AMTH250

Introduction to LaTeX

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July 18, 2011

Contents

1 Introduction to LaTeX

The reference for these notes is *The Not So Short Introduction to LaTeX 2ε* by Tobias Oetiker and others (see LaTeX Resources on the Moodle). In these notes it will be referred to by the abbreviation NSSI.

1.1 How LaTeX Works

There are two 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 pdflatex to produce a pdf file.

The mechanics of doing all this will be covered in the first assignment. The rest of this section 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.

```
                        This is
            a silly
                      way                    to type
     a                                      sentence.


          Followed     by                        a
new                             paragraph.
```

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:

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

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 understanding 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. `\textrm{...}` roman
2. `\texttt{...}` `typewriter`
3. `\textsl{...}` *slanted*
4. `\textsf{...}` sans serif
5. `\textbf{...}` **bold face**
6. `\textit{...}` *italic*

7. `\textsc{...}` SMALL CAPITALS
8. `\emph{...}` *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}. \\
\emph{Emphasized text} differs from \textit{italic text}
in that \textsf{it can be \emph{combined} with other font
changes.}
```

This *sentence* uses a *number* of different **fonts** *which* MAKES it **hard** to READ. *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 ...}` tiny
2. `{\scriptsize ...}` very small
3. `{\footnotesize ...}` quite small
4. `{\small ...}` small
5. `{\normalsize ...}` normal
6. `{\large ...}` larger
7. `{\Large ...}` larger still
8. `{\LARGE ...}` quite large
9. `{\huge ...}` very large
10. `{\Huge ...}` huge

Example:

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

When combining changes of font **size and type**, remember that the **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 `\indent` and `\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 `\\` or `\newline` force a new line to be started without starting a new paragraph.

2. The command `\newpage` can be used to force a new page to be started.

Example:

```
This is how to start a new line \\
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 `\smallskip`, `\medskip` and `\bigskip` commands.

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 ...
different spacings ...

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 `article` document class. The additional command `\chapter` is available in the `report` and `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

```
\subsubsection*{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[1]

Example:

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

\usepackage{amsmath}
\usepackage{graphicx}
\usepackage{hyperref}
\usepackage{epstopdf}

\title{AMTH250 \hfill \\[6mm]
       Introduction to \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{...}
```

[1] You usually need to run a document through LaTeX twice to get the table of contents correct.

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 `\item` command. List can be nested, that is you can have lists within lists.

Example:

```
\begin{enumerate}
  \item The \texttt{enumerate} environment numbers the
    elements in the list.
  \item The \texttt{itemize} environment precedes each
    item by a large dot as follows:
    \begin{itemize}
      \item This is the first item of an \texttt{itemize}
        environment.
      \item And this is the second.
    \end{itemize}
  \item This is an example of the \texttt{description}
    environment.
    \begin{description}
      \item[First] item in the list.
      \item[Second] item in the list.
    \end{description}
\end{enumerate}
```

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

   First item in the list.

   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 `$` and `$` (most commonly), 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.

Whitespace

There are some important differences between mathematics mode and text:

1. As for text mode, most spaces and line breaks have no significance in mathematics mode.

2. Blank lines are not allowed in mathematics mode.

Example:

```
You can type a formula in a way that is almost most unreadable,
but as long as there are no blank lines it is OK
$$          x       ^
            2  +   y
            ^
                   2=z
    ^                              2 $$
```

You can type a formula in a way that is almost most unreadable, but as long as there are no blank lines it is OK

$$x^2 + y^2 = z^2$$

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 a mechanism for handling this: equations can be labelled with `\label{...}` and then referred to with `\ref{...}`.

Example:

```
Here is a numbered equation
\begin{equation}
  x^2 + y^2 = z^2 .
\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

$$x^2 + y^2 = z^2. \tag{1}$$

When an equation has been labelled

$$\sin^2 \theta + \cos^2 \theta = 1 \tag{2}$$

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[2] The dollar signs around mathematics takes care of this automatically so use `$x$` rather that `\textit{x}`. The `\mathbf` command is used to produce bold maths symbols which are often used for vector and matrices. These are identical to bold roman text letters produced by `\textbf` and are not italicized.

[2]More precisely, variables are printed in italics whereas constants and names of standard functions or operators are printed in romans.

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 $A x = b$ and \textit{A x = b}.
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 A, x and b, but obey different spacing rules as in $Ax = b$ and $A\ x = b$. 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. `\alpha`, `\beta`, `\gamma` ...
2. Uppercase Greek letters are referred to by their name with the first letter capitalized, e.g. `\Gamma`, `\Delta`, `\Lambda` ...
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 Σ 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 `{...}`. However when the exponent or subscript is a single character the braces are not necessary.
4. Exponents and subscripts may be mixed and/or nested.

Example:

```
If you forget the braces you can get unintended results.
For example compare
$$ X_{ab} = y^{12}  \qquad X_ab = y^12 $$
Here are the right and wrong ways to nest exponents and
subscripts.
$$ e^{x^{2}} \qquad {e^{x}}^{2}  $$
$$ P_{a_{0}} \qquad {P_{a}}_{0}  $$
Here are some examples of mixed exponents and subscripts:
$$ A_{ij}^{3} \qquad A^{3}_{ij} \qquad 3^{- P_{0}}
     \qquad P_{x^{3}} $$
```

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

$$X_{ab} = y^{12} \qquad X_ab = y^12$$

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

$$e^{x^2} \qquad e^{x2}$$

$$P_{a_0} \qquad P_{a0}$$

Here are some examples of mixed exponents and subscripts:

$$A_{ij}^3 \qquad A^3_{ij} \qquad 3^{-P_0} \qquad P_{x^3}$$

3.2.4 Fractions and Roots

Example:

```
Fractions are written with the \verb+\frac{...}{...}+
command. Here are some examples:
$$ \frac{n!}{(n-k)! k!} \qquad 2^{\frac{1}{2}}
     \qquad \frac{3^5}{4^5} $$
Sometimes it is preferable to use the slash form, e.g $1/2$,
as it can be easier to read in some contexts.
Compare
$$ x^{\frac{3}{4}} \qquad \text{to} \qquad x^{3/4} $$
and compare $\frac{3}{4}$ hour to $3/4$ hour.
```

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

$$\frac{n!}{(n-k)!k!} \qquad 2^{\frac{1}{2}} \qquad \frac{3^5}{4^5}$$

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

$$x^{\frac{3}{4}} \qquad \text{to} \qquad x^{3/4}$$

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 58 of NSSI.

Example:

```
$$ \lim_{x \rightarrow 0} \frac{\sin x}{x} = 1 $$
but if we forget the backslash we get
$$ \lim_{x \rightarrow 0} \frac{sin x}{x} = 1 $$
```

$$\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1$$

but if we forget the backslash we get

$$\lim_{x \rightarrow 0} \frac{sinx}{x} = 1$$

3.2.6 Integrals, Sums, Products

1. Integrals are generated by `\int`
2. Sums are generated by `\sum`
3. Products are generated by `\prod`
4. Limits of integration etc. are generated by superscripts and subscripts.

Example:

```
$$ \int \sin x dx = - \cos x \qquad
     \int_{0}^{\infty} e^{-x} dx = 1 $$

$$ \sum_{k=1}^n k =  \frac{1}{2} n (n + 1) \qquad
     \prod_{\text{$k$ even}} P_k = 1 $$

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.
```

$$\int \sin x dx = -\cos x \qquad \int_0^\infty e^{-x} dx = 1$$

$$\sum_{k=1}^{n} k = \frac{1}{2} n(n+1) \qquad \prod_{k \text{ even}} P_k = 1$$

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 `\frac`
2. Alternatively, they can be written using the prime symbol `'`.
3. The partial derivative symbol is `\partial`

Example:

```
$$ \frac{d^2 y}{d x^2} + y(x) = 0 \qquad
     y'' + y = 0 \qquad
     \frac{\partial^2 \phi}{\partial x^2} +
     \frac{\partial^2 \phi}{\partial y^2} = 0 $$

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.
```

$$\frac{d^2 y}{dx^2} + y(x) = 0 \qquad y'' + y = 0 \qquad \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$$

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.

3.2.8 Accents

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

1. $\overline{x}$ `$\overline{x}$`
2. $\hat{x}$ `$\hat{x}$`
3. $\check{x}$ `$\check{x}$`
4. $\tilde{x}$ `$\tilde{x}$`
5. $\acute{x}$ `$\acute{x}$`

6. $\grave{x}$ `$\grave{x}$`
7. $\dot{x}$ `$\dot{x}$`
8. $\ddot{x}$ `$\ddot{x}$`
9. $\breve{x}$ `$\breve{x}$`
10. $\bar{x}$ `$\bar{x}$`
11. $\vec{x}$ `$\vec{x}$`
12. $\mathring{x}$ `$\mathring{x}$`
13. $\underline{x}$ `$\underline{x}$`

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:

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

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

3.2.10 Spacing

A number of examples have already used `\qquad` to separate formulas on one line. A `\qquad` 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:

