Appendix A Spreadsheet Basics

You will need to use a spreadsheet program to do several labs (and it is useful and faster for several more). There are many spreadsheet programs. You need to have one that can make graphs and can fit lines and to the graphs. A few labs require a polynomial order 2 fit to graphs. *Microsoft® Excel*, *LibreOffice Calc* (with an add-on), and *Apple® Numbers* are examples of some common spreadsheet programs that have these features. Some examples of ones that do not (yet) have trend-lines are *Google Drive Spreadsheet*, and *Numbers for iOS®*.

1.1 Layout

1.1.1 Cells

A spreadsheet is made of a grid, with cells labeled by their row and column. The rows are labeled with consecutive letters, and the columns are labeled with consecutive numbers. You can select individual cells, or drag or `Shift` select multiple cells, or `Ctrl` select several separate cells. You can click on the letter or number headers to select a row or column at a time, or the blank in the far top left corner to select the whole table.

	A	B	C	D	
1					
2					
3					
4					

The cells can contain different types of content, based on what you enter into them. Here are a few of the ones you may need in this lab:

Number Anything that starts with a number.

Text Automatic if starts with text, forced if you start the `"` character.

Formula Anything that starts with an `=` character.

Note that the spreadsheet will often change the characters you put in the cell based on the content. For example, if you type `3+2` into the cell, it will see the 3, assume it is a number, and compute the sum and store that in the cell, as the number 5. You could type `=3+2` instead, and that would be stored a formula, retained the original form. The form stored in the cell is shown in the *formula bar*, a bar often below the menus.

Most spreadsheet programs also allow you to format the cells. This allows you to have control over the display, without having to change the data underneath. You can set scientific format, with control over the number of sig figs, decimal format, with control over the number of decimal places, or even more exotic formats, like currency display.

You can also format other purely graphical things, like borders, fonts, and colors on a per cell basis.

1.1.2 Formulas

Other than nicely structured data storage and display, one of the key advantages of a spreadsheet are the formulas. Any cell that starts with an equals sign (`=`) will be treated as a formula. The contents are evaluated every time any cell is changed. This allows a spreadsheet to be a dynamic calculator.

Math is done using normal symbols (`+-*/`). Multiplication (`*`) must always be written out. Use parenthesis to group to avoid errors. You can raise to a power using the caret `^` symbol.

To refer to a cell in a formula, just type the name. For example, to square the contents of the A3 cell, you would type `=A3^2`.

There are many standard functions. For example, `sqrt(4)` will take the square root of 4. Common functions are provided in Table 1. Note that the trigonometric functions always take radians. A function to convert degrees to radians, `radians`, is provided. Most spreadsheet programs provides a way to search for functions, and Google is useful.

Function	**Comment**
`pi()`	The value of π
`sin(A1)`	The sin of A1, with A1 in radians
`cos(A1)`	The cos of A1, with A1 in radians
`tan(A1)`	The tan of A1, with A1 in radians
`radians(A1)`	Returns the value of A1 converted to radians
`asin(A1)`	The $\sin^{-1}$ of A1, returns radians
`sum(A1:A3)`	The sum of the cells A1 through A3
`average(A1:C1)`	The average of the cells A1 through C1

Table A.1: Common functions.

1.2 Features

1.2.1 Copy and Paste

Formulas become much more powerful with copy and paste. If you copy a cell (Ctrl + C) and paste it (Ctrl + V) into a cell that is offset from the original cell, all the formulas that contain cell references will be adjusted to match the new offset. For example, if you have a formula in cell A1 that contains the formula `=sin(B3)`, and you copy and paste A1 to the cell below it, A2, then the formula pasted into the new cell will be `=sin(B4)`.

If you don't want a formula to change, prefix the part that need to be constant with an `$` character. You can fix both the row and the column. For example, A1 would be written as `$A$1`.

1.2.2 Quick Fill

Most programs allow a quick-fill operation. This is usually indicated by a small dark box in the lower right corner of the currently selected cell(s). If you drag this box, the cells you expand it over will get filled with the currently selected formula.

If the selected cell(s) do not contain formulas, this often will try to repeat the selected cells intelligently. For example, if you have cells containing first 1 and then 2 selected, and use quick-fill, the next cell will contain 3, then 4, etc.

There is usually a manual option for quick-fill that can be accessed without the mouse, as well.

1.2.3 Naming

If you want to give a cell a name, to make your formulas look nicer, you can usually set the name. Look for a box near the formula bar with the current name (A2, for example) in it. It is usually best to name the cells with a distinct name that won't clash with the automatic cell names or formulas; a name starting with the underscore character (`_`) is a good choice. Using `_m` for mass in your formulas is much more descriptive than `$C$7`, for example, and tends to lead to fewer mistakes.

