READ ME FIRST

GENERAL LABORATORY INSTRUCTIONS

Welcome to PHYS 101 L, **The Physics of How Things Work I Lab**. This is a one-credit laboratory to accompany PHYS 101. You should be taking PHYS 101 concurrently or have already had it if you are enrolled in 101L.

Laboratory work has several goals. It provides you with an opportunity to observe and verify some of the ideas of the text and lectures. It provides a place for observing physical effects in a quantitative way so that the underlying patterns may be recognized. It is a time for relating concrete observations to abstract ideas. Most importantly, *the laboratory is a place of learning.*

Remember, in addition to whatever apparatus is made available: **The mind of the student is part of the operating equipment. It should be maintained operational at all times!**

GENERAL PROCEDURES

You *must* have an $8\frac{1}{2}'' \times 11''$ scientific/engineering-ruled (graph-paper) spiral notebook. These notebooks will supply the graph paper that you will need and afford you a place to make notes. This lab manual has data sheets onto which you should put your data and calculations, and hand in at the end of the laboratory period. If you need to record data separately, then record it in your scientific notebook, tear out, and include with the other materials that you hand in. As you carry out the activities in the lab manual you will find references to data or other information that need to be entered onto the data sheets. In addition there will be questions to be answered and graphs to be made and analyzed. These items will be set in **bold face type** to alert you that they must be answered.

The laboratory exercises are designed to be completed within the laboratory so that when you have finished your work, you may hand it to your instructor as you leave. Be sure to staple everything together and have your name prominently and clearly displayed.

Prepare yourself for the next laboratory period by reading the instructions of the assigned experiment before you come to the laboratory. Your instructor may quiz you briefly at the start of class to determine if you are prepared.

Unless specifically instructed to do otherwise, laboratory work will only be done in groups of two or three. You should work only at your assigned place. Do not move any apparatus from one laboratory table to another without the instructor's permission. General supplies are to be obtained from the instructor's bench. For additional information or assistance, consult the laboratory instructor.

CARE OF APPARATUS: Every student must exercise appropriate care in using the laboratory apparatus. Each person will be held personally responsible for his/her apparatus. At the beginning of each laboratory period, inspect the apparatus to make sure that it is in good condition. Report anything missing or broken to your instructor promptly.

PLOTTING OF CURVES: Unless instructed otherwise, all graphs must be drawn on the graph paper from the notebook or drawn with the computer and printed out for inclusion with your other work. Scales for the coordinate axes should be so chosen that the graph is not confined to a small part of the paper, and that the decimal parts of units can be easily located. This can be done if each small division is made equal to one, two, five, or ten units. The same scale need not be used on both axes. The independent variable should normally be plotted along the x axis (horizontal) and the dependent variable along the y axis (vertical). Each axis should be labeled with the name of the quantity being plotted and the scale divisions used. The numbers should increase from left to right and from bottom to top. The graph should be labeled to indicate what the curve intends to show.

SIGNIFICANT FIGURES: When we say that a length is 9.2 cm, we mean that this is a length that has been, or can be, measured. Implicit in our statement is information about the precision with which the measurement has been made. By 9.2 cm we mean a length that is closer to 9.2 cm than to either 9.1 cm or 9.3 cm. Had we estimated between the 0.1 cm divisions, or used a ruler with finer divisions, we might have said the length was 9.23 cm (Fig. 1). This means a length closer to 9.23 cm than to 9.22 cm or 9.24 cm. The last figure in a quoted measurement is in some sense uncertain, and does not have the same significance as the figures to its left.