```
$$ \int_a^b f(x) \, dx  \qquad \qquad \int_a^b f(x) dx $$

$$ \int \!\!\!\! \int f(x,y) \, dx \, dy \qquad \qquad
     \int \int f(x,y) dx dy  $$
```

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

$$\iint f(x,y)\,dx\,dy \qquad \int\int f(x,y)dxdy$$

3.2.11 Mathematical Symbols

There is a huge array of mathematical symbols available in LaTeX. See the tables on pages 75–82 of NSSI or `symbols.pdf` in the LaTeX resources. 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:

```
$$ f(x) > 0 \quad \text{for all $x \in X$} $$

$$ \epsilon_{\text{mach}} \approx 2.2 \times 10^{-16} $$
```

$$f(x) > 0 \quad \text{for all } x \in X$$

$$\varepsilon_{\text{mach}} \approx 2.2 \times 10^{-16}$$

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.

4 Tables, Arrays and Alignment

4.1 Tables

4.1.1 Simple Tables

Tables are created with the `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	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

Notes:

1. Tables are usually placed in the centre of the page, hence the `center` environment.
2. Directly after the `\begin{tabular}` command, the number and alignment of the columns in the table is specified. The alignments are `l` – left, `c` – center, and `r` – right. In our example `{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 `\\`.

4.1.2 Adding Lines

1. Vertical lines are indicated by a `|` between alignment specifiers.
2. Horizontal lines are indicated by the command `\hline` at the appropriate position.
3. The `\cline` command can be used to add partial horizontal lines. `\cline{i-j}` draws a line in columns `i` to `j`.

Example:

```
\begin{center}
  \begin{tabular}{|l||cl|}
    \hline
    Name & Date & Formula \\
    \hline
    Newton   & 1687 & $F = m a$ \\
    \cline{2-3}
    Einstein & 1905 & $E = m c^2$ \\
    \hline
  \end{tabular}
\end{center}
```

Name	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

4.1.3 Vertical Spacing

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

Example

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

Name	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

4.1.4 `multicolumn`

The `\multicolumn` command is used to spread items across columns of a table.

Example:

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

Physics Formulas		
Name	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

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 & $F = m a$ \\
    Einstein & 1905 & $E = m c^2$ \\
    \hline
  \end{tabular}
\end{center}
```

Physics Formulas

Name	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

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:

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

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

```
$$ y = \left\{ \begin{array}{rcc}
        -1 & \text{for} & x < 0 \\
         0 & \text{for} & x = 0 \\
         1 & \text{for} & x > 0
      \end{array} \right. $$
```

$$y = \left\{ \begin{array}{rcl}
-1 & \text{for} & x < 0 \\
0 & \text{for} & x = 0 \\
1 & \text{for} & x > 0
\end{array} \right.$$

LaTeX will usually complain if brackets don't come in pairs, thus the use of `\right.` as an invisible right bracket. Another way to produce the output from the example use the "cases" environment from Subsection 4.2.3 below.

4.2.2 Matrices

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

Environment	Braces
`matrix`	None
`pmatrix`	( )
`bmatrix`	[ ]
`Bmatrix`	{ }
`vmatrix`	| |
`Vmatrix`	‖ ‖

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:

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

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

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

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

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

4.2.3 Cases

The following example shows how to use the `cases` environment. Note the use of `\quad` spacing.

Example:

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

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

4.3 Aligning Equations

Standard LaTeX has a `eqnarray` environment for aligning equations, (see NSSI §3.5), but the `align` environment from `amsmath` 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*}
```

$$\begin{aligned} x &= r \cos \theta \\ y &= r \sin \theta \end{aligned}$$

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*}
```

$$
\begin{aligned}
I &= \int_0^{\pi} \sin t \, dt \\
&= [-\cos t]_0^{\pi} \\
&= -\cos \pi + \cos 0 \\
&= 2
\end{aligned}
$$

Example:

The `\intertext` command allows text to interspersed with equations while maintaining the alignment.

