AN INTRODUCTION TO LaTeX

A crash course in writing up formal mathematics

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INTRODUCTION

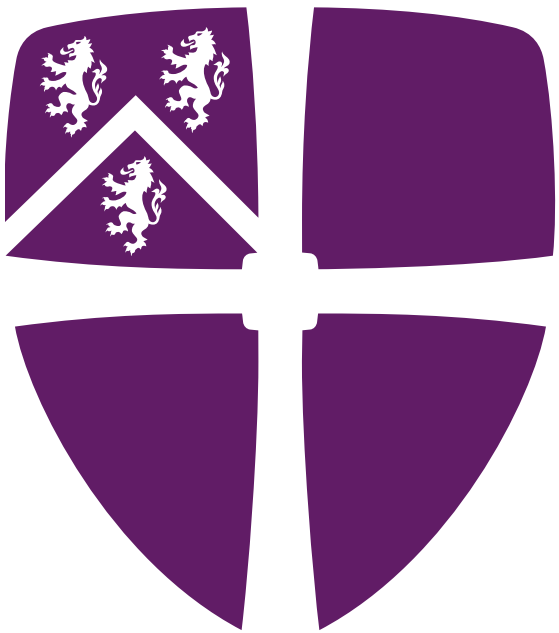
Introduction

LaTeX is:

- pronounced “laytek” not “layteks”
- a system for the writing and high-quality typesetting of documents — but particularly useful for mathematics
- **NOT:** “What You See Is What You Get” (like Word)
- **BUT:** “You Asked For It, You Got It” (like a programming language)
- is like a compiler for typesetting programs, transforming a text input file to a PDF output file - you write commands to describe what the text is, not how it looks
- something that will longer to get used to (compared to e.g. Word).... but it is far more powerful and reliable once you master it.

Getting LaTeX

CIS computers



LaTeX is accessible via TeXnic Center on NPCS machines at: **All Programs > Miscellaneous > MikTeX 2.9 > TeXnic Center**

Getting LaTeX

Windows

Best LaTeX bundle is MiKTeX:
http://miktex.org/
Graphical front-ends:

- TeXnicCenter:
  http://www.texniccenter.org/
- Winshell:
  http://www.winshell.org/
- TeXworks:
  http://tug.org/texworks/

Getting LaTeX

Apple

Best LaTeX bundle is MacTeX:
http://www.tug.org/mactex/
Graphical front-ends:

- texmaker:
  http://www.xm1math.net/texmaker/
- TeXShop:
  http://pages.uoregon.edu/koch/texshop/
- TeXworks:
  http://tug.org/texworks/

Getting LaTeX

Linux

If not already installed (it usually is) install the “tetex” or “texlive” distributions.
Graphical front-ends:

- Kile (KDE): `http://kile.sourceforge.net/`
- Emacs with AUCTeX
- TeXworks: `http://tug.org/texworks/`
- Texmaker: `http://www.xm1math.net/texmaker/`

LaTeX BASICS

How does it work?

- You write your document in a **plain text** file with commands that describe its structure and meaning.
- The LaTeX program processes your text and commands to produce a 'beautifully formatted' document.
- Typically we use the `pdflatex` compiler to produce a PDF document.

```
\textit{Hamlet}: To be, or not to
be, that is the question
```

hamlet.tex

pdflatex hamlet.tex

Hamlet: To be, or not to be, that is the question

hamlet.pdf

LaTeX Commands

- LaTeX typesetting is made by using special tags or commands that provide a variety of ways to format, structure or modify your document
- Most of the LaTeX commands are simple words preceded by a backslash '\' and have the following general syntax

```
\command-name[options]{argument}
```

- Some examples (more later):
  - **No arguments**: greek letters: α `\alpha`, Γ `\Gamma`
  - **One argument**: *italic text* `\textit{italic text}`
  - **One argument and options**: the document class `\documentclass[a4paper]{article}`

LaTeX Environments

- Environments are used to format or structure bigger blocks of text in a LaTeX documents.
- Environments are used by an opening tag `\begin` and a closing `\end` tag, e.g.

```
\begin{center}
This text will be centre aligned.
\end{center}
```

- Everything inside those tags will be formatted in a manner depending on the name of the environment.
- Environments are used for formatting or grouping together larger blocks of text, or for special types of content such as lists or tables.

