DATA AND CALCULATIONS
(Including an Introduction to Excel on the Macintosh)

Please purchase a laboratory notebook (speckled cover with grid-line pages for graphing) for use in this and all following laboratories. The notebook will contain a record of your work in the laboratory, with drawings, data tables, graphs, calculations, and comments. At a minimum the notebook should contain a description with diagrams of the experimental setup, your data always organized in tables (set up the table before you acquire the data), appropriate calculations and graphs, and a final summary of the laboratory which presents an analysis of your work. You should develop your notebook as you do your laboratory work rather than working on scrap paper and transferring the details to the notebook at the end of the laboratory period. We'll talk more about your use of the notebook in laboratory; but please remember --- **data must be in tables, graphs and drawings are good (and save time), and the summary analysis is important.** You will leave your notebook with your instructor before leaving the laboratory. Your instructor will return the notebook to you at the beginning of the next laboratory period.

Introduction

Many introductory physics labs have four important components: experiment design, data acquisition, computations, and interpretation. This lab is designed to give you substantial experience with the third, and a little experience with the second and fourth. You will take some data that involve the motion of a ball and will do some calculations that involve these data, but the emphasis in this lab is on the mechanics of using the lab computers to do the calculations, rather than on the physical interpretation of the results. You will, nevertheless, get some exposure to the concepts of position and velocity.

The lab computers are Apple Macintoshes, and the primary tool for doing calculations on sets of data is the standard spreadsheet program Excel. The "Learning to Use Microsoft Excel" document attached to this writeup provides a hands-on description of the basic aspects of Excel. You can use this introduction with Excel 98 on the Mac or Excel 97 on a PC. The computers on campus all have these versions of Excel. **If you wish, you should work through the "Learning to Use Microsoft Excel" document before your scheduled laboratory.**

While the use of computers and software will make your lab work easier, and hopefully more instructive and fun as well, don't let the computers get in your way. For example, Excel is a good way to perform the same mathematical operations on sets of data containing many numbers, but a hand calculator makes a lot more sense for simple "one-shot" calculations. Similarly, you can often make a quick plot of some data in your lab book more quickly than you could get Excel to do it. Don't let the computer become a labor-generating device instead of a labor-saving device!

Taking the Data

The experimental component of this lab consists of observing the motion of a small bowling ball across the floor. The floor has been marked at 1 m intervals and the time required for the ball to reach various points will be determined by a dozen or so students armed with stopwatches. All these observers will then report their measurements so all the students in the lab can record the results in their lab notebooks.

Experiment 1: In this case everyone measures the time for the ball to reach the *same* point in order to obtain an estimate of the uncertainty in the time measurements.

Experiment 2: Each observer measures the time at which the ball reaches a different distance mark.

Experiment 3: Same as 2, except that the ball rolls on felt instead of the bare concrete floor, and the ball has a higher initial speed.

Doing the Calculations

Before jumping into the use of Excel, you should do a bit of work on your data by hand to make sure that you have a clear understanding of what Excel is going to do for you. First make a histogram (plot of number of occurrences *vs.* measured value) in your notebook for the data from experiment 1. Depending on the outcome of the experiment, you will probably want to group together ranges of measurements before plotting the histogram. What numerical value for the uncertainty in the measured time would you infer from these results? (we'll talk about averages, variances, and standard deviations at the beginning of the laboratory period).

Next make a graph of the position of the ball *vs*. time for experiment 2 in your notebook. Make sure to label axes and include units. Then calculate the average speed of the ball during each of the intervals between measurements. The ball's average speed is just the distance it travels divided by the time it takes to travel that far. Plot these results *vs.* the times at the ends of the intervals. Does the relationship between the position and average speed seem reasonable?

The first step in the computer processing of your data is to get it into Excel. Construct a table ("worksheet") that has times for experiment 2 in the first column and the corresponding distances in the second. Do this by opening Excel; you should see a new spreadsheet or a table with cells. Continue to select a cell with your mouse and enter a column heading or a data point to construct a table. Save your table by clicking on the on the "Save File Tool" icon (the third icon from the left in the toolbar – looks like a floppy disk). In the dialog box that appears, make sure that the "Desktop" is selected in the top box. Then type in the name you wish to give your data file, followed by "return". Later on you can save updated versions of the same file by simply clicking on the "Save File Tool" icon. Your file should appear as an icon on the Mac desktop.

A useful way to begin the analysis of any set of data is to see what it **looks** like. Thus, you should make a graph of distance versus time. Use Excel to construct a graph by selecting (drag your mouse over your data, including the column headings, while holding the mouse button down). Then, click on the chart wizard icon on the toolbar at the top. You should play around with the various chart options in the wizard windows but eventually you should finish with a distance (y-axis) versus time (x-axis) plot of your data. Be sure to give the graph a title and label the axes.

What else can we do with this stuff? What about a speed calculation? You can calculate the ball's average speed for each of the measuring intervals by an appropriate formula (distance traveled divided by the time interval). For data in columns A and B and row 3, the formula to enter in C3 might be "=(B3-B2)/(A3-A2)". Enter such a formula for your first average speed calculation. To get the average speeds corresponding to the other measurement intervals, click on cell C3 (if it was not already selected), position the mouse over the lower-right corner of the cell until the cursor changes to a thin, black cross, hold the mouse button down, drag down to the bottom of column C, and then release the button. All the cells should now contain the appropriate values. Check to see that these look like the values that you obtained with your hand

calculations. You can see the formula that was used in each case by selecting that cell. Don't forget to label the column as you did before. Now make a graph of average velocity *vs*. time as you did for the position. This time, however, the columns that you are plotting are not adjacent in the table, so select one portion of the table (t values) and then select the second portion (v values) while holding down the "apple" key.

This feature, entering and using formula, in Excel tables will be very useful during the coming laboratories. Just remember the "=" sign indicates to Excel that the cell will contain a formula or expression that Excel must evaluate. This expression may contain built-in Excel functions such as functions to calculate sums, averages, or standard deviations. For example, you could use Excel to determine easily the average and standard deviation of a data column. (see "Learning to Use Microsoft Excel" and "Useful Excel Functions")

This is a good place to mention one of the great features of Excel: if you change the contents of any cell, the contents of all cells that depend on the changed cell will also change accordingly. In fact, even graphs that depend on the cell will automatically change. This makes it easy to correct errors, but it is also very handy for looking at the effects of altering the values of quantities that are used in calculations.

It's easy to print out a copy of your data table or graph; just click on the table or graph to select it, and then click on the "Print Tool" icon (the fourth one from the left). A few moments later your table or graph should come out of the laser printer. Make photocopies of the table and both graphs so you and your lab partner each have a set and tape or paste them in your lab notebooks.

You have now completed the analysis for experiment 2. Repeat the process for generating the plots of position *vs.* time and average velocity *vs.* time using the data from experiment 3. Start from scratch by selecting another "sheet" using the tabs at the bottom of the spreadsheet. To record your work, paste or tape copies of the tables and graphs in your notebook and describe briefly what you conclude about the motion of the ball from the graphical results from both experiments.

Finishing Things Up

When you are finished calculating, plotting, and playing around with Excel, exit the program by selecting "Quit" from the "File" menu.. When the main Mac desktop window reappears, drag your file icons over the "Trash" icon, and release the mouse button. If you do not see your files on the desktop (outside all windows), look for them in the Excel folder. Select "Shut Down" from the "Special" menu to turn the Mac off.

Be sure to leave your notebook with your laboratory instructor as you leave the laboratory.