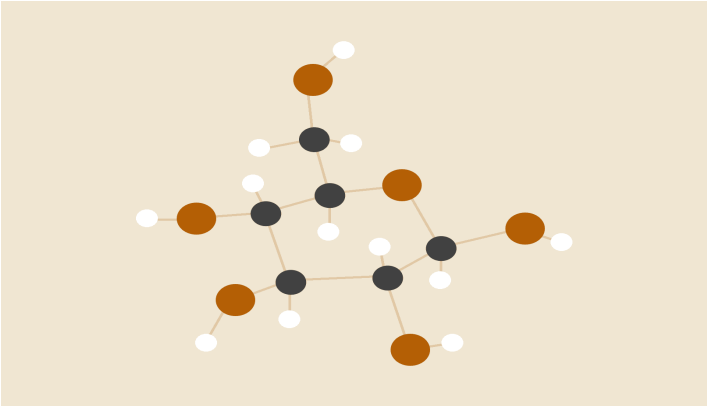
1st Lab Manual

MEASUREMENT OF THE FUNDAMENTAL PHYSICAL QUANTITIES

Measuring Length, Mass, and Time



Lab Group #?

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Date

PHY 101 FALL2026-27
Instructor:
Number of pages: 8

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PRE-LAB QUESTIONS

“Pre-Lab Questions” are prepared and turned in at the beginning of each laboratory session. Prelabs are homework assignments that help students prepare for laboratory experiments.

Please answer the following questions before you start this lab:

1. What is a digital multimeter, and which electrical quantities can it measure? What are the units and symbols of those?

2. How should a voltmeter and an ammeter be connected in a circuit to measure voltage and current correctly? What happens if they are connected incorrectly? *Explain*.

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 paying special attention to units and significant figures.

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. For the purposes of this and future experiments, let us define the precision of the measuring instrument to be the smallest division of the instrument. For the meter stick and the ruler, the smallest division is the millimeter. Therefore, their precision is 1. mm = 0.1 cm = 0.001 m. Measurements using either the meter stick or the ruler (with millimetric marks) should be recorded to the nearest tenth of a centimeter. A vernier caliper has a precision of 0.02 mm. This means that the vernier caliper gives two extra significant figures over the ruler and the meter stick and should be used to measure dimensions around 1.0 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 74.52 g. The precision of this scale is 0.01 g. Significant figures are all the numbers which can be read from an instrument plus an estimated number (doubtful). Using a ruler or a meter stick the width of this page is measured and recorded as W = 0.2165 m. The last digit in this number is an estimate (doubtful), since it is the smallest division of the scale. The rules for significant figures are the following:

1. The leftmost nonzero digit is the most significant.
2. If no decimal point exists, the rightmost nonzero digit is the least significant.
3. If there is a decimal point, the rightmost digit is the least significant, even if it is zero.
4. All digits between the least and most significant digits are significant. The following are examples: the numbers 1834, 18340 and 1000. Both the first two numbers have four significant figures. The numbers 1000 and 0.0001 have one significant figure. The number 1834.0 has five significant figures.
5. A very important principle to remember is that you can NOT improve the precision of your experiment by manipulating numbers in any way. For the purpose of doing calculations:

a. When multiplying or dividing several quantities, the number of significant figures in the final answer should not exceed the number of significant figures in the measurement with the least number of significant figures.

b. When adding or subtracting, the number of decimal places in the result should equal the smallest number of decimal places of any term in the sum. Adding 123 + 5.35, the answer is 128 and not 128.35. As another example, add the numbers 1.0001 + 0.0003 = 1.0004. The answer has five significant figures even though one of the terms in the sum, 0.0003, has only one significant figure. Therefore, when adding or subtracting, we consider the number of decimal places and not significant figures.

c. In intermediate steps of calculations, keep two extra decimal places and then round off properly in the final answer. If you round off to the proper number of significant figures in every calculational step, then it is easy to see how after several steps this could lead to loss of accuracy. Hence, the justification of the above rule.

d. The rules for rounding off are simple. First, truncate the number to the proper number of significant figures and treat the extra digits as a decimal fraction. Then:

   i. If the fraction is greater than 0.5, round up.

   ii. If the fraction is less than 0.5, round down.

   iii. If the fraction is 0.5, round up only if the least significant figure is odd. This is

an esoteric rule whose sole purpose is to avoid a systemic error if one rounds up every time the fraction 0.5.