Our first document

- We write our document in a plain text file with a `.tex` extension, e.g. `example1.tex`
- All LaTeX documents must follow the same basic structure:

```
\documentclass{article}
% Preamble: List any packages we want to use.
% Top matter : Title, author, etc.
\begin{document}
Hello world!
\end{document}
```

- Note: A percent sign `%` starts a comment — LaTeX will ignore the rest of the line after this character.

Hello world!

Our first document II

- The first line is always a `documentclass` command which declares the type of document.
- Valid document classes include: `article`, `book`, `report`, `beamer` (for presentations).
- The `documentclass` command can take options to adjust the general layout of the document:
  - Papersize: `a4paper`
  - Font size: `10pt, 11pt, 12pt, 14pt`
  - Misc: `draft`, `landscape`, `oneside`, `twoside`
- The actual written content of our document then goes in the `document` environment
- The document contents can be any combination of plain text, commands, and environments.

Errors

- Like a programming language, LaTeX can (and probably will) generate errors when it is trying to compile your document. If it does, you need to debug and fix it before it will produce any output.
- Common errors
  - Opening braces `{` not being matched with a closing `}`, (ditto `[`, `]`, `$`)
  - Mis-spelled command names, e.g. `\documentclas{article}`
  - Mis-spelled or mis-matched environment names in the `begin` and `end` tags.
  - Opening an environment and forgetting to close it with the `end` tag.
  - Un-escaped special characters (e.g. `\`, `%`, `$`)

Advice on Dealing with Errors

- Compile your document regularly to ensure you only have to check a small amount of code at one time.
- Fix errors as soon as they arise — if what you just typed caused an error, you can start your debugging there.
- One initial problem may cause dozens of errors; sometimes fixing one thing will sort all the problems.
- If you can't find the error, then comment out all the text you've just written and re-compile it. Then uncomment the text one line at a time, compiling at each step until you find the problem.

TYPESETTING TEXT

Text basics

- Type your text between `\begin{document}` and `\end{document}`.
- For the most part, you can just type your text normally.

```
Words are separated by one or
more spaces.

Paragraphs are separated by
one or more blank lines.

Double backslash \\ breaks a
line.
```

Words are separated by one or more spaces.
Paragraphs are separated by one or more blank lines.
Double backslash
breaks a line.

- Space in the source file is collapsed in the output.

```
To  be,   or  not to  be,
that   is the   question.
```

To be, or not to be that is the question.

Special Characters

- Quotation marks should be written using a backtick ` on the left and a regular apostrophe ' on the right

```
`Single quotes'
``Double quotes''
```

‘Single quotes’
“Double quotes”

- Several characters have special meanings in LaTeX and cannot be used in regular text: `# $ % & ~ _ ^ { } \`
- To use these symbols in text, you have to escape it by preceding it with a backslash, i.e. `\%` produces % (and not a comment)
- Since `\\` is defined to be a line break we must use `\backslash` for \.
- Dashes come in three sizes -, –, — from `-`, `--`, `---`.

Bold, italics, and underline

```
Some of the \textbf{greatest}
discoveries in
\underline{science} were made
by \textbf{\textit{accident}}.
```

Some of the **greatest** discoveries in <u>science</u> were made by ***accident***.

- `textbf` makes text bold
- `textit` italicises text
- `underline` underlines text
- Note: `emph` can also be used to italicise text, but sometimes its behaviour changes when you include other packages