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

$$
\begin{aligned}
I &= \int_0^{\pi} \sin t \, dt \\
\intertext{which is easily integrated}
&= [-\cos t]_0^{\pi} \\
&= -\cos \pi + \cos 0 \\
&= 2
\end{aligned}
$$

Example:

The `\align` environment can also create multiple aligned columns where the ampersand doubles as an *alignment point* and as a *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
     & \frac{d}{dx} e^x &= e^x \\
  \frac{d}{dx} \cos x &= - \sin x
     & \frac{d}{dx} \log x &= \frac{1}{x} \\
\end{align*}
```

$$\frac{d}{dx}\sin x = \cos x \qquad \frac{d}{dx}e^x = e^x$$
$$\frac{d}{dx}\cos x = -\sin x \qquad \frac{d}{dx}\log x = \frac{1}{x}$$

Notes:

1. The `align` environment itself starts mathematics mode, and therefore it is not enclosed in `$$` signs.
2. Blank lines are not allowed within the `align` environment.
3. While the `align` and `eqnarray` environments are similar and used for similar purposes, alignment marks, i.e. `&`, are used differently and spacing is slightly different in the two.

5 Some 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 **floats** in LaTeX.

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

1. `h` for *here*
2. `t` for *top* of a page
3. `b` for *bottom* of a page
4. `p` for a special *page* containing only floats
5. `!` for *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 form 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 Section 4 and encloses it in a `table` environment.

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

Name	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

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 & $F = m a$ \\
      Einstein & 1905 & $E = m c^2$ \\
      \hline
    \end{tabular}
  \end{center}
\end{table}

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

Table 1: Physics Formulas

Name	Date	Formula
Newton	1687	$F = ma$
Einstein	1905	$E = mc^2$

Two famous formulas from physics are shown are shown in Table 1.

5.2 Including Graphics

Figures typically contain graphics from other sources. These can come in a variety of formats, for example `pdf`, `jpg` or `png`.

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` (encapsulated postscript) file from Scilab called `brown.eps`. Unlike `pdf`, `jpg` and `png` formats, pdflatex does not handle `eps` files itself, so the you need to include

```
\usepackage{epstopdf}
```

in the preamble.

Now to commands to incorporate `brown.eps` are:

```
\begin{figure}[!ht]
  \begin{center}
    \includegraphics[angle=270, width=0.7\textwidth]{brown.eps}
    \caption{Brownian Motion}
  \end{center}
\end{figure}
```

The `\includegraphics` command has the following optional controls

`width`	scale to specified width
`height`	scale to specified height
`angle`	rotate counterclockwise
`scale`	scale

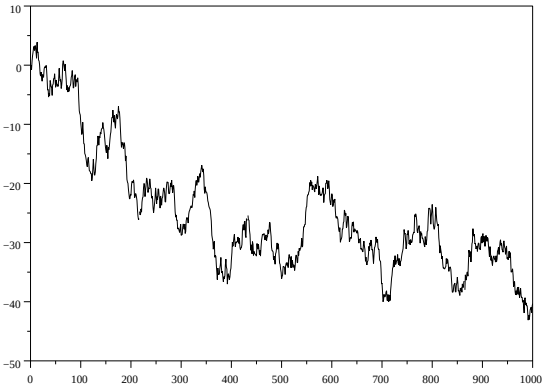

Figure 1: Brownian Motion

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

In the example above we used `angle=270` because Scilab graphs are presented in landscape form and `width=0.7\textwidth` to scale so that its width is 0.7 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 this section was produced by:

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

The `{99}` in this example tells LaTeX that no bibliographic item numbers will be *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 `eqnarray` environment, see [1] §3.5, or the `align` environment, see [2] §3.6.

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 §6.1 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:

```
\newcommand{\Seqn}{Schr\"{o}dinger equation}
```

Now we can use the `\Seqn` command, but we have to be careful to follow it immediately by `{}` to get spacing correct.

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

The Schrödinger equation is the basis of quantum mechanics.

5.5 More LaTeX

In these notes 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 many topics in NSSI which we haven't covered in these notes. 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 2ε*.

[2] American Mathematical Society, *User's Guide for the* `amsmath` *Package*.