AMTH142
Lectures on LATEX
Gary Bunting
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1 Introduction to \LaTeX

The reference for these lectures is *The Not So Short Introduction to \LaTeX* 2\textsuperscript{e} by Tobias Oetiker and others (see \LaTeX Resources on the web page). In these lectures it will be referred to by the abbreviation NSSI.

1.1 How \LaTeX Works

There are three steps in producing a document using \LaTeX:

1. Create a \LaTeX input file. This contains the text and formatting commands and must be a plain text (ASCII) file with the extension `.tex`.

2. Run the file through \LaTeX. This produces a `.dvi` (device independent) file which may be viewed, for example, by `xdvi` on Linux systems.

3. Convert the `.dvi` file to form which can be printed. Typically this will result in a `.pdf` (pdf – portable document format) file.

The mechanics of doing all this will be covered in the first practical. The rest of this lecture will cover the structure of \LaTeX input files.

1.2 \LaTeX Input Files

1.2.1 Spaces

1. One or more whitespace characters such as spaces, tabs or linebreaks are treated as single space.

2. One or more blank lines start a new paragraph.

Example:

Note: Examples in these notes will usually take the form of \LaTeX input in typewriter text, followed by the result in slightly smaller type.

\begin{quote}
This is a silly way to type a sentence.
\end{quote}

\begin{quote}
Followed by a new paragraph.
\end{quote}

This is a silly way to type a sentence. Followed by a new paragraph.
1.2.2 Special Characters

Some characters have a special meaning and will not print as expected. The most important of these are:

```
# $ % & { } \n```

Except for the backslash itself, these can be printed by preceding them with a backslash. The `$\backslash$` command is used to print a backslash.

Example:

```
\# \$ \% \& \{ \} $\backslash$
```

1.2.3 Comments

A `%` is used for comments. When \LaTeX\ encounters a `%` the rest of the line is ignored.

Example:

```
The rest of this line will be ignored, % THIS IS A COMMENT
% and another comment
as will the line above.
```

The rest of this line will be ignored, as will the line above.

1.2.4 \LaTeX\ Commands

\LaTeX\ commands begin with a backslash `\`. A big part of learning \LaTeX\ consists of learning its commands and their effects.

Example:

```
\LaTeX{} is the topic of this lecture.
```

\LaTeX\ is the topic of this lecture.
1.3 Input File Structure

\LaTeX input files must follow a certain structure:

1. Each input file must begin with a command

\documentclass{...}

The document class determines the overall layout of the document. The \LaTeX document classes are:

- article: This is the only one you will need for this unit.
- report: This is used for longer documents containing several chapters, e.g. PhD theses.
- book: For books.
- slides: For overhead projector slides.
- letter: For letters.

2. After that follows commands which influence the style of the document or load packages which add new capabilities to \LaTeX. This is often referred to as the preamble.

3. The body of the text is started with

\begin{document}

4. Next follows the text of the document itself interspersed with \LaTeX commands.

5. The whole thing is terminated with

\end{document}

Example:

The following is a small but complete input file for a \LaTeX document:

\documentclass{article}
\begin{document}
  This is a very short article.
\end{document}
2 Formatting Text

2.1 Special Symbols

2.1.1 Quotation Marks

1. For quotation marks use "" for opening quotes and "" for closing quotes.

2. For single quotes use one of each.

Example:

Do you mean "'eye'" or 'i'? 

Do you mean “eye” or ‘i’?

2.1.2 Dashes and Hyphens

There are three types of dashes in LaTeX.

Example:

1 - short-dashes and hyphens

2 -- long--dashes

3 --- longer---dashes

1 - short-dashes and hyphens
2 – long–dashes
3 — longer—dashes

2.2 Font Selection

2.2.1 Font Types

The font types generally available in \LaTeX are:

1. \texttt{...} roman
2. \texttt{...} typewriter
3. \textsl{...} slanted
4. \textsf{...} sans serif
5. \textbf{...} bold face
6. \textit{...} italic
7. \textsc{...} \textbf{small capitals}

8. \emph{...} \textit{emphasized}

Example:

This \textit{sentence} \texttt{uses} a \textsl{number} of \textsf{different} \textbf{fonts} \textit{which} \textsc{makes} it \textbf{hard} to \textsc{read}. \texttt{\emph{Emphasized text} differs from \textit{italic text} in that \textsf{it can be \emph{combined} with other font changes.}}

This \textit{sentence uses a number of different fonts which makes it hard to read}. \textit{Emphasized text differs from italic text in that it can be combined with other font changes.}

2.2.2 Font Sizes

The font size, either 10pt (the default), 11pt or 12pt, for the whole document is set within the initial \documentclass command, e.g.

\documentclass[12pt]{article}

The font size and type of title and section headings are chosen automatically by \LaTeX.

The font sizes generally available in \LaTeX are:

1. {\tiny ...} \textit{tiny}
2. {\scriptsize ...} \textit{very small}
3. {\footnotesize ...} \textit{quite small}
4. {\small ...} \textit{small}
5. {\normalsize ...} \textit{normal}
6. {\large ...} \textit{larger}
7. {\Large ...} \textit{larger still}
8. {\LARGE ...} \textit{quite large}
9. {\huge ...} \textit{very large}
10. {\Huge ...} \textit{huge}
Example:

When combining changes of font \textbf{size and type}, remember that the \textbf{size} change comes first.

When combining changes of font \textbf{size and type}, remember that the \textbf{size} change comes first.

2.3 Spacing and Indentation

2.3.1 Paragraphs and Indentation

We have already seen that in \LaTeX{} a blank line starts a new paragraph. By default \LaTeX{} indents each paragraph except the first paragraph of a Chapter, Section etc. This can be controlled using the commands \texttt{\indent} and \texttt{\noindent}.

Example:

Normally paragraphs are indented.

\noindent But this one isn’t.

Normally paragraphs are indented.
But this one isn’t.

2.3.2 Line and Page Breaks

1. The commands \texttt{\}\ or \texttt{\newline} force a new line to be started without starting a new paragraph.

2. The command \texttt{\newpage} can be used to force a new page to be started.

Example:

This is how to start a new line \texttt{\}\ without starting a new paragraph.

Of course, a new paragraph is started by a blank line.

This is how to start a new line
without starting a new paragraph.

Of course, a new paragraph is started by a blank line.
2.3.3 Spacing Between Paragraphs

By default \LaTeX{} adds no extra space between paragraphs. Sometimes, to make certain paragraphs stand out, you need to add extra space. This can be done with the \texttt{\smallskip}, \texttt{\medskip} and \texttt{\bigskip} commands.

\textbf{Example:}

Here is an example of \ldots different spacings \ldots
\smallskip
between paragraphs.
\medskip
This is useful in highlighting certain paragraphs.
\bigskip
It is also useful with equations, tables and diagrams.

Here is an example of \ldots different spacings \ldots between paragraphs. This is useful in highlighting certain paragraphs.

It is also useful with equations, tables and diagrams.

2.4 Sections and Subsections

The sectioning commands
\section{...}
\subsection{...}
\subsubsection{...}
are available in the \texttt{article} document class. The additional command \texttt{\chapter} is available in the \texttt{report} and \texttt{book} document classes.

The numbering of sections is done automatically by \LaTeX{}, as is the font selection for titles and spacing between sections.

The
\subsubsection*{...}
command does not print the subsubsection number.
Example

\subsection*{Example}

This is how examples are introduced in these notes.

Example

This is how examples are introduced in these notes.

2.5 Titles and Tables of Contents

The following example gives the first few lines of *this* document:\footnote{You usually need to run a document through \LaTeX{} twice to get the table of contents correct.}:

Example:

\documentclass[11pt,twoside,a4paper]{article}

\usepackage{amsmath}
\usepackage{graphicx}

\title{AMTH142 \ \ Lectures on \LaTeX{}}
\author{Gary Bunting}
\begin{document}
\maketitle
\tableofcontents
\newpage
