Using Spreadsheet Programs in Lab

Spreadsheet programs like Microsoft Excel, Apple Numbers, or Apache OpenOffice, are extremely useful for organizing and analyzing data from laboratory experiments. This document does not provide a general introduction to their basic features, which can more easily be discovered through trial and error. Instead, it provides guidelines for how to use a spreadsheet program effectively through a series of best practices.

To understand these, you should already know how to accomplish the following tasks

- Enter a simple arithmetic formula that uses built-in functions
- Use a cell reference within a formula to use another cell's value as an input
- Specify that the cell being referenced has either an absolute or relative position

Guidelines for using a spreadsheet for calculations

1. All physical constants and parameters appear in explicitly labeled cells, preferably at the top of the spreadsheet. If any value has to be updated, that happens in one place only. Conversion factors (another category of constants) also belong in this section for easy inspection.
2. All data also appear in explicitly labelled cells, but because there will be many of them to account for multiple trials, only one label at the top of the column is needed.
3. Units should be specified either in the row immediately below the labels or parenthetically in the same cell but after the quantity, depending on space constraints.
4. Adjust cell width so that all the relevant quantities are visible on the page at once. This will require judicious choices for labels to avoid their being too wide.
5. Data from each trial occupies a single row, so that when formula errors are discovered they can be corrected by simply filling that column down
6. Do not spend time on fancy formatting while working in the lab. For example, write Greek letters out, e.g., delta or theta, and change them later when writing your report.
7. Formulas can only use cell references, standard functions, and numerical constants, e.g., digits, π, simple roots. Any physical constants should be referenced from their fixed position as described in rule 1.
8. Formulas should not be so complicated that they cannot be easily inspected. This can be accomplished by algebraic simplification before entering them.
9. Take advantage of sorting capabilities to ensure that your data adequately and evenly cover a significant span of the available possibilities.
10. Compare data with theory by using a curve fit (a.k.a., regression) based on the theory's predictions. Whenever possible, express those predictions via a linear relation by algebraically transforming the data.

The following illustrates these guidelines in practice.

These data were collected in an experiment that tested the relationship between the pressure and length of a cylindrical pocket of air trapped beneath a column of mercury (Hg). Along the top are listed a variety of numbers that do not vary throughout this experiment. Some are specific to this experiment, such as the pocket offset and today's atmospheric pressure, while others are standard constants, such as the density of mercury, the gravitational field strength, and various conversion factors. Changing any of these values will immediately change all quantities calculated from them throughout the spreadsheet. Starting on the fifth row are the data in columns A-F, while columns G-N are calculated values.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	pocket offset		pressure atm.		pressure atm.		Hg density		gravity strength		rad –> degree	mmHg –> Pa	Pa -> kPa	cm –> m
2	cm		mmHg		Pa		kg/m^3		N/kg		°/radian	Pa/mmHg	kPa/Pa	m/cm
3	0.3		752.1		100271		13600		9.80		57.29577951	133.322	0.001	0.01
4														
5	Trial number	closed position	closed height	open position	open height	Hg length	cosine theta	theta	theta change	air pocket size	air pocket size	pocket pressure	inverse pocket	pocket pressure
6		cm	cm	cm	cm	cm		degrees		cm	m	Pa	1/m	kPa
7	4	16.2	30.7	38.9	53.4	22.7	1.000	0.0		15.9	0.159	1.305E+05	6.29	130.5
8	6	16.2	32.6	39.0	54.1	22.8	0.943	19.4	19.4	15.9	0.159	1.289E+05	6.29	128.9
9	12	16.8	36.9	39.5	55.7	22.7	0.828	34.1	14.6	16.5	0.165	1.253E+05	6.06	125.3
10	16	17.5	41.5	40.2	57.4	22.7	0.700	45.5	11.5	17.2	0.172	1.215E+05	5.81	121.5

This demonstrates the first six rules: the parameters and data are plainly visible and well identified with units, everything fits on one screen, each row of data describes a single trial, and the angle θ is written out as "theta." (Aside: writing "angle" instead of "theta" would be clearer, but I needed an illustration of rule 6.)

