

A Hitchhiker's Guide to LaTeX
(or how I learned to stop worrying and love
writing my dissertation)

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1 Introduction

LaTeX (which is pronounced LAY-TECK) is commonly used by scientists to write their research articles, as it is the easiest for them to include mathematical symbols, figures, tables, etc. in their work in a platform-independent manner. Increasingly many scientific journals require that submitted articles be typeset in LaTeX. The purpose of this article is to provide a minimalist introduction to LaTeX.

2 Headers

The header used in this document is

```
\documentclass[12 pt]{article}

\usepackage{amsmath,amstext,amsgen,amsbsy,amsopn,amsfonts,graphicx,
overcite,theorem}

\renewcommand{\baselinestretch}{1.5}

\begin{document}
```

One must first specify the type of document one is writing, as each style entails the availability (or lack thereof) of certain commands and formats. The ‘article’ type is our primary concern, but several others include ‘letter’, ‘book’, and ‘report’. Additionally, many universities (including Cornell University) have special variations of reports corresponding to the required style

for Masters and Doctoral theses.

One can also specify the default font size of one's document. In the present case, I wrote "12pt" to illustrate where this goes. In the absence of this argument—i.e., had I written only

```
‘‘\documentclass{article}’’
```

the default font size would have been set automatically to 10 pt.

To use mathematical fonts, one must use various packages containing the appropriate code. In fact, one can do a huge variety of things with such packages, which are widely available on the World Wide Web. (These packages can be downloaded for free.) The ones I included in this document are an exceedingly small subset of those available. The package `amsmath.sty`, for example, permits the use of some mathematical fonts. (Observe that the actual file name in this case has the suffix ".sty" but that that portion of the name is not cited in the argument of

```
\usepackage
```

As another example, `graphicx.sty` allows one to incorporate graphics. Additionally, `theorem.sty` allows one to define theorem environments and `overcite.sty` changes the citation format in the document to use superscripts rather than brackets with numbers in them.

The command

```
\renewcommand{\baselinestretch}{1.5}
```

is used to change the vertical spacing between lines. Single spacing corresponds to an argument of 1; moreover, single spacing is the default configuration, so failure to specify a vertical stretch will result in single spacing.

To get double-spacing, for example, one uses the argument 1.67 for 10 point fonts, 1.62 for 11 point fonts, and 1.66 for 12 point fonts.² (Technically, this does not hold for every font. Rather, I am referring to LaTeX's standard font, which is Computer Modern Roman.)

Optionally, one may then make command aliases. For example,

```
\newcommand{\R}{\mathbb{R}}
```

indicates that one may use

```
\R
```

rather than

```
\mathbb{R}
```

to make the symbol \mathbb{R} , which represents the real numbers. I do not use such code in my writing, although it does have its uses. In the aforementioned example, whatever old meaning

```
\R
```

may have had is no longer applicable. To ensure that one can use the blackboard bold font and other mathematical notation, one must cite appropriate style files. *The LaTeX Companion* discusses which packages contain which fonts and symbols.²

One can also define environments. For example, I sometimes define a theorem environment with the following command:

```
{\theorembodyfont{\rmfamily} \theoremheaderfont{\itshape}  
\newtheorem{thm}{Theorem}}
```

After these preliminary steps are completed, one begins the document with

```
\begin{document}
```

Note that the final line of the document must be

```
\end{document}
```

Every

```
\begin{blah}
```

statement must have an accompanying

```
\end{blah}
```

statement or your LaTeX code will not compile.

3 Organizing the Paper

3.1 Title and Authors

Most papers include information concerning the title, author, etc. I used the following code in the present paper:

```
\title{A Hitchhiker's Guide to LaTeX \}
```

```
(or how I learned to stop worrying and love writing my dissertation)}
```

```
\author{Mason A. Porter \} mason@math.gatech.edu \} \} School of
```

```
Mathematics \} \} Center for Nonlinear Science \} School of Physics \} \}
```

`Georgia Institute of Technology}`

`\date{July, 2002}`

`\maketitle`

One uses the two characters

`\`

to implement a carriage return (and hence to advance a line). As we will see later, this is also very useful for mathematical equations and matrices.

3.2 Sections and Subsections

One designates a section (with an associated number) using the command

`\section{Blah}`

If one wishes the section 'Blah' not to be numbered, one instead employs

`\section*{Blah}`

For subsections, one similarly utilizes

`\subsection{Blah}`

and

`\subsection*{Blah}`

In scientific papers, bibliographies are typically not numbered. The other sections may or may not be—it depends on the journal.

3.3 Font Formats

Boldface is obtained using either

```
{\bf Boldface}
```

or

```
\begin{bfseries}Boldface\end{bfseries}
```

Italics is obtained using either

```
{\it Italics}
```

or

```
\begin{itshape}Italics\end{itshape}
```

Other pertinent formats include

```
{\em blah}
```

to emphasize *blah*,

```
{\tt blah}
```

to write `blah` in a typewriter font, and many others (SMALL CAPS, *slanted*, *etc.*). See page 171 of *The LaTeX Companion*² for additional information.

3.4 Alignment and Spacing

It is often desirable to align the text of a document. For example, one can center text with the command

```
\begin{centering}
This text is centered.
\end{centering}
```

With this command, one obtains

This text is centered.

By replacing ‘centering’ with ‘flushleft’, one can flush text to the left. Similarly, ‘flushright’ allows one to flush text to the right. These two environments appear as follows:

This text is flushed to the left.

This text is flushed to the right.