1.2.4 Click Entry

If you have started typing a formula (the initial equals sign must be present), you can click on any other cell to insert the name of that cell. You can even drag-select to insert a range.

1.2.5 Tables

Some software have a table feature that allows you to group your rows and columns in to individual tables. Feel free to use it, but it generally won't make a huge difference.

1.3 Graphing

1.3.1 Making a Graph

To make a graph, select the numbers you want included (Ctrl select to get non-adjacent rows or columns of numbers) and insert scatter plot (sometimes called an x-y plot). Do not chose the one with connected dots! You'll add a fit line later.

If the plot did not get the right data the first time, you can usually right-click the points and choose *select data*. That way you can manually set the x and y ranges. There is even usually a switch row-column button.

1.3.2 Labels

You can select the chart title and axis title from the chart layout options, or by double clicking an existing title or label. Be sure you have both axes labeled with units, and a title. You do not need a legend (the box that is usually included by default) if you only have one set of data on your plot.

1.3.3 Trend-line

You can add a best-fit line usually by right-clicking the dots and clicking *add trend-line*. There are options that usually are presented here, or by right-clicking the line and choosing *format*, that you will often need. The type of trend-line will depend on the data; in this lab you will use linear (a straight line) or polynomial order 2 mostly. You will always want to check the *Display equation* option.

1.3.4 Multiple Datasets in a Graph

You will usually need to use the select data option mentioned above to add multiple sets of data. Data sets are often called *Series*. You will need to enable the legend, and chose reasonable names for each series.

1.4 Printing

There is usually a way to print graphs so they are separate, and exactly fill a page. This is usually accomplished by selecting the graph, right-clicking, and selecting *move to new sheet*.

To print a spreadsheet, be sure to look for the fit to 1 by 1 page option under page setup. This saves paper, and avoids printing one set of numbers over multiple pages. For more advanced users, you can usually set the exact cell range you want printed.

1.5 Further Help

Exact procedures for several different programs, such as Excel® 2007, are posted at the 102M website, `http://www.ph.utexas.edu/~phy102m` under *Spreadsheet Tutorials*.

Appendix B Units and Quantities

2.1 Common Quantities with Units

Quantity	Abbreviation(s)	Derived SI Unit	SI Base Units
Mass	m	kg	kg
Time	t, T	s	s
Length	x, y, r, d, ℓ	m	m
Area	A	m^2	m^2
Volume	V	m^3	m^3
Velocity	v	m/s	m/s
Acceleration	a	m/s^2	m/s^2
Force	F	N	kgm/s^2
Energy	E, KE, PE	J	kgm^2/s^2
Work	W	Nm, J	kgm^2/s^2
Power	P	W, J/s	kgm^2/s^3
Momentum	p	kgm/s	kgm/s
Torque	τ	Nm	kgm^2/s^2
Moment of Inertia	I	kgm^2	kgm^2
Angular Momentum	L	kgm^2/s	kgm^2/s
Angular Velocity	ω	Hz	$1/s$, rad/s
Angular Acceleration	α	Hz^2	$1/s^2$, rad/s^2
Density	ϱ	Kg/m^3	kg/m^3
Spring Constant	k	N/m	kg/s^2
Linear Density	μ	kg/m	kg/m
Frequency	f	Hz	$1/s$
Angular Frequency	ω	Hz	$1/s$
Wavelength	λ	m	m
Temperature	T	K (or C)	K (or C)
Heat	Q	J	Kgm^2/s^2
Specific Heat	c	J/kgK	J/kgK
Latent Heat	L	J/kg	J/kg
Pressure	P	Pa, N/m^2	$kg/(ms^2)$

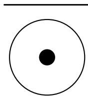
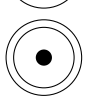
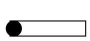
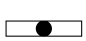
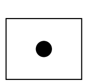
2.2 Unitless Quantities

Quantity	Abbreviation(s)	Remarks
Coefficient of Friction	μ	Normally between 0 and 1
Coefficient of Elasticity	ε	Used in collisions
Angle	θ	Radians are 'pure' units
Cycles	$---$	Sometimes seen as rotations
Mode number	n	Used when counting antinodes