MATERIALS AND DATA SHEETS

1. Ruler
2. Vernier Caliper
3. Micrometer
4. Pendulum
5. Stop watch
6. Digital balance.

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. The values that you record on your data sheet must have:

1. Using a two meter sticks, one having centimetric divisions and one having millimetric divisions, measure the length and the width of the lab table and record them in meters. Record your data in data table (1) in units of meters (m) in column (1), centimeters (cm) in column (2) and millimeters (mm) in column (3). Use scientific notation any time the data or the calculation is larger than 1000.
2. Calculate the area of the tabletop in m^2, cm^2 and mm^2 and enter it in the data table. Remember the units. When you multiply the numbers, you also must multiply the units.

Table 1: Measuring the Lab Table			
	meter	centimeter	millimeter
Length, $L \pm \Delta L$			

Width, W±ΔW			
Area, A±ΔA			

Procedure 2: Cylindrical Objects

Using a vernier caliper or a micrometer, measure the dimensions of the cylindrical block in mm and record your measurement in data table (2). You have a cylinder. The precision of the vernier caliper is 0.02 mm and the precision of the micrometer is 0.01 mm. Measure the mass of the cylinder and put it into the table. Calculate the surface area, the volume and the density of the cylinder and enter it in your data table in various units. Make sure you are using the correct number of significant figures in your calculations.

Table 2: Cylinder

	meter	centimeter	millimeter
Diameter, d±Δd			
Radius, r = d/2, r±Δr			
Height, H±ΔH			
Surface Area, A±ΔA			
Volume, V±ΔV			
Mass, M±ΔM	____kg	___g	XXX

Density, ρ±Δρ	___kg/m^3	___g/cm^3	XXX

Procedure 3: Time Measurement

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 s. You will use the stop watch in your cell phones.

You have a pendulum the length of the string is about 1 m. Pull the bob to the side to a small enough angle so that you clearly measure the time for at least three swings. Using a digital stopwatch in your cell phone measure the time it takes the pendulum to make 3 swings record this time in data table (3) in the relevant place. Then, you divide this by 3 to calculate the period of one swing and put this result in the relevant place. Repeat this for 5 and 10 swings and complete the table (3).

It should be noted here that a source of error in this procedure is the reaction time of the person handling the stopwatch. This is the time difference between the actual release of the pendulum bob and the start of the stopwatch. Also, at the end of the measurement, generally, there will be a difference between the end of the last swing and the stopping of the stopwatch. Based on this observation, do you think it is wise to measure the time for just one swing? Measuring the time for 3, 5 and 10 swings will increase the accuracy of the period measurements. Please comment on why the precision is increasing the accuracy of the period measurements. Which period calculation you trust most? Explain your answer.

Table 3: Pendulum		
Time for 3 swings t±Δt (seconds)	Time for 5 swings t±Δt (seconds)	Time for 10 swings t±Δt (seconds)
Period T±ΔT (seconds)	Period T±ΔT (seconds)	Period T±ΔT (seconds)

(t±Δt)/3	(t±Δt)/5	(t±Δt)/10

CALCULATIONS

Do all the calculations required to fill in the data tables. Make sure you round off your end results to the proper number of significant figures and give the units of all measured and calculated quantities.

CONSIDERATIONS

1. What are the types of errors you encountered in this experiment? Random or systematic? Explain.
2. Please comment on why the precision is increasing the accuracy of the period measurements. Which period calculation you trust most? Explain your answer.