There are additional formats as well as alternative methods to achieve the formats above. For example, I apply ‘centering’ rather than ‘center’ when we discuss embedding graphics into LaTeX documents. (The latter still works, but the former is a better alternative in that context.)

One can manually insert horizontal space with the command

```
\hspace{number in}
```

One can manually insert vertical space with the command

```
\vspace{number in}
```

One can also use ‘cm’ instead of ‘in’, but I’m American, so I don’t use the metric system except when performing scientific calculations. Vertical

spacing is useful for placing figures. Horizontal spacing is useful for placing qualifiers (such as $x \in X$) in equations. Here is an example of using these commands:

This spacing is really screwed up. To obtain it, I used the command

```
\vspace{.4 in}
```

and then

```
\hspace{.6 in}
```

at the pertinent places in the text. Note additionally that the arguments for these two commands can be negative—sometimes one wants less horizontal or vertical space than that produced by the default command.

Another useful command is to prevent a paragraph from indenting. One simply uses the command

```
\noindent
```

as we see below:

This sentence is not indented.

There are myriad other formatting possibilities. Among those that frequently occur are multiple columns (which is used by many journals), sections of text with larger margins (to produce a column that is not as wide), paragraphs with different vertical spacing, *etc.* (These latter two are frequently used in conjunction to display long quotes.) To learn such formatting techniques, see *The LaTeX Companion*.²

3.5 Lists

There are numerous ways to list items in LaTeX. One of them uses the following sequence of commands:

```
\begin{enumerate}
\item[A.]{This is the first item.}
\item[B.]{This is the second item.}
\item[C.]{This is the third item.}
\end{enumerate}
```

This produces the following text:

- A. This is the first item.
- B. This is the second item.
- C. This is the third item.

The argument “[A.]” (and its variants) yield the labeling of the items. One can put any sort of text within the two brackets to achieve the desired labeling. If one does not wish to have any labels, one may type

```
\begin{enumerate}
\item{This is the first item.}
\item{This is the second item.}
\item{This is the third item.}
\end{enumerate}
```

to produce

1. This is the first item.
2. This is the second item.
3. This is the third item.

3.6 Footnotes

Footnotes can be inserted with the command

```
\footnote{Stuff to include in footnote}
```

Here is a footnote.¹

3.7 Putting Comments in LaTeX Documents

Any line that starts with

```
%
```

will be ignored by the LaTeX compiler.

4 Mathematics

The utility of LaTeX for scientists lies in the ease of using it to produce mathematical exposition. In this section, I will provide a primer for this application of LaTeX.

¹That is how I produced this footnote.

4.1 Math Mode

One must switch to math mode in order to utilize mathematical symbols. If these symbols are in the middle of a paragraph, one encloses it with single dollar signs on each side. For example, to write $x = 5$, one types

```
$x = 5$
```

The spacing around the equal sign is optional. One can also write

```
$x=5$
```

or use any other desired spacing convention. However, one can insert spaces into the result equations by using a tilde. For example,

```
$x~ =5$
```

yields $x = 5$. This is useful, for example, if one is writing bibliography entries manually.

To place text in math mode, one uses either

```
\text{blah}
```

or

```
\mbox{blah}
```

The font for x in math mode is not the same as ‘x’, so if one is including words between mathematical symbols, it is important to use the correct font. For example, x^2 *this cause eyestrain* is written entirely in math mode, whereas x^2 this does not cause eyestrain is obtained with the command

```
x^2 ~$\text{this does not cause eyestrain}$
```

(Note the use of a tilde to obtain a space.) Hence, to write $f(x) = x$ for $x \in X$, one writes

```
$f(x) = x \hspace{.1 in} \text{for} \hspace{.1 in} x \in X$
```

Notice this application of horizontal spacing. Alternatively, one can accomplish the same thing with

```
\mbox{ for }
```

or

```
{~for~}
```

With these formulations, one is specifying the number of spaces rather than the horizontal distance.

4.2 Equations

In many situations, it is desirable to display mathematics rather than inserting them directly in sentences. This is especially true of important equations. If one does not wish the equations to be numbered, one may use a command such as

```
$$x + y = z$$
```

which yields the following when compiled:

$$x + y = z$$

Notice that the above equation has not been numbered. If one wishes to number this equation, one can use code such as

```
\begin{equation}
x + y = z
\end{equation}
```

The equation is now numbered, as we see below:

$$x + y = z \tag{1}$$

Subsequent equations will be automatically numbered appropriately. (The next one will be equation (2), *etc.*)

To use this format without numbering the equation, one may type

```
\begin{equation}
x + y = z \notag
\end{equation}
```

The numbers of the other equations in a document will be adjusted automatically. To label equations, one may type

```
\begin{equation}
x - y = w \label{blahblah}
\end{equation}
```

which yields

$$x - y = w \tag{2}$$

To refer to equation (2), one simply types

```
\ref{blahblah}
```

so one need not remember the numbers of one's equations. If one adds or removes equations, the numbers in these references will also be updated automatically. Observe that this method of displaying equations is automatically in math mode. One does not use dollar signs in this situation.

It is often desirable to display multiple equations at once. There are various ways to do this—each of these yields different spacings and alignments. The one I like to use is written as follows:

```
\begin{align}
a + b = 1, \notag \\
a + c = 42, \notag \\
a + d = 666. \label{all}
\end{align}
```

and look like this:

$$\begin{aligned} a + b &= 1, \\ a + c &= 42, \\ a + d &= 666. \end{aligned} \tag{3}$$

There are several things you should notice. First, I used the line break

```
\\
```

to advance a line. Second, I used the

```
\notag
```

command to ensure that the equation is labeled only once (at the bottom).