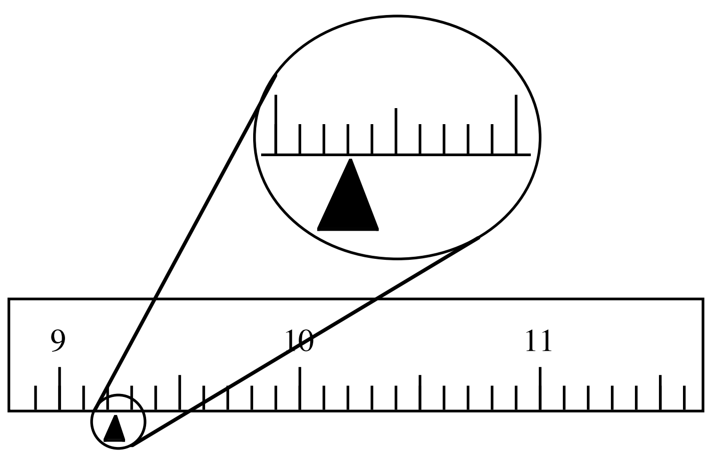

Fig. 1. Position of a reference mark along a scale. The inset shows a magnified view, which permits greater precision in locating the position of the mark.

The number of digits reported in a measurement, irrespective of the location of the decimal place, is called the number of *significant figures*. The number of significant figures is a reflection of how well you know a given quantity. Length is, in the classical sense, assumed to be infinitely divisible. This means that to specify a length "exactly" would require an infinite number of significant figures. Therefore, all numbers that represent measurements carry with them information about how well that number is known.

Measured values are often used to calculate other quantities. For example, we can determine the circumference C of a circle from a measurement of the radius r of the circle and the expression

$$C = 2\pi r.$$

The value of π is well known and has been determined to many significant figures. To seven significant figures, $\pi = 3.141593$. If we had measured the radius of a circle to be 1.60 cm, direct application of Eq. (1) gives a numerical answer of

$$C = 10.053098 \text{ cm}.$$

However, this is not a physically meaningful or sensible answer. The circumference can only be known to the same precision as the radius. In this case, the precision is three significant figures. We *round off* the answer to the correct number of significant figures:

$$C = 10.1 \text{ cm}.$$

Note that the last figure has been rounded up. The rule we will follow is that *if the first digit beyond the last significant figure is 5 or greater, the last significant figure is to be increased by unity (one). All other figures beyond the last significant figure are dropped. If the digit beyond the last significant figure is less than 5, the last significant figure remains unchanged.* Thus 10.05 rounds off to 10.1, but 10.04 rounds off to 10.0. (Most pocket calculators that round off automatically use this rule.)

Another numerical example will further illustrate the point. Let us calculate the area of a paperback book cover. Suppose the cover is a rectangle whose sides we measure to be 10.6 cm and 17.9 cm. To find the area A of a rectangle we multiply the length l times the width w.

$$A = l \times w.$$

The arithmetic product of 10.6 and 17.9 is 189.74. However, it is *not* correct to give the area of the cover as 189.74 cm^2. Doing so implies that the area is known to be between 189.73 cm^2 and 189.75 cm^2, a precision that is unwarranted on the basis of the precision with which the lengths of the individual sides are known.

To see what we mean, notice that the length of the first edge of the cover is between 10.55 cm and 10.64 cm, and the length of the second edge is between

17.85 cm and 17.94 cm. The product of the least of these numbers is 188.3175 and the product of the greater is 190.8816. We see, then, that even the last place *before* the decimal is uncertain, so it would be a mistake to give an answer with more than three figures. Thus we round off the computed area of 189.74 cm^2 to 190 cm^2. The general rule is that *your answer must have no more significant figures than is warranted by the least precise of your values* (that is, the value with the fewest significant figures).

Sometimes it is not clear whether the final zero or zeros in a number are significant figures or are merely needed to locate the decimal point. In the preceding example, the result of 190 cm was correct to three figures so that the zero was a significant figure. To clearly indicate the number of significant figures, we often express a number in *scientific notation*. Thus, we can write 190 cm as 1.90×10^2 cm. The presence of the final zero indicates that the number is known to three significant figures. We will assume integers to be precise. Thus the answer to what is the cost of two hamburgers at $1.89 each is $3.78 and not $4.