2.3 Measured Quantities

Quantity	Value
Standard acceleration of gravity	$9.80665\,\mathrm{m}/\mathrm{s}^2$
Speed of light	$299792458\,\mathrm{m}/\mathrm{s}$
Speed of sound standard temperature and pressure	$343.2\,\mathrm{m}/\mathrm{s}$
Density of water	$1.00\,\mathrm{g}/\mathrm{cm}^3$
Density of aluminum	$2.70\,\mathrm{g}/\mathrm{cm}^3$
Density of steel	$7.83\,\mathrm{g}/\mathrm{cm}^3$
Density of brass	$8.44\,\mathrm{g}/\mathrm{cm}^3$
Density of copper	$8.96\,\mathrm{g}/\mathrm{cm}^3$
Density of liquid nitrogen	$0.808\,\mathrm{g}/\mathrm{cm}^3$
Specific heat of water	$4186\,\mathrm{J}/\mathrm{kgK}$
Specific heat of ice (-10° C)	$2000\,\mathrm{J}/\mathrm{kgK}$
Specific heat of aluminum	$900\,\mathrm{J}/\mathrm{kgK}$
Specific heat of copper	$386\,\mathrm{J}/\mathrm{kgK}$
Latent heat of vaporization, water	$2.260 \times 10^6\,\mathrm{J}/\mathrm{kg}$
Latent heat of vaporization, nitrogen	$2.01 \times 10^5\,\mathrm{J}/\mathrm{kg}$
Latent heat of vaporization, helium	$2.1 \times 10^4\,\mathrm{J}/\mathrm{kg}$
Latent heat of sublimation, water	$3.34 \times 10^5\,\mathrm{J}/\mathrm{kg}$
Temperature of boiling liquid nitrogen	$-195.79^\circ \pm 0.01^\circ$ C
Temperature of boiling liquid helium	-268.9° C
Temperature of boiling water	100° C
Temperature of melting ice	0° C

2.4 Common Moments of Inertia

	Situation	Inertia
	Disk/Cylinder, around center, radius R	$I = \frac{1}{2}MR^2$
	Ring, around center, radii from R_1 to R_2	$I = \frac{1}{2}M\left(R_1^2 + R_2^2\right)$
	Thin bar, around edge, length L	$I = \frac{1}{3}ML^2$
	Thin bar, around center, length L	$I = \frac{1}{12}ML^2$
	Rectangle, around center, W by L	$I = \frac{1}{12}M\left(L^2 + W^2\right)$

2.5 Greek Letters

Name	Uppercase	Lowercase
Alpha	A	α
Beta	B	β
Gamma	Γ	γ
Delta	Δ	δ
Epsilon	E	ϵ, ε
Zeta	Z	ζ
Eta	H	η
Theta	Θ	θ
Iota	I	ι
Kappa	K	κ
Lambda	Λ	λ
Mu	M	μ
Nu	N	ν
Xi	Ξ	ξ
Omikron	O	o
Pi	Π	π
Rho	P	ρ
Sigma	Σ	σ, ς
Tau	T	τ
Upsilon	Υ	υ
Phi	Φ	ϕ, φ
Chi	X	χ
Psi	Ψ	ψ
Omega	Ω	ω

Appendix C Capstone Lab Software

3.1 Capstone Guidelines

Most labs have the following tools across the top:

Autoscale This button scales all displayed data, or selected data, to fit the axes.

Data runs ▾ This allows you to go back to previous data runs (unless you deleted them). Multiple runs can be selected or deselected here. Clicking the little arrow in the corner of this button is different than clicking the button itself.

Data selection This adds a nearly-transparent selection box to the currently selected graph (click on a graph before clicking this button). Drag and resize the box to select data. Right click the selection box to get options, including delete.

Data Cursor This adds a draggable cursor that allows you to measure the coordinates at any point. Multiple cursors can be added. (Button disabled on some labs).

Curve fitting ▾ This allows you to measure the slope. Clicking directly on the button will toggle the fit line. Clicking on the small black down arrow will bring down a list of fit functions; clicking these will toggle them. You will often want linear fits. This will add the fit to the currently active data; often you may need to delect the fit on your old data before making a fit on your new data. (Button disabled on some labs).

Delete data points This will delete the currently selected data points. Very useful to remove points if you left it running too long.

Labs have a record button on the bottom (Space), as well as a delete last data run button. The previous run will be hidden unless the data runs button is selected, but can be recovered using the data runs button. Deleted runs can not be undone (except by using undo).

There is also an undo button (shortcut: Windows + Z).

You can manually scale an axis by dragging directly on the axis (the numbers next to the graph). You can manually pan the graphs by dragging anywhere on the graph.