Finally, these equations are not aligned. To align the equal signs in equation (3), type the following:

```

\begin{align}
a + b &= 1, \notag \\
a + c &= 42, \notag \\
a + d &= 666. \label{all12}
\end{align}

```

In general, insert an ampersand & immediately preceding the portion of the equation according to which you wish to set the alignment. The alignment produces the following result:

$$\begin{aligned}
 a + b &= 1, \\
 a + c &= 42, \\
 a + d &= 666.
 \end{aligned}
 \tag{4}$$

An alternative way to display multiple equations is to type

```

\begin{eqnarray}
a + b = 1, \notag \\
a + c = 42, \notag \\
a + d = 666. \label{all13}
\end{eqnarray}

```

To align things in this case, use an ampersand immediately to the left and the right of the character you wish to use for alignment:

```

\begin{eqnarray}
a + b &=& 1, \notag \\
a + c &=& 42, \notag \\
a + d &=& 666. \label{all14}
\end{eqnarray}

```



```
\end{eqnarray}
```

A third (of several other) ways to display multiple equations is

```
\begin{gather}
a + b = 1, \notag \\
a + c = 42, \notag \\
a + d = 666. \label{all14}
\end{gather}
```

4.3 Mathematical Symbols to Know and Love

As an appendix to this introduction, I have included many symbols that you will use frequently. I obtained these from pages 218-222 of *The LaTeX Companion*.² If there are any symbols you need that have not been included, you should look there.

In this section, I will present a few examples of how to use these symbols. There are also several things I would like to illustrate.

To write a subscript (such as x_1), one uses the command

```
 $x_1$ 
```

For a superscript (x^1), instead write

```
 $x^1$ 
```

If the subscript (or superscript) contains multiple characters, they must be enclosed by braces. For example, the command to write x_{12} is

```
 $x_{12}$ 
```

The command

`x_12`

yields x_12 . This particular facet of LaTeX manifests often. It occurs, for example, in the limits of integrals, when denoting averages of quantities, *etc.* In general, whenever some LaTeX command requires an argument, use braces `{ }` if this argument consists of multiple characters. Additionally, commands such as

`\pi`

are considered to be one character. Finally, because of this use of braces, one uses

`\{`

and

`\}`

to actually write left and right braces.

Here are some examples to illuminate the usage of important mathematical symbols. To write

$$h(y) \equiv \int_{-\infty}^y \left[f(x) \frac{\partial^2 g(x)}{\partial x^2} dx \right], \quad (5)$$

one types

```
\begin{equation}
```

```
h(y) \equiv \int_{-\infty}^y \left[ f(x) \frac{\partial^2 g(x)}{\partial x^2} dx \right].
```

```
\end{equation}
```

Note the use of braces for the lower limit of the integral. Additionally, note the use of

`\frac{ }{ }`

for expressing division (or, in this case, derivatives). Finally, note the application of

`\left`

and

`\right`

which are used to automatically adjust the size of brackets, braces, parentheses, vertical bars, inner product symbols, *etc.* to the appropriate size. The left and right symbols to be adjusted need not be the same. Moreover, if there is only one symbol, one may use a period as a placeholder for the other, as the following example illustrates:

$$i\hbar \left\langle \psi \left| \frac{\partial \psi}{\partial t} \right. \right\rangle = i\hbar \left[\sum_{i,j=1, i \neq j}^d \dot{A}_{n_i} A_{n_j}^* + \sum_{i=1}^d \nu_{n_i n_i} |A_{n_i}|^2 + \sum_{i,j=1, i \neq j}^d \nu_{n_i n_j} A_{n_i} A_{n_j}^* \right]. \quad (6)$$

is written using the code

```
\begin{equation}
i\hbar \left\langle \psi \left| \frac{\partial \psi}{\partial t} \right. \right\rangle = i\hbar \left[ \sum_{i, j = 1, i \neq j}^d
\dot{A}_{n_i} A_{n_j}^*
+ \sum_{i = 1}^d \nu_{n_i n_i} |A_{n_i}|^2
+ \sum_{i, j = 1, i \neq j}^d \nu_{n_i n_j} A_{n_i} A_{n_j}^* \right].
\end{equation}
```

This example also illustrates the use of summation and inner products (which is where the size adjustment has been applied). The size of a character can also be specified manually. See *The LaTeX Companion*² for details. Additionally, note that failure to include either a pair or a place-holder will result in a compilation error.

Other commands that you will be using involve different mathematical fonts. The real numbers \mathbb{R} and complex numbers \mathbb{C} are typically written using the blackboard bold font and hence via the commands

`\mathbb{R}`

and

`\mathbb{C}`

respectively. One can make calligraphic characters such as \mathcal{O} with the command

`\mathcal{O}`

Another font that is occasionally used (for Lie algebras) consists of germanic characters. For example, one may write

`\mathfrak{g}`

to write \mathfrak{g} .