Different fonts

- LaTeX has its own pre-defined collection of fonts and it can be quite difficult to change them
- Fortunately, there are commands that lets you format the argument using different font families if needed:

```
\texttt{monospaced text}

\textrm{Roman serif text}

\textsf{sans-serif text}
```

monospaced text

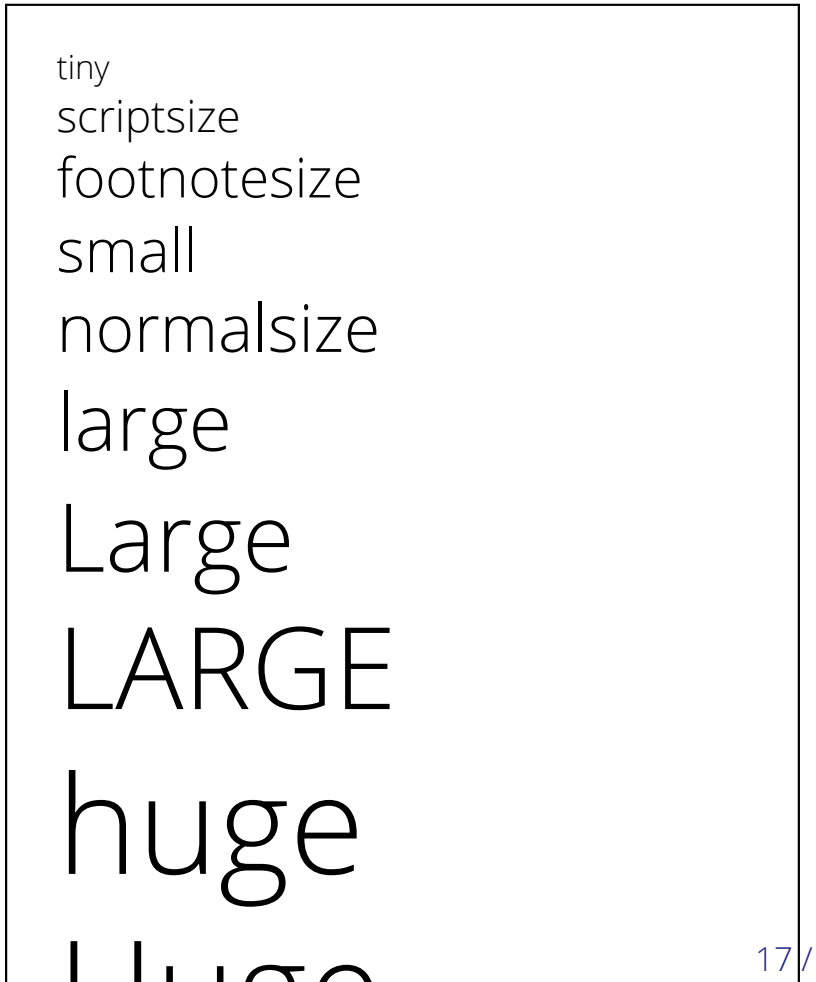
Roman serif text

sans-serif text

Different font sizes

- Similarly, LaTeX doesn't let you have full control over font sizes but there are commands to vary the size of fonts (but you should question whether you really need to do so).

```
\tiny{tiny}\\
\scriptsize{scriptsize}\\
\footnotesize{footnotesize}\\
\small{small}\\
\normalsize{normalsize}\\
\large{large}\\
\Large{Large}\\
\LARGE{LARGE}\\
\huge{huge}\\
\Huge{Huge}\\
```



DOCUMENT STRUCTURE

Adding a title

```
\documentclass[a4paper]{article}
\title{Alice's Adventures in Wonderland}
\author{Lewis Carroll}
\date{1865}
\begin{document}
\maketitle
\end{document}
```

Alice's Adventures in Wonderland

Lewis Carroll

1865

Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do: once or twice she had peeped into the book her sister was reading, but it had no pictures or conversations in it, 'and what is the use of a book,' thought Alice 'without pictures or conversation?'