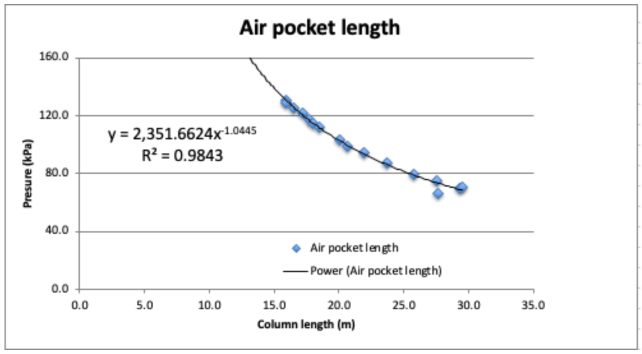
This next figure displays the formula within each cell to illustrate rule 7 and 8. Excel has the very useful capability of highlighting the linked cells within the currently active cell. Here, cell L8 is accessed for editing, and all its input cells are highlighted in corresponding colors. This makes it very easy to compare the spreadsheet's numerical formula against an algebraic formula based on theory. Note that the dollar signs indicated fixed cell locations.

	E	F	G	H	I	J	K	L	M	N
1	pressure atm.		Hg density		gravity strength		rad –> degree	mmHg –> Pa	Pa -> kPa	cm –> m
2	Pa		kg/m^3		N/kg		°/radian	Pa/mmHg	kPa/Pa	m/cm
3	=C3*L3		13600		9.8		=180/PI()	133.322	=1/1000	=1/100
4										
5	open height	Hg length	cosine theta	theta	theta change	air pocket size	air pocket size	pocket pressure	inverse pocket	pocket pressure
6	cm	cm		degrees		cm	m	Pa	1/m	kPa
7	53.4	=D7-B7	=(E7-C7)/F7	=$K$3*ACOS(G7)		=B7-$A$3	=J7*$N$3	=$G$3*$I$3*(F7*$N$3)*G7+$E$3	=1/K7	=L7*$M$3
8	54.1	=D8-B8	=(E8-C8)/F8	=$K$3*ACOS(G8)	=H8-H7	=B8-$A$3	=J8*$N$3	=$G$3*$I$3*(F8*$N$3)*G8+$E$3	=1/K8	=L8*$M$3
9	55.7	=D9-B9	=(E9-C9)/F9	=$K$3*ACOS(G9)	=H9-H8	=B9-$A$3	=J9*$N$3	=$G$3*$I$3*(F9*$N$3)*G9+$E$3	=1/K9	=L9*$M$3

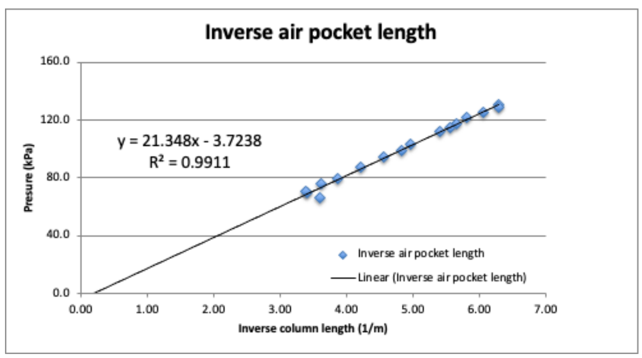
In the first figure, the trials are not in sequential order, and to illustrate why, here are the data in the order they were collected. It is not easy to see whether these trials satisfy rule 9 and well-represent the possibilities. To make that apparent, I sorted them by angle, then calculated the change in angle (column I), which showed where more data was needed.

5	Trial number	closed position	closed height	open position	open height	Hg length	cosine theta	theta
6		cm	cm	cm	cm	cm		degrees
7	1	18.3	49.2	41.0	60.2	22.7	0.485	61.0
8	2	27.9	75.3	50.7	56.7	22.8	-0.816	144.7
9	3	20.4	61.4	43.0	63.6	22.6	0.097	84.4
10	4	16.2	30.7	38.9	53.4	22.7	1.000	0.0
11	5	22.2	69.3	44.9	64.8	22.7	-0.198	101.4
12	6	16.2	32.6	39.0	54.1	22.8	0.943	19.4
13	7	24.0	74.9	46.8	65.2	22.8	-0.425	115.2
14	8	26.1	74.4	48.9	59.0	22.8	-0.675	132.5

Finally, representing data in a graph reveals relationships that are not easily discernable from the numbers themselves. The pressure P and column length L are predicted to be inversely proportional ($P \propto 1/L$), so this graph shows them graphed with a power law fit.



The variation is well represented by a power-law exponent of – 1.0445, which is almost an exact inverse relationship. However, the human eye is not adept at discerning that relationship, though it is very good at linear trends. The next graph shows the pressure plotted against the inverse length itself, i.e., by letting the *x* coordinate be $1/L$, which is an exact linear relation and makes it much more convincing that the data behave as expected.



The other thing immediately apparent from the graph is that the second point from the left is an outlier. That signals that those data may be incorrect and might account for the non-zero *y* intercept, which is in conflict with what theory predicts. While it is not fair to simply discard that point, doing so demonstrates that remeasuring that case may be worthwhile.