Hence, to write

$$\begin{aligned} F : V &\longrightarrow \mathbb{H}, \\ v &\mapsto \alpha \in \mathbb{H} \end{aligned} \tag{7}$$

one uses the command

```

\begin{align}
F: V &\xrightarrow{\mathbb{H}}, \text{notag} \\
&v \mapsto \alpha \in \mathbb{H}
\end{align}

```

One can also negate commands using LaTeX. For example, $x \notin \mathbb{R}$ may be written using the command

```
$x \not\in \mathbb{R}$
```

For many symbols, negated commands are already included. In that event, one can use either that command or a sequence like that above. For example, $a \neq b$ may be written using either

```
$a \neq b$
```

or

```
$a \not = b$
```

Another important example involves writing matrices. For example, one may use the command

```

\begin{equation}
\begin{pmatrix}
0 & 1 & 42 \\
-1 & 0 & 42
\end{pmatrix}
\end{equation}

```

to write

$$\begin{pmatrix} 0 & 1 & 42 \\ -1 & 0 & 42 \end{pmatrix} \tag{8}$$

Instead of using parentheses, one may write matrices in other formats. To do this, one uses—instead of ‘pmatrix’—one of the following: ‘matrix’ to just show an array of numbers, ‘bmatrix’ to use square brackets, ‘vmatrix’ to use straight lines (which is occasionally used to denote the determinant of a matrix), and ‘Vmatrix’ to use double lines. For example,

```
\begin{equation}
\begin{matrix}
0 & 1 & 42 \\ \ -1 & 0 & 42
\end{matrix}
\end{equation}
```

yields

$$\begin{matrix} 0 & 1 & 42 \\ -1 & 0 & 42 \end{matrix} \tag{9}$$

Finally, the code

```
\begin{equation}
\left[
\begin{array}{ccc}
0 & 1 & 42 \\
-1 & 0 & 42
\end{array}
\right]
\end{equation}
```

also produces

$$\left[\begin{array}{ccc} 0 & 1 & 42 \\ -1 & 0 & 42 \end{array} \right] \tag{10}$$

Additional useful commands include

`\nabla`

for ∇ ,

`\sqrt{x}`

for \sqrt{x} , and

`\sqrt[m]{x}`

for $\sqrt[m]{x}$. Note that

`\grad`

does not produce the desired symbol. The sample file that has been included with this document⁴ redefines this command, but it is recommended that you do not do this. Finally, note that the character ∇ is actually called “nabla.” To produce the Laplacian operator ∇^2 , one simply writes

`\nabla^2`

For derivatives, one may write

,

In fact, this character yields a different result depending on whether one is in math mode: ∇ was produced in math mode, whereas ∇ was not. One may also use the ∇ symbol multiple times to indicate higher-order derivatives.

Triple dots are often useful in mathematical notation. For example, (x_1, \dots, x_n) is produced with the command

`(x_1, \cdots, x_n)`

Observe that the dots are centered vertically. Alternate spacings for these dots are obtained with commands such as

`\ldots`

Additionally,

`\cdot`

and

`\dot`

produce appropriately spaced single dots.

4.4 Other Mathematical Notation

I have presented a few examples above, but there is a lot more that one can do. For example, one can use LaTeX to construct commutative diagrams, boxed formulas, continued fractions, Feynman diagrams, and numerous other things.

5 Graphics

There are numerous different commands to display graphics in documents produced in LaTeX. The one I use most often is

`\begin{figure}[htb]`

`\begin{centering}`

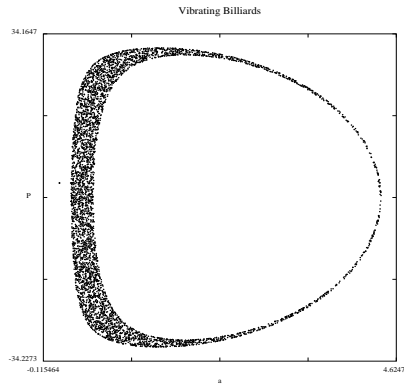


Figure 1: This is a caption. In it, one can enter math mode in the usual manner.

```

\leavevmode
\includegraphics[width = 2.5 in, height = 3 in]
{/home/mason/research/vibrate/mult/fig1.ps}

\vspace{ -.5 in}

\caption{This is a caption. In it, one can enter
math mode in the usual manner.} \label{figgy1}
\end{centering}
\end{figure}

```

This produced Figure 1, which is labeled in the same manner as are equations in this document. The first thing I did was enter a figure environment. This environment (just like any other) can be customized ad nauseum if one

wishes to do so. (If you are interested in this topic, see *The LaTeX Companion*.²) The argument [htb] is optional but often quite useful. It indicates my spacing preferences: first to try to put the plot immediately in that spot, then to try to put it on the top of a page and then to try to put it on the bottom of a page. The argument [thb] would indicate the top of the page as a first choice, ‘here’ as the second choice, and the bottom of the page as the third choice. Another possibility is ‘p’ for a page of figures. In the absence of such arguments—i.e., if “[htb]” were not included in the graphics command above—LaTeX’s float-placing algorithm (where figures are a type of float) assumes the preference ‘tbp’. If necessary, there are many more things one can do to manipulate the placement of figures. (By the way, the reason that LaTeX often doesn’t put graphics where you want them is that there are spacing considerations concerning the size of a float that can be placed in a spot of a certain size. Hence, advanced manipulation includes the adjustment of such parameters.)

To actually embed the figure, I use the

```
\includegraphics
```

command, although there are several available alternatives. I also choose to specify the length and width of my figures. There are many other optional arguments for this command, some of which can be helpful in placing graphics, but I do not use them unless I have to do so. Many such commands are specified in *The LaTeX Companion*.² Other tools are available on the Web in style files that have spread among the LaTeX community. (Such tools build on LaTeX and make certain types of commands [such as rotating figures] easier to implement. Other common style files, such as those published by

academic societies like the American Physical Society, are devoted to formats of a specified journal or selection of journals.) *The LaTeX Companion* discusses many of these files. I have already discussed how to include such files in a document's preamble. The easiest way to find them is to search for them on the Web—LaTeX packages are compiled in myriad places, so any one that is widely used is very easy to find.