So she was considering in her own mind (as well as she could, for the hot day made her feel very sleepy and stupid), whether the pleasure of making a daisy-chain would be worth the trouble of getting up and picking the daisies,

Chapters and Sections

- We organise typically organise a document into numbered sections and subsections.
- Longer documents should use the `book` or `report` document classes and also use chapters.

```
\chapter{The first chapter} % Only useable in books and
reports
\section{The first section}
\subsection{A subsection}
\subsection{Another subsection}
\section{The second section}
```

Chapter 1

The first chapter

1.1 The first section

1.1.1 A subsection

1.1.2 Another subsection

1.2 The second section

Table of Contents

- If you've structured your document into sections and/or chapters, then creating a table of contents for your document is straightforward with the command `\tableofcontents`:
- NB: You need to run LaTeX *twice* to get the table to show correctly.

```
\documentclass{book}
\title{Harry Potter and the Philosopher's Stone}
\author{J. K. Rowling}
\date{1997}

\begin{document}
\maketitle
\tableofcontents
\chapter{The Boy Who Lived}
\chapter{The Vanishing Glass}
\chapter{The Letters from No One}
\chapter{The Keeper of the Keys}
\chapter{Diagon Alley}
% etc
\end{document}
```

Harry Potter and the Philosopher's Stone

J. K. Rowling

1997

Contents

1 The Boy Who Lived **2**

2 The Vanishing Glass **3**

3 The Letters from No One **4**

4 The Keeper of the Keys **5**

5 Diagon Alley **6**

Unordered lists

Unordered (bullet point) lists are produced by the `itemize` environment. Each entry in the list is started by the control sequence `\item`.

```
\begin{itemize}
  \item The individual entries
 are indicated with a black
dot, a so-called bullet.
  \item The text in the
entries may be of any length.
\end{itemize}
```

- The individual entries are indicated with a black dot, a so-called bullet.
- The text in the entries may be of any length.

Ordered lists

Ordered (numbered) lists have the same syntax inside a different environment, this time we use `enumerate`:

```
\begin{enumerate}
  \item The labels consists of
 sequential numbers.
  \item The numbers starts at
1 with every call to the
enumerate environment.
\end{enumerate}
```

1. The labels consists of sequential numbers.
2. The numbers starts at 1 with every call to the enumerate environment.

TYPESETTING MATHEMATICS

Mathematical expressions

- We use dollar signs $ to mark maths in text

```
% not so good:
Let a and b be distinct
positive integers, and let c =
 a - b + 1.
% much better:
Let $a$ and $b$ be distinct
positive integers, and let $c
= a - b + 1$.
```

Let a and b be distinct positive integers, and let c = a - b + 1.

Let a and b be distinct positive integers, and let $c = a - b + 1$.

- Dollar signs must be used in pairs — one to begin the mathematics, and one to end it.
- Again, LaTeX handles spacing automatically; it ignores your spaces.

```
Let $y=mx+b$ be \ldots

Let $y = m x +   b$ be \ldots
```

Let $y = mx + b$ be ...
Let $y = mx + b$ be ...

Equations

- Bigger and scarier pieces of maths should be displayed it on their own line
- Either as an `equation` with an equation number:

```
The mass-energy equivalence is
 described by the famous
equation
\begin{equation}
E=mc^2
\end{equation}
discovered in 1905 by Albert
Einstein.
```

The mass-energy equivalence is described by the famous equation

$$E = mc^2 \tag{1}$$

discovered in 1905 by Albert Einstein.

- ...or unnumbered between `\[ \]` if its less interesting:

```
The area of a circle, $A$, is
given by
\[
A = \pi r^2
\]
```

The area of a circle, A, is given by

$$A = \pi r^2$$

Subscripts and superscripts

- Use the caret symbol ^ for superscripts and underscore _ for subscripts.

```
$y = c_2 x^2 + c_1 x + c_0$
```

$$y = c_2 x^2 + c_1 x + c_0$$

- Sub/superscripts longer than one character need to be enclosed in curly braces { } to group them correctly.

```
% oops!
$F_n = F_n-1 + F_n-2$
% better!
$F_n = F_{n-1} + F_{n-2}$
```

$$F_n = F_n - 1 + F_n - 2$$
$$F_n = F_{n-1} + F_{n-2}$$

Brackets and parentheses

- There are a variety of brackets, bracers, and delimiters usable in maths mode:

```
$( a ), [ b ], \{ c \}, | d |,
\| e \|, \langle f \rangle,
$\\
$\lfloor g \rfloor, \lceil h \
rceil,
\ulcorner i \urcorner$
```

$(a), [b], \{c\}, |