\section{Introduction to \LaTeX{}}

2.6 Environments

These are generally associated with a pair of matching commands

\begin{...}
\end{...}
2.6.1 Lists

\LaTeX{} has three types of list environments:

1. enumerate
2. itemize
3. description

The individual items in the list are introduced by the \texttt{item} command. List can be nested, that is you can have lists within lists.

Example:

\begin{enumerate}
\item This is the first item of an \texttt{itemize} environment.
\item And this is the second.
\end{enumerate}

\begin{description}
\item[First] First item in the list.
\item[Second] Second item in the list.
\end{description}

1. The \texttt{enumerate} environment numbers the elements in the list.
2. The \texttt{itemize} environment precedes each item by a large dot as follows:
   - This is the first item of an \texttt{itemize} environment.
   - And this is the second.
3. This is an example of the \texttt{description} environment.

\textbf{First} item in the list.
\textbf{Second} item in the list.
2.6.2 Centering Text

Example:

\begin{center}
This is an example of centered text. Centering is useful when including tables and diagrams.
\end{center}

This is an example of centered text.
Centering is useful when including tables and diagrams.

2.6.3 Verbatim

Text enclosed between a \begin{verbatim} and \end{verbatim} pair is printed exactly as is in typewriter font, including spaces and linebreaks, and with \LaTeX{} commands ignored.

Example:

\begin{verbatim}
\LaTeX{} commands are ignored in verbatim environments, but spaces and linebreaks are faithfully followed.
\end{verbatim}

\LaTeX{} commands are ignored in verbatim environments, but spaces and linebreaks are faithfully followed.

The verbatim environment is used for the examples in these notes. The same effect within paragraphs can be obtained with the \verb{} command. The character immediately following the \verb{} is the delimiting character; the following text will be printed verbatim until this delimiting character is reached again.

Example:

An important difference between \verb+\verb+ and \verb+\texttt+ is that \LaTeX{} commands have their intended effect inside \verb+\texttt+, while inside \verb+\verb+ they are printed verbatim.
In this example I have used \texttt{+} as the delimiter.
An important difference between \verb and \texttt is that \LaTeX commands have their intended effect inside \texttt, while inside \verb they are printed verbatim. In this example I have used + as the delimiter.

3 Formatting Mathematics

3.1 Mathematics Modes

There are two mathematics modes in \LaTeX:

1. Mathematics within text is enclosed between \( and \), or between $ and $ or between \begin{math} and \end{math}. This is often referred to as paragraph mode.

2. Mathematics displayed on a separate line is enclosed between \[ and \], or between $$ and $$ or between \begin{displaymath} and \end{displaymath}. This is often referred to as display mode.

Example:

Here is a formula
\[ x^2 = y^2 + z^2 \]
within a paragraph.
Here is the same formula
\[ x^2 = y^2 + z^2 \]
in display mode.

Here is a formula $x^2 = y^2 + z^2$ within a paragraph. Here is the same formula
\[ x^2 = y^2 + z^2 \]
in display mode.

3.1.1 Numbered Equations

The pair \begin{equation} and \end{equation} are used to obtain numbered equations. When equations are numbered, that numbering can be used to refer to particular equations. \LaTeX has simple mechanism for handling this: equations can be labelled with \label{...} and then referred to with \ref{...}.

Example:

Here is a numbered equation
\begin{equation}
\begin{aligned}
x^2 + y^2 &= z^2
\end{aligned}
\end{equation}
When an equation has been labelled
\begin{equation} \label{eq:pythag}
\sin^2 \theta + \cos^2 \theta = 1
\end{equation}
it can be referred to in the text, in this case as Equation (\ref{eq:pythag}).

Here is a numbered equation
\begin{equation}
x^2 + y^2 = z^2. \quad (1)
\end{equation}

When an equation has been labelled
\begin{equation}
\sin^2 \theta + \cos^2 \theta = 1 \quad (2)
\end{equation}
it can be referred to in the text, in this case as Equation (2).

3.2 Basics
3.2.1 Mathematics Fonts
Mathematical symbols are generally printed in italics. The dollar signs around mathematics takes care of this automatically so use $x$ rather that \textit{x}. On the other hand, bold math letters created with \textbf{mathbf} are identical to to those created with \textbf{textbf} and are not italicized.

Example:
Mathematical symbols like $A$, $x$ and $b$ are the same as italic letters \textit{A}, \textit{x} and \textit{b}, but obey different spacing rules as in $Ax = b$ and \textit{A x = b}. On the other hand, bold math letters like \textbf{mathbf{X}} are identical to bold roman text letters like \textbf{textbf{X}} and are not italicized. Numbers look the same whether in maths mode or not, e.g $123.456$ is the same as 123.456.

Mathematical symbols like $A$, $x$ and $b$ are the same as italic letters \textit{A}, \textit{x} and \textit{b}, but obey different spacing rules as in $Ax = b$ and \textit{A x = b}. On the other hand, bold math letters like \textbf{mathbf{X}} are identical to bold roman text letters like \textbf{X} and are not italicized. Numbers look the same whether in maths mode or not, e.g 123.456 is the same as 123.456.

3.2.2 Greek Letters
1. Lowercase Greek letters are referred to by their name, e.g. \texttt{\alpha}, \texttt{\beta}, \texttt{\gamma}...
2. Uppercase Greek letters are referred to by their name with the first letter capitalized, e.g. \( \Gamma, \Delta, \Lambda \ldots \)

3. Greek letters can only be used in mathematics mode, not in ordinary text.

Example:

$$ V = \frac{4}{3} \pi r^3 $$

To use a Greek letter like $\Sigma$ in ordinary text we have to be in mathematics mode.

$$ V = \frac{4}{3} \pi r^3 $$

To use a Greek letter like $\Sigma$ in ordinary text we have to be in mathematics mode.

3.2.3 Exponents and Subscripts