A required argument of any command for including graphics is the name of the file. Note that this argument must include directory names if the figure of interest is not in the same directory of the LaTeX file in which it is being embedded.

One may then specify a caption, which is ordinarily placed below figures. (By contrast, captions are ordinarily placed above tables. Of course, one should consult the stylistic requirements of the journal or publisher to which one is submitting one's work to be certain.) Observe that I used vertical spacing to manipulate the location of this caption. Observe also that I have elected to center both the figure and the caption.

5.1 Types of Figure Files

It is standard to embed postscript files in LaTeX documents. Such files have the suffix .ps or .eps, where the 'e' stands for 'encapsulated.' Most journals require figures to be in postscript format, as that is a universal format (that doesn't depend on one's operating system, *etc.*).

One can embed other types of files (whether or not the associated format is universal), but .ps files are standard and *should be used whenever possible*. I have noted in particular that past MTBI students have used .bmp files, which

are *not* universal. If you ask them, they may remember that I have ranted in the past about not using this type of file because publishers will almost never except submissions in non-universal formats. However, in cases in which it is most convenient to use .bmp files, one may use the same commands that I specified above with one minor distinction—one’s figure is called blah.bmp rather than blah.ps or blah.eps.

One can use Matlab to convert .bmp files into .ps files. To load a .bmp file into Matlab, type

```
A = imread('file.bmp','bmp');  
image(A);
```

If the picture comes out the way you want, you just need to save it. If it is mostly blank, however, type

```
map = [0 0 0;1 1 1];  
colormap(map);
```

For a discussion of using different types of figures with LaTeX, go to the Los Alamos ArXiv (which is now at Cornell University) at xxx.arxiv.org, scroll down to the bottom of the page, click on 'help', click on frequently asked questions, scroll down to to “Information for submitters (procedure and submission preparation,” and click on the question, “How do I make bitmaps of some of my figures?”

5.2 Graphics with Multiple Columns

It is sometimes useful to display graphics using multiple columns. For example, consider the following code (which is adapted from that in a document

by Warwick Tucker):

```
\begin{figure}[h]
\centerline{
\includegraphics[width=0.40\textwidth, height=0.40\textwidth]
{/home/mason/research/vibrate/mult/time13.ps}
\hspace{1cm}
\includegraphics[width=0.40\textwidth, height=0.40\textwidth]
{/home/mason/research/vibrate/mult/time23.ps} }
\caption{\label{figs1} (a) This is the left figure.
\hspace{1cm} (b) This is the right figure.}
\end{figure}
```

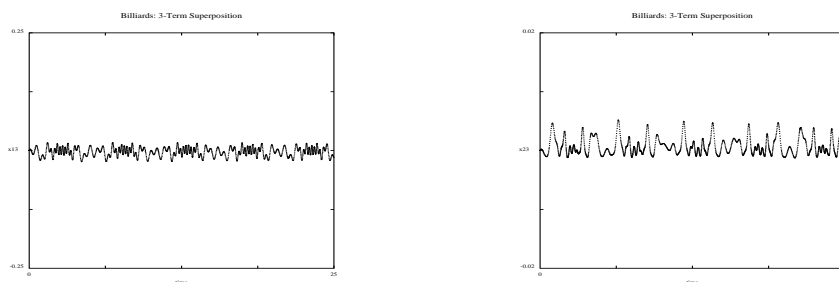


Figure 2: (a) This is the left figure. (b) This is the right figure.

This code is somewhat different from that used for Figure 1. In particular, the graphics and captions were centered in a different manner. Note, moreover, the manner in which the length and width of the plots have been

specified. Instead of specifying an absolute width and length, these quantities have been specified in terms of the width of the text. The prefactor of .40 indicates this relative value. This sort of command is also useful in other contexts; for example, it can help specify an environment (such as a definition or a theorem). Finally, note that including multiple graphics at once is easily accomplished by using multiple

```
\includegraphics
```

commands.

5.3 A Note on Plagiarism

You may be wondering why I have elected to place this section in this portion of the paper. The reason is that in past year's, many MTBI students have used graphics produced by other people in their documents. Technically, one is supposed to explicitly ask them for permission to do this before 'borrowing' their figures. In the assignment that I give, this will be a requirement for using any figure one downloads from the Web or obtains from another source in any other manner. If you are given permission to use somebody else's figure, the conventional way to acknowledge this permission is to state it at the end of the caption. (Phrases such as "Figure courtesy J. Random Professor" are typically employed.)

