Do so first with the provided ruler, and then with the digital caliper. Record these measurements as well; again, being sure to take note of any variations, paying careful attention to any difference in precision between the two measuring tools.
3. Calculate the volume and the density of each cube using the measurements obtained with the digital caliper and most precise electronic balance. The following formulas might prove useful:

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

4. Ask your lab assistant for the material of each cube and search for the theoretical density of them. Calculate the percentage error.

PART II

1. Select the longest cylinder from the **M4a** lab kit. 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. These values can be automatically calculated by using the following formulas. *(*They also may be calculated using a graphing calculator or MSExcel).*

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

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

Why are there discrepancies in the different measurements of the cylinder?

PART III

1. Measure the length, diameter, and mass of each of the remaining three cylinders. Be sure to use the measuring tool that will give the greatest possible precision. Record these measurements in the appropriate **Data Table**.
2. Calculate the volume and density of each cylinder. The following formula will prove useful:

$$\text{Volume}_{\text{cylinder}} = \pi \times \text{Radius}^2 \times \text{Length}$$

3. Ask your lab assistant for the material of each cylinder and search for the theoretical density of them. Calculate the percentage error.

PART IV

This set of procedures uses the air track and side bumper to launch a cart with a consistently constant velocity. In order 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. Repeat the procedure using the computer photogate timer to determine the time for five different trials.
5. Ask a Lab instructor for assistance to set up the range finder timing system.
6. Repeat the procedure, this time using the computer range finder for the five trials.
7. Calculate the mean and the standard deviation for each of the timing 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.

Experiment M4a: 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: M4a: Measurements

NAME: ____________________________ DATE: _________________

TABLE I – MASS AND DIMENSIONS

Cube	1st Mass Measurement (g) (least precise)	2nd Mass Measurement (g) (most precise)	1st Dimensions Measurement rule (mm)		2nd Dimensions Measurement caliper (mm)	
1			L:		L:	
			W:		W:	
			H:		H:	
2			L:		L:	
			W:		W:	
			H:		H:	

Cube	Volume (cm^3)	Density (g/cm^3)	Cube Material and Theoretical Density (g/cm^3)	% Error
1				
2				

Data Sheets: M4a: Measurements

NAME: ____________________________ DATE: _________________

TABLE II -- DIAMETER MEASUREMENTS

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

Mean: ________________ Standard Deviation: _______________

TABLE III -- MASS, VOLUME, and DENSITY

Cylinder	Measured Length & Diameter (mm)		Measured Mass (g)	Calculated Volume (cm^3)	Calculated Density (g/cm^3)	Material and Theoretical Density (g/cm^3)	% Error
1	L:						
	D:						
2	L:						
	D:						
3	L:						
	D:						

Data Sheets: M4a: Measurements

NAME: ____________________________ DATE: _________________

TABLE IV – Time and Velocity

Length (m): _____________

	Measured time			
Trials	**Clock (s)**	**Stop Watch (s)**	**Photogate (s)**	**Range Finder (s)**
1				
2				
3				
4				
5				
Mean of time (s)				
Standard Deviation of time (s)				
Velocity (m/s)				