Appendix D Useful Equations

Uncertainty of addition and subtraction: On page 3

$$\delta C = \delta A + \delta B \tag{0.2.1}$$

Uncertainty of multiplication and division: On page 4

$$\delta C = C_0 \left(\frac{\delta A}{A_0} + \frac{\delta B}{B_0} \right) \tag{0.2.3}$$

Uncertainty of raising to a power: On page 4

$$\delta C = n C_0 \frac{\delta A}{A_0} \tag{0.2.4}$$

Absolute percent error: On page 5

$$E_V(\%) = \left| \frac{V_{\text{accept}} - V_{\text{meas}}}{V_{\text{accept}}} \right| \times 100\% \tag{0.2.5}$$

Relative percent error: On page 5

$$E_V(\%) = \left| \frac{V_1 - V_2}{(V_1 + V_2)/2} \right| \times 100\% \tag{0.2.6}$$

Freefall position: On page 18

$$x = x_0 + v_0 t + \frac{1}{2} a t^2 \tag{1.2.2}$$

Freefall velocity: On page 18

$$v = v_0 + at \tag{1.2.3}$$

Newton's law in equilibrium: On page 31

$$\mathbf{F}_{\text{net}} = 0 \tag{2.3.1}$$

Atwood machine acceleration: On page 40

$$a = \frac{m_2 - m_1}{m_1 + m_2} g \tag{3.3.1}$$

Atwood machine tension: On page 41

$$T = \frac{2 m_1 m_2}{m_1 + m_2} g \tag{3.3.2}$$

Potential Energy: On page 47

$$PE = mgh \tag{4.1.1}$$

Kinetic Energy (linear): On page 47

$$KE = \frac{1}{2}mv^2 \tag{4.1.2}$$

Total energy for Atwood Machine: On page 49

$$E_i = m_1 h_{1,i} g + m_2 h_{2,i} g \tag{4.2.1}$$

Delta KE for Atwood: On page 49

$$\Delta KE = \frac{1}{2}\left(m_1 + m_2\right) v^2 \tag{4.2.3}$$

Delta PE for Atwood: On page 49

$$\Delta PE = \left(m_1 - m_2\right) gd \tag{4.2.4}$$

Kinetic Energy for disk: On page 50

$$\Delta KE_{\text{pul}} = I\left(\frac{v}{R}\right)^2 \tag{4.3.1}$$

Kinetic energy for string: On page 50

$$\Delta KE_{\text{str}} = \frac{1}{2}m_{\text{str}}v^2 \tag{4.3.2}$$

Coefficient of Restitution: On page 57

$$C_R = \frac{v_{2f} - v_{1f}}{v_{1i} - v_{2i}} \tag{5.2.5}$$

Conservation of Angular Momentum: On page 73

$$I_i \omega_i = I_f \omega_f \tag{7.1.1}$$

Density: On page 83

$$\rho = \frac{m}{V} \tag{8.2.1}$$

Buoyancy: On page 84

$$F_{\text{B}} = \rho_{\text{fl}} V_{\text{ob}} g \tag{8.3.1}$$

Volume from buoyancy: On page 84

$$V_{ob} = V_{\text{Arch}} = \frac{m_{\text{ob}} - m_{\text{app}}}{\rho_{\text{fl}}} \tag{8.4.2}$$

Density from Archimedes: On page 85

$$\rho_{\text{fl}} = \frac{m_{\text{ob}} - m_{\text{app}}}{V_{\text{ob}}} \tag{8.4.3}$$

Hook's law: On page 94

$$\Delta F = -k\Delta x \tag{9.2.1}$$

Period of a spring: On page 94

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{9.2.2}$$

Period of a pendulum: On page 95

$$T = 2\pi\sqrt{\frac{\ell}{g}} \tag{9.3.2}$$

Full period of a pendulum: On page 96

$$T = 2\pi\sqrt{\frac{\ell}{g}}\left(1 + \frac{1}{16}\theta_{\text{max}}^2 + \frac{11}{3072}\theta_{\text{max}}^4 + \cdots\right) \tag{9.4.1}$$

Wave dispersion relation: On page 101

$$v = f\lambda \tag{10.1.1}$$

Standing Waves: On page 101

$$f_n = n\frac{v}{2L} \tag{10.2.1}$$

Velocity on a String: On page 103

$$v = \sqrt{\frac{F_T}{\mu}} \tag{10.3.2}$$

Temperature change: On page 111

$$\Delta Q = mc\Delta T \tag{11.2.1}$$

Latent heat: On page 112

$$\Delta Q = \Delta m\ L \tag{11.2.2}$$

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Bibliography

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