6 Tables

The table (1) was produced using the following code:

Steps	h	$E(h)$	$E(h)/h$
1	2	4.3891×10^0	2.1946
2	1	3.3891×10^0	3.3891
4	2^{-1}	2.3266×10^0	4.6532
8	2^{-2}	1.4286×10^0	5.7144
16	2^{-3}	8.0581×10^{-1}	6.4465
32	2^{-4}	4.3039×10^{-1}	6.8862
64	2^{-5}	2.2278×10^{-1}	7.1290
128	2^{-6}	1.1339×10^{-1}	7.2570
256	2^{-7}	5.7206×10^{-2}	7.3224
512	2^{-8}	2.8733×10^{-2}	7.3556
1024	2^{-9}	1.4399×10^{-2}	7.3723
2048	2^{-10}	7.2077×10^{-3}	7.3807
4096	2^{-11}	3.6059×10^{-3}	7.3849
8192	2^{-12}	1.8035×10^{-3}	7.3871
16384	2^{-13}	9.0186×10^{-4}	7.3880

Table 1: Estimates of C_E .

```

\begin{table}
\centerline{
\begin{tabular}{|c|c|c|r|} \hline
Steps & $ h $ & $ E(h) $ & $ E(h) / h $ \\ \hline
1 & $ 2 $ & $ 4.3891 \times 10^0 $ & $ 2.1946 $ \\
2 & $ 1 $ & $ 3.3891 \times 10^0 $ & $ 3.3891 $ \\
4 & $ 2^{-1} $ & $ 2.3266 \times 10^0 $ & $ 4.6532 $ \\
8 & $ 2^{-2} $ & $ 1.4286 \times 10^0 $ & $ 5.7144 $ \\
16 & $ 2^{-3} $ & $ 8.0581 \times 10^{-1} $ & $ 6.4465 $ \\
32 & $ 2^{-4} $ & $ 4.3039 \times 10^{-1} $ & $ 6.8862 $ \\
64 & $ 2^{-5} $ & $ 2.2278 \times 10^{-1} $ & $ 7.1290 $ \\
128 & $ 2^{-6} $ & $ 1.1339 \times 10^{-1} $ & $ 7.2570 $ \\
256 & $ 2^{-7} $ & $ 5.7206 \times 10^{-2} $ & $ 7.3224 $ \\
512 & $ 2^{-8} $ & $ 2.8733 \times 10^{-2} $ & $ 7.3556 $ \\
1024 & $ 2^{-9} $ & $ 1.4399 \times 10^{-2} $ & $ 7.3723 $ \\
2048 & $ 2^{-10} $ & $ 7.2077 \times 10^{-3} $ & $ 7.3807 $ \\
4096 & $ 2^{-11} $ & $ 3.6059 \times 10^{-3} $ & $ 7.3849 $ \\
8192 & $ 2^{-12} $ & $ 1.8035 \times 10^{-3} $ & $ 7.3871 $ \\
16384 & $ 2^{-13} $ & $ 9.0186 \times 10^{-4} $ & $ 7.3880 $ \\
\hline
\end{tabular}}\caption{Estimates of $C_E$}\label{tab1}
\end{table}

```

Note that the

```
\begin{table}
```

and


```
\end{table}
```

commands do not function in PCTex. (These commands are a good way to make a table if one is using a unix flavor of LaTeX.) One alternative is to obtain (3) with the figure environment:

```
\begin{figure}
```

```
\centerline{
```

```
\begin{tabular}{|c|c|c|r|} \hline
```

```
Steps & $ h $ & $ E(h) $ & $E(h) / h$ \\ \hline
```

```
1 & $ 2 $ & $ 4.3891\times 10^0 $ & 2.1946 \\
```

```
2 & $ 1 $ & $ 3.3891\times 10^0 $ & 3.3891 \\
```

```
4 & $ 2^{-1} $ & $ 2.3266\times 10^{0} $ & 4.6532 \\
```

```
8 & $ 2^{-2} $ & $ 1.4286\times 10^{0} $ & 5.7144 \\
```

```
16 & $ 2^{-3} $ & $ 8.0581\times 10^{-1} $ & 6.4465 \\
```

```
32 & $ 2^{-4} $ & $ 4.3039\times 10^{-1} $ & 6.8862 \\
```

```
64 & $ 2^{-5} $ & $ 2.2278\times 10^{-1} $ & 7.1290 \\
```

```
128 & $ 2^{-6} $ & $ 1.1339\times 10^{-1} $ & 7.2570 \\
```

```
256 & $ 2^{-7} $ & $ 5.7206\times 10^{-2} $ & 7.3224 \\
```

```
512 & $ 2^{-8} $ & $ 2.8733\times 10^{-2} $ & 7.3556 \\
```

```
1024 & $ 2^{-9} $ & $ 1.4399\times 10^{-2} $ & 7.3723 \\
```

```
2048 & $ 2^{-10} $ & $ 7.2077\times 10^{-3} $ & 7.3807 \\
```

```
4096 & $ 2^{-11} $ & $ 3.6059\times 10^{-3} $ & 7.3849 \\
```

```
8192 & $ 2^{-12} $ & $ 1.8035\times 10^{-3} $ & 7.3871 \\
```

```
16384 & $ 2^{-13} $ & $ 9.0186\times 10^{-4} $ & 7.3880 \\
```

```
\hline
```

```
\end{tabular}}\caption{Estimates of $C_E$}
```

Steps	h	$E(h)$	$E(h)/h$
1	2	4.3891×10^0	2.1946
2	1	3.3891×10^0	3.3891
4	2^{-1}	2.3266×10^0	4.6532
8	2^{-2}	1.4286×10^0	5.7144
16	2^{-3}	8.0581×10^{-1}	6.4465
32	2^{-4}	4.3039×10^{-1}	6.8862
64	2^{-5}	2.2278×10^{-1}	7.1290
128	2^{-6}	1.1339×10^{-1}	7.2570
256	2^{-7}	5.7206×10^{-2}	7.3224
512	2^{-8}	2.8733×10^{-2}	7.3556
1024	2^{-9}	1.4399×10^{-2}	7.3723
2048	2^{-10}	7.2077×10^{-3}	7.3807
4096	2^{-11}	3.6059×10^{-3}	7.3849
8192	2^{-12}	1.8035×10^{-3}	7.3871
16384	2^{-13}	9.0186×10^{-4}	7.3880

Figure 3: Estimates of C_E .