1. Exponents and superscripts are specified by a caret `^`.

2. Subscripts are specified by an underscore `_`.

3. Exponents and subscripts are usually enclosed in braces `{...}`.

4. Exponents and subscripts may be mixed and/or nested.

Example:

If you forget the braces you can get unintended results.

For example compare

$$ X_{ab} = y^{12} \quad \text{qquad} X_{ab} = y^{12} $$

Here are the right and wrong ways to nest exponents and subscripts.

$$ e^{x^{2}} \quad \text{qquad} \{e^{x}\}^{2} $$

$$ P_{a_{0}} \quad \text{qquad} \{P_{a}\}_{0} $$

Here are some examples of mixed exponents and subscripts:

$$ A_{ij}^{3} \quad \text{qquad} A^{3}_{ij} \quad \text{qquad} 3^{- P_{0}} \quad \text{qquad} P_{x^{3}} $$

If you forget the braces you can get unintended results. For example compare

$$ X_{ab} = y^{12} \quad X_{ab} = y^{12} $$

Here are the right and wrong ways to nest exponents and subscripts.

$$ e^{x^{2}} \quad e^{x^{2}} $$

$$ P_{a_{0}} \quad P_{a_{0}} $$
Here are some examples of mixed exponents and subscripts:

\[ A_{ij}^3 \quad A_{ij}^3 \quad 3^{-P_0} \quad P_{x^3} \]

### 3.2.4 Fractions and Roots

**Example:**

Fractions are written with the \verb+\frac{...}{...}+ command. Here are some examples:

\[
\frac{n!}{(n-k)! \, k!} \quad 2^{\frac{1}{2}} \quad \frac{3^5}{4^5}
\]

Sometimes it is preferable to use the slash form, e.g. $1/2$, as it can be easier to read in some contexts. Compare:

\[
x^{-\{\frac{3}{4}\}} \quad \text{to} \quad x^{\{3/4\}}
\]

and compare $\frac{3}{4}$ hour to $\frac{3}{4}$ hour.

Fractions are written with the \verb+\frac{...}{...}+ command. Here are some examples:

\[
\frac{n!}{(n-k)! \, k!} \quad 2^{\frac{3}{4}} \quad 3^5 \quad 4^5
\]

Sometimes it is preferable to use the slash form, e.g. $1/2$, as it can be easier to read in some contexts. Compare:

\[
x^{\frac{3}{4}} \quad \text{to} \quad x^{3/4}
\]

and compare $\frac{3}{4}$ hour to $3/4$ hour.

**Example:**

Here is how we write square roots $\sqrt{b^2 - 4ac}$ and other roots $\sqrt[127]{2}$.

Here is how we write square roots $\sqrt{b^2 - 4ac}$ and other roots $\sqrt[127]{2}$.

### 3.2.5 Standard Functions

The names of certain standard mathematical functions and abbreviations are obtained by putting a backslash \ before their name. See the list on page 51 of NSSI.

**Example:**

\[
\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1
\]

but if we forget the backslash we get

\[
\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1
\]
\[ \lim_{x \to 0} \frac{\sin x}{x} = 1 \]

but if we forget the backslash we get

\[ \lim_{x \to 0} \frac{\sin x}{x} = 1 \]

3.2.6 Integrals, Sums, Products

1. Integrals are generated by \texttt{\int}

2. Sums are generated by \texttt{\sum}

3. Products are generated by \texttt{\prod}

4. Limits of integration etc. are generated by superscripts and subscripts.

Example:

\[ \int \sin x \, dx = - \cos x \quad \int_0^{\infty} e^{-x} \, dx = 1 \]

\[ \sum_{k=1}^n k = \frac{1}{2} n (n + 1) \quad \prod_{\text{k even}} P_k = 1 \]

Integrals, \( \int \sin x \, dx = - \cos x \), sums, \( \sum_{k=1}^n k = \frac{1}{2} n (n + 1) \), and products look different within paragraph mode.

\[ \int \sin x \, dx = - \cos x \quad \int_0^{\infty} e^{-x} \, dx = 1 \]

\[ \sum_{k=1}^n k = \frac{1}{2} n (n + 1) \quad \prod_{\text{k even}} P_k = 1 \]

Integrals, \( \int \sin x \, dx = - \cos x \), sums, \( \sum_{k=1}^n k = \frac{1}{2} n (n + 1) \), and products look different within paragraph mode.

3.2.7 Derivatives

1. Derivatives are easily constructed using \texttt{\frac}

2. Alternatively, they can be written using the prime symbol \texttt{'}.

3. The partial derivative symbol is \texttt{\partial}
Example:

\[ \frac{d^2 y}{d x^2} + y(x) = 0 \quad y'' + y = 0 \]
\[ \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0 \]

Again, the slash form, $d\sin x/\ dx = \cos x$, is is sometimes preferable to the fraction form, $\frac{d\sin x}{dx} = \cos x$, in paragraph mode.

\[ \frac{d^2 y}{dx^2} + y(x) = 0 \quad y'' + y = 0 \quad \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0 \]

Again, the slash form, $d\sin x/\ dx = \cos x$, is sometimes preferable to the fraction form, $\frac{d\sin x}{dx} = \cos x$, in paragraph mode.

3.2.8 Accents

There are a lot of these so make sure you use the right one for your particular need.

1. $\overline{x}$
2. $\hat{x}$
3. $\check{x}$
4. $\tilde{x}$
5. $\acute{x}$
6. $\grave{x}$
7. $\dot{x}$
8. $\ddot{x}$
9. $\breve{x}$
10. $\bar{x}$
11. $\vec{x}$
12. $\mathring{x}$
13. $\underline{x}$
3.2.9 Brackets

For mathematical formulas to look right brackets must be the correct size. \LaTeX{} will determine the correct size bracket if the opening bracket of a pair is preceded by $\left$ and the closing bracket is preceded by $\right$. Curly brackets are written $\{ $ and $\}$. 

Example:

$$
\left[ \sum_{k=0}^n (x_k - \bar{x})^2 \right]^{\frac{1}{2}} \quad \left[ \sum_{k=0}^n (x_k - \bar{x})^2 \right]^{\frac{1}{2}}
$$

3.2.10 Spacing

A number of examples have already used $\quad$ to separate formulas on one line. A $\quad$ is double the space of a $\quad$.

Another use of spacing is to adjust the position of symbols in formulas; sometimes small changes can make a big improvement. These are most often needed with integrals. The spacings available are:

1. $\!$ – negative thinspace
2. $\,$ – thinspace
3. $\:$ – medspace
4. $\;$ – thickspace

Example:

$$\int_a^b f(x) \, dx \quad \int_a^b f(x) \, dx$$

$$\int \!\!\! \int f(x,y) \, dx \, dy \quad \int \!\!\! \int f(x,y) \, dx \, dy$$
3.2.11 Mathematical Symbols

There is a huge array of mathematical symbols available in \LaTeX. See the tables on pages 60–66 of NSSI and the file symbol.ps in the directory for this lecture. You should at least have a glance at these to see what is available.

3.2.12 Including Text

Text can be included in mathematical formulas by using the \text{...} command. This is part of the amsmath package and is preferable to the \mbox of standard \LaTeX.