`\end{figure}`

Note, however, that this table is now labeled as a figure when it's compiled. One can produce a table using neither the *table* nor **figure** environments. If one does this, one cannot use a caption easily. (One can still put one in manually; one just can't use the *caption* command.) This has the advantage of circumventing the incompatibility of the **table** environment with PCTex. The code is

```

\centerline{
\begin{tabular}{|c|c|c|r|} \hline
Steps & $ h $ & $ E(h) $ & $ E(h) / h $ \\ \hline
1 & $ 2 $ & $ 4.3891 \times 10^0 $ & $ 2.1946 $ \\
2 & $ 1 $ & $ 3.3891 \times 10^0 $ & $ 3.3891 $ \\
4 & $ 2^{-1} $ & $ 2.3266 \times 10^0 $ & $ 4.6532 $ \\
8 & $ 2^{-2} $ & $ 1.4286 \times 10^0 $ & $ 5.7144 $ \\
16 & $ 2^{-3} $ & $ 8.0581 \times 10^{-1} $ & $ 6.4465 $ \\
32 & $ 2^{-4} $ & $ 4.3039 \times 10^{-1} $ & $ 6.8862 $ \\
64 & $ 2^{-5} $ & $ 2.2278 \times 10^{-1} $ & $ 7.1290 $ \\
128 & $ 2^{-6} $ & $ 1.1339 \times 10^{-1} $ & $ 7.2570 $ \\
256 & $ 2^{-7} $ & $ 5.7206 \times 10^{-2} $ & $ 7.3224 $ \\
512 & $ 2^{-8} $ & $ 2.8733 \times 10^{-2} $ & $ 7.3556 $ \\
1024 & $ 2^{-9} $ & $ 1.4399 \times 10^{-2} $ & $ 7.3723 $ \\
2048 & $ 2^{-10} $ & $ 7.2077 \times 10^{-3} $ & $ 7.3807 $ \\
4096 & $ 2^{-11} $ & $ 3.6059 \times 10^{-3} $ & $ 7.3849 $ \\
8192 & $ 2^{-12} $ & $ 1.8035 \times 10^{-3} $ & $ 7.3871 $ \\
16384 & $ 2^{-13} $ & $ 9.0186 \times 10^{-4} $ & $ 7.3880 $ \\
\hline
\end{tabular}}

```

It produces the following result:

Steps	h	$E(h)$	$E(h)/h$
1	2	4.3891×10^0	2.1946
2	1	3.3891×10^0	3.3891
4	2^{-1}	2.3266×10^0	4.6532
8	2^{-2}	1.4286×10^0	5.7144
16	2^{-3}	8.0581×10^{-1}	6.4465
32	2^{-4}	4.3039×10^{-1}	6.8862
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256	2^{-7}	5.7206×10^{-2}	7.3224
512	2^{-8}	2.8733×10^{-2}	7.3556
1024	2^{-9}	1.4399×10^{-2}	7.3723
2048	2^{-10}	7.2077×10^{-3}	7.3807
4096	2^{-11}	3.6059×10^{-3}	7.3849
8192	2^{-12}	1.8035×10^{-3}	7.3871
16384	2^{-13}	9.0186×10^{-4}	7.3880

Note that because I didn't use the `float` environment, this table is not automatically separated from the surrounding text.

Some of the conventions in the code for tables differ from those discussed previously in this article, as I copied the formatting from someone else's document when producing this table. (I have acknowledged the appropriate party at the conclusion to this paper, although it ordinarily is not necessary to do this for bits of LaTeX code. If somebody else actively helps you typeset a paper, on the other hand, then that person most definitely should be acknowledged.)

As in matrices, ampersands & have been used to separate entries and double backslashes have been used to separate lines in the table. The character — yields the vertical lines in the table. The command

`\hline`

constructs a horizontal line. The parameter `c` indicates a center-adjusted column, whereas `l` indicates a left-adjusted column, and `r` produces a right-adjusted column. For more information concerning LaTeX's tabular environment, see Chapter 5 of *The LaTeX Companion*.²

7 Bibliography and Citations

I have discussed briefly the fact that it is paramount to cite the work of others. This includes not only books and journal articles, but also Web pages, private conversations, *etc.* In this section, I discuss how to formally include a bibliography. There are a couple ways to proceed.

If one produces multiple papers, the best way is to produce a file `blah.bib` that contains references that may be cited. For your purposes, this will not be necessary, although you can ask me about this if you are interested. (I use a single `.bib` file [called `ref.bib`] for all the papers I cite, but one can also use more than one `.bib` file. Each one, for example, may have a different theme. Perhaps one includes all of one's own work. Perhaps another includes works by others from 2001. Perhaps a third includes works by others from 2000.) When compiled, the bibliography file `blah.bib` produces the file `latexfile.bbl` (corresponding to the LaTeX file `latexfile.tex`), which stores the information

for the bibliography entries in `blah.bib` that one has actually used. As an example, I have included the file `lala.bbl` that corresponds to the present file.

To implement the procedure described above, the commands I use in the present LaTeX file are

```
\bibliographystyle{plain}  
\bibliography{/home/mason/research/vibrate/ref}
```

Note, however, that this is what one does in a Unix environment. On a personal computer (for example, if one is using PCTex), one should navigate the directory's on one's computer in the way normally associated with the relevant operating system.

The commands to create a bibliography are the final ones placed before ending the document. The first command indicates the style of one's bibliography. Different journals—especially those in disparate fields—have different required styles. (For example, many physics journals have the annoying habit of not including titles for articles that are cited.) These styles may be implemented using style files that are available online.

If one is not using a `.bib` file, one simply includes the exact information in the `.bbl` file at this point in lieu of the commands above. There is no separate file, and one obviously need not specify the bibliography format a priori if one is typing bibliography entries manually. See the sample document by Ricardo Sáenz⁴ as well as `lala.bbl` for examples of how to do make such entries. If using a `.bib` file, the pertinent information is obtained automatically during the compilation process. Otherwise, one must include this information manually. (The advantage of using a `.bib` file is twofold: First

one need not repeatedly type the same information multiple times. Second, it helps keep things organized.)

Before proceeding, let's briefly consider the contents of a manually-entered bibliography. An example of a bibliography item for a journal article is

```
\bibitem{shep4}
Armelle Barelli, Jean Bellissard, Philippe Jacquod, and Dima~L.
Shepelyanksy.
\newblock Two interacting {H}ofstadter butterflies.
\newblock {\em Physical Review B}, 55(15):9524--9533, April 1997.
```

The 'shep4' is the label used to cite this item in the text. For example, I have used

```
\cite{companion}
```

to cite *The LaTeX Companion*. The brackets in

```
{H}
```

were applied in ref.bib to force that 'H' to be capitalized. (In many journals, only the first word in article titles are capitalized; however, as Hofstadter is a proper name, I used braces to indicate that the character should be copied exactly.)

An example of a bibliography item for a book is

```
\bibitem{vibe}
Isaac~B. Bersuker and Victor~Z. Polinger.
\newblock {\em Vibronic Interactions in Molecules and Crystals}.
```

`\newblock` Number~49 in Springer Series in Chemical Physics.
Springer-Verlag,
New York, NY, 1989.

After one has typed all the necessary bibliography entries, one uses the command

```
\end{thebibliography}
```

as all

```
\begin
```

commands must be complemented with the corresponding

```
\end
```

8 Compiling LaTeX Documents

To compile the LaTeX document `blah.tex` (with a GUI interface), one types `'latex blah.tex'` or simply `'latex blah'`. This yields a `.dvi` file `blah.dvi`.

To apply an external bibliography file, one then types `'bibtex blah'`. One must then type `'latex blah'` once more. (In fact, one has to repeat these two commands several times to make sure that the bibliography is entered correctly. Once one no longer receives the message that there is some change in the bibliography when typing the command `'latex blah'`, then one can stop doing this. I don't have a good explanation for why this is necessary.)

When using Unix, one can view `.dvi` files directly with the program `xdvi`, but one ordinarily wishes to obtain a postscript (`.ps`) file. To do so, type the

command ‘dvips blah.dvi -o blah.ps’. (This is accomplished automatically when compiling the LaTeX code on Mac and Windoze implementations of LaTeX.) To print the file directly, instead type ‘dvips blah.dvi’. (The -o is to output to a file.) Postscript files (on any system) can be view with the program Ghostview (which is available for all major platforms), which can be downloaded for free. (MacGS is the Mac version of this program.)

It is sometimes desirable to obtain a .pdf file—especially when dealing with people who are not scientists. (Surprisingly many people simply don’t know how to handle .ps files and seem unwilling to download Ghostview.) Some versions of Ghostview can convert files to .pdf format. Otherwise, one may use the command ‘ps2pdf blah.pdf blah.ps’ in Unix to obtain a .pdf file. One can also use Adobe Acrobat to do this.

9 Other Commands

The discussion in this section does not even come close to exhausting LaTeX’s versatility. If you want to do something that has not been discussed here, please either ask me about it or take a look at the sources in the bibliography. The source I used most often is *The LaTeX Companion*.² Other viable books concerning LaTeX include *The Joy of Tex*,⁵ *The Texbook*,³ and *LaTeX: Line by Line*.¹

10 Disclaimer

I have attempted to discuss multiple flavors of LaTeX. I use a Unix implementation, but I have attempted to discuss situations that are different for LaTeX on other operating systems. Note in particular that the `table` environment does not work on PCTex (at least as implemented on the MTBI computers). One can, however, use the `tabular` environment and insert captions manually, as I discussed above.

11 Some Final Notes

The present document is not meant to be a comprehensive discussion of LaTeX. Its purpose is to help people writing their first (or perhaps second) mathematical document from LaTeX. To assist future generations of MTBI students, please e-mail me at *mason@math.gatech.edu* if there are any topics that have not been included that you feel should have been incorporated. In particular, any MTBI students who attempted to do something in their projects that is not discussed here should contact me. (Please also provide a sample of your LaTeX code.) Please also contact me if you find any errors in this document.

12 Acknowledgements

Comments by Steve Wirkus yielded marked improvements in this tutorial. The LaTeX code for the table and the second set of figures was adapted from a document produced by Warwick Tucker. Finally, I would like to thank

the MTBI program (and the associated Powers That Be) for providing the funding (i.e., paychecks) for the time I spend producing this document.

References

- [1] Antoni Diller. *Latex: Line by Line*. John Wiley & Sons, New York, New York, 1993.
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- [4] Ricardo A. Sáenz. First order partial differential equations: Mtbi lecture notes. Unpublished, July 1999.
- [5] Michael D. Spivak. *The Joy of Tex*. American Mathematical Society, Providence, Rhode Island, second edition, 1990.