Example:

\[
\begin{align*}
\epsilon_{\text{mach}} & \approx 2.2 \times 10^{-16} \\
\end{align*}
\]

\[
\begin{align*}
\epsilon_{\text{mach}} & \approx 2.2 \times 10^{-16} \\
\end{align*}
\]

3.3 The amsmath Package

This package makes available a number of features including:

1. A large number of additional mathematical symbols.
2. Easy to use matrix facility.
3. A variety of methods for aligning equations.
4. An easy way of adding new function names.

To access the package include \usepackage{amsmath}

in the preamble.

We will use features of this package in the next lecture.

4 Tables and Arrays

4.1 Tables

4.1.1 Simple Tables

Tables are created with the \texttt{tabular} environment.
Example:

\begin{center}
\begin{tabular}{lcl}
Name & Date & Formula \\
Newton & 1687 & $F = m a$ \\
Einstein & 1905 & $E = m c^2$ \\
\end{tabular}
\end{center}

Name \hspace{1cm} Date \hspace{1cm} Formula
\begin{tabular}{lcl}
Newton & 1687 & $F = ma$ \\
Einstein & 1905 & $E = mc^2$ \\
\end{tabular}

Notes:

1. Tables are usually placed in the centre of the page, hence the \texttt{center} environment.

2. Directly after the \texttt{\begin{tabular}} command, the number and alignment of the columns in the table is specified. The alignments are \texttt{l} – left, \texttt{c} – center, and \texttt{r} – right. In our example \texttt{lcl} specifies three columns with the indicated alignments.

3. Within each line of the table columns are separated by an ampersand, \&, and the line terminated by \texttt{\}.

4.1.2 Adding Lines

1. Vertical lines are indicated by a \texttt{|} between alignment specifiers.

2. Horizontal lines are indicated by the command \texttt{\hline} at the appropriate position.

3. The \texttt{\cline} command can be used to add partial horizontal lines. \texttt{\cline\{i-j\}} draws a line in columns \texttt{i} to \texttt{j}.

Example:

\begin{center}
\begin{tabular}{|l||c|l|}
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \\
\cline{2-3}
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}
4.1.3 Vertical Spacing

Vertical spacing of tables can be altered by using changing \texttt{arraystretch}. In the example below this is altered within the \texttt{center} environment; if it were done outside the environment the change would affect the \textit{whole} document.

Example

\begin{verbatim}
\begin{center}
\renewcommand{\arraystretch}{1.25}
\begin{tabular}{|l||cl|}
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \\
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}
\end{verbatim}

4.1.4 \texttt{multicolumn}

The \texttt{multicolumn} command can be used to spread items across columns of a table.

Example:

\begin{verbatim}
\begin{center}
\renewcommand{\arraystretch}{1.25}
\begin{tabular}{|l||cl|}
\hline
\multicolumn{3}{|c|}{Physics Formulas} \\
\hline
\multicolumn{3}{|c|}{\hspace{1cm}Formula} \\
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \\
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}
\end{verbatim}
<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton</td>
<td>1687</td>
<td>$F = ma$</td>
</tr>
<tr>
<td>Einstein</td>
<td>1905</td>
<td>$E = mc^2$</td>
</tr>
</tbody>
</table>

In this example

\multicolumn{3}{c}{Physics Formulas} \"

indicates that the entry should span 3 columns. A \multicolumn line has its own vertical lines.

Example:

\begin{center}
\renewcommand{\arraystretch}{1.25}
\begin{tabular}{|l||cl|}
\multicolumn{3}{c}{Physics Formulas} \\
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \ \\
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}

\begin{center}
\begin{tabular}{|l||cl|}
\multicolumn{3}{c}{Physics Formulas} \\
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \ \\
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}

4.2 Mathematical Arrays

4.2.1 Arrays

The array environment is used to align mathematical formulas and works in much the same way as the tabular environment.
Example:

$$ \mathbf{A} = \left[ \begin{array}{cccc} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{array} \right] $$

\[
\mathbf{A} = \begin{bmatrix}
  a_{11} & a_{12} & \cdots & a_{1n} \\
  a_{21} & a_{22} & \cdots & a_{2n} \\
  \vdots & \vdots & \ddots & \vdots \\
  a_{m1} & a_{m2} & \cdots & a_{mn}
\end{bmatrix}
\]

$$ y = \begin{cases}
  -1 & \text{for } x < 0 \\
  0 & \text{for } x = 0 \\
  1 & \text{for } x > 0
\end{cases} $$

\[
y = \begin{cases}
  -1 & \text{for } x < 0 \\
  0 & \text{for } x = 0 \\
  1 & \text{for } x > 0
\end{cases}
\]

\[
\text{\LaTeX} \text{ will usually complain if brackets don’t come in pairs, thus the use of } \right. \text{ as an invisible right bracket.}
\]

### 4.2.2 Matrices

The \texttt{amsmath} package provides a convenient way of formatting matrices. There are a number of different environments which enclose matrices in different types of braces:

<table>
<thead>
<tr>
<th>Environment</th>
<th>Braces</th>
</tr>
</thead>
<tbody>
<tr>
<td>matrix</td>
<td>None</td>
</tr>
<tr>
<td>pmatrix</td>
<td>()</td>
</tr>
<tr>
<td>bmatrix</td>
<td>[]</td>
</tr>
<tr>
<td>Bmatrix</td>
<td>{}</td>
</tr>
<tr>
<td>vmatrix</td>
<td></td>
</tr>
<tr>
<td>Vmatrix</td>
<td></td>
</tr>
</tbody>
</table>

As for tables and arrays, the matrix elements are separated by \& and the line terminated by \\. Unlike tables and arrays, matrices do not need alignment specifiers.
Example:

$$ \mathbf{A} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix} $$

$$ \mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{bmatrix} $$

Note the different spacing in this example and the same matrix constructed earlier using brackets and the `array` environment.

4.3 Aligning Equations

Standard \LaTeX{} has a `eqnarray` environment for aligning equations, (see NSSI §3.5), but the `amsmath align` environment is more convenient. The `align` environment produces numbered equations, the examples below use `align*` which leaves equations unnumbered.

Example:

Our first example aligns the = symbols:

```
\begin{align*}
  x &= r \cos \theta \\
  y &= r \sin \theta 
\end{align*}
```

\[ x = r \cos \theta \]
\[ y = r \sin \theta \]
Example:

The following structure is common:

\begin{align*}
I &= \int_{0}^{\pi} \sin t \, dt \\
&= \left[ - \cos t \right]_{0}^{\pi} \\
&= - \cos \pi + \cos 0 \\
&= 2
\end{align*}

Example:

The \texttt{\intertext} command allows text to interspersed with equations while maintaining the alignment.

\begin{align*}
I &= \int_{0}^{\pi} \sin t \, dt \\
\text{\texttt{\intertext} (which is easily integrated)} \\
&= \left[ - \cos t \right]_{0}^{\pi} \\
&= - \cos \pi + \cos 0 \\
&= 2
\end{align*}

which is easily integrated

\begin{align*}
I &= \int_{0}^{\pi} \sin t \, dt \\
&= \left[ - \cos t \right]_{0}^{\pi} \\
&= - \cos \pi + \cos 0 \\
&= 2
\end{align*}
Example:
The \texttt{align} environment can also create multiple aligned columns where the ampersand doubles as an \textit{alignment point} and as a \textit{column separator}. In this example the first and third ampersands on each line are alignment points while the second ampersand on each line is a column separator.

\begin{align*}
\frac{d}{dx} \sin x &= \cos x \\
& \quad \frac{d}{dx} e^x &= e^x \\
& \quad \frac{d}{dx} \cos x &= -\sin x \\
& \quad \frac{d}{dx} \log x &= \frac{1}{x}
\end{align*}

5 Special Topics

5.1 Figures and Tables

5.1.1 Placement

Figures and tables generally cannot be broken up, so \LaTeX{} has a problem whenever it starts a figure or table and reaches the end of a page before that figure or table is finished. In such a case, the figure or table will be held over until the page is finished. You might also actually prefer a figure or table to appear at either the top or bottom of a page. Figures and tables are referred to as \texttt{floats} in \LaTeX{}.

The \texttt{figure} and \texttt{table} environments have an additional placement specifier, which indicates the allowable placements of the float. These are

1. \texttt{h} for \textit{here}
2. \texttt{t} for \textit{top} of a page
3. \texttt{b} for \textit{bottom} of a page
4. \texttt{p} for a special \textit{page} containing only floats
5. \texttt{!} for \textit{try really hard} to follow my placement
A figure could be started, for example, by

\begin{figure}[!ht]
which tells \LaTeX{} to try hard to place the figure here, or if that is not possible at the top of a page.

The placement of floats is a common problem with \LaTeX{}, see NSSI §2.12 for more information on this.

5.1.2 Tables

The table environment is quite distinct from the tabular environment, although the latter is often used within the table environment. For small tables there is usually no problem with placement, but larger tables should always be enclosed in a table environment.

Example:

This example simply takes the table from Lecture 4 and encloses it in a table environment.

\begin{table}[!ht]
\begin{center}
\begin{tabular}{|l||c|l|}
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \\
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}
\end{table}

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton</td>
<td>1687</td>
<td>$F = ma$</td>
</tr>
<tr>
<td>Einstein</td>
<td>1905</td>
<td>$E = mc^2$</td>
</tr>
</tbody>
</table>

5.1.3 Captions

Captions can be added to floats with the \caption command. The caption can be made to appear at either the top or bottom of the float by the placement of the \caption command. Figures and tables are numbered and can be referenced using \label and \ref as explained in §3.1.1.
Example:

\begin{table}[!ht]
\caption{Physics Formulas} \label{tbl:physics}
\begin{center}
\begin{tabular}{|l||cl|}
\hline
Name & Date & Formula \\
\hline
Newton & 1687 & $F = ma$ \\
Einstein & 1905 & $E = mc^2$ \\
\hline
\end{tabular}
\end{center}
\end{table}

Two famous formulas from physics are shown in Table \ref{tbl:physics}.

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton</td>
<td>1687</td>
<td>$F = ma$</td>
</tr>
<tr>
<td>Einstein</td>
<td>1905</td>
<td>$E = mc^2$</td>
</tr>
</tbody>
</table>

5.2 Including Graphics

Figures typically contain graphics from other sources. The most useful format for graphics is eps (encapsulated postscript) which can easily be incorporated into pdf documents. Scilab and most other programs producing graphs can save graphs in this format (as a .eps file).

There are a number of ways of including graphics in \LaTeX, we will use the graphicx package, so you will need to include

\usepackage{graphicx}

in the preamble.

Example:

This example shows how to include an eps file from Scilab called brown.eps:
0 100 200 300 400 500 600 700 800 900 1000
−50 −40 −30 −20 −10 0 10

Figure 1: Brownian Motion

The \includegraphics command has the following optional controls

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>width</td>
<td>scale to specified width</td>
</tr>
<tr>
<td>height</td>
<td>scale to specified height</td>
</tr>
<tr>
<td>angle</td>
<td>rotate counterclockwise</td>
</tr>
<tr>
<td>scale</td>
<td>scale</td>
</tr>
</tbody>
</table>

For .eps files from different sources, you usually need to experiment with these to get things right.

In the example above we used width=0.6\textwidth to scale so that its width is 0.6 times the width of the text on the page. When a graph won’t appear where you want it to it is usually because the graph is too large to fit in the available space. Often scaling can be used to shrink the graph so that it fits into the available space.

5.3 Bibliographies

Bibliographies can be produced using the thebibliography environment. Items in the bibliography begin with the \bibitem command (similar to \item in list environments) followed by a marker which can then be used with the \cite command to refer to the bibliographic item. Bibliographies
are placed at the end of documents (and headed References in the `article`
document class). For large bibliographies it is worth learning about the `bibtex`
package.

The bibliography at the end of these lectures was produced by:

```latex
\begin{thebibliography}{99}
  \bibitem{NSSI} Tobias Oetiker et. al. \textit{The Not So Short Introduction to \LaTeXe{}}.
  \bibitem{AMSM} American Mathematical Society, \textit{User’s Guide for the \texttt{amsmath} Package}.
\end{thebibliography}
```

The \{99\} in this example tells \LaTeX{} that no bibliographic item numbers
will be \textit{no wider} than the number 99.

The following shows how bibliographic items can be cited:

**Example:**

Equations can be aligned using either the \texttt{eqnarray}
environment, see \cite{NSSI} \S3.5, or the \texttt{align}
environment, see \cite{AMSM} \S3.6.

Equations can be aligned using either the \texttt{eqnarray} environment, see [1] \S3.5, or the \texttt{align} environment, see [2] \S3.6.

### 5.4 Macros

**Macros** are used to extend \LaTeX. These include `newcommand` for defining new commands, `newenvironment` for defining new environments. The `amsmath` package has `DeclareMathOperator` for defining new maths operators like `\cos`.

A typical use is when we need to repeat a \LaTeX construction a number of
times. Including such a construction as a macro has the advantages of
(a) often saving typing, and (b) ensuring the construction is done exactly
the same way every time.

It is good practice to collect all macros together, either at the beginning
of the document or in a separate file included with an `\include` command.
See NSSI \S6.1 for more on macros.

**Example:**

Suppose we want to write “Schrödinger equation” many times in a document. We define a new command `\Seqn` do this:

```latex
\newcommand{\Seqn}{\textit{Schr"{o}dinger equation}}
```
Now we can use the `\texttt{\textbackslash Seqn}` command, but we have to be careful to follow it immediately by `{}` to get spacing correct.

The `\texttt{\textbackslash Seqn{}}` is the basis of quantum mechanics.

The Schrödinger equation is the basis of quantum mechanics.

## 5.5 More \LaTeX

In these lectures I have tried to give an outline of the most important and useful features of \LaTeX. All the assignments for this unit will be written using \LaTeX, so here are some tips for learning more about \LaTeX:

1. \LaTeX is best learned through practice, and the more practice the better. Try to use \LaTeX as much as possible, for example try writing assignments for other subjects in \LaTeX.

2. \LaTeX is far too large to learn all at once, it is more important to have a familiarity with general features of \LaTeX, know where to look things up, and to understand the possibilities and limitations of \LaTeX.

3. There are numerous topics in NSSI which we haven’t covered in these lectures. I suggest at least glancing through NSSI to get an idea of what more can be done in \LaTeX, for example indexing, footnotes, theorem environments and so on.

4. There are numerous \LaTeX packages for specialized areas. If, for example, you need to write one or two chemical formulas you can probably do a reasonable job using what we have learned about mathematical formulas. However if you needed to do this as part of your work, then it it would be very worthwhile to find out about packages for chemical formulas, since they will allow you to do the job much better and more quickly.

### References

[1] Tobias Oetiker et. al. *The Not So Short Introduction to \LaTeX 2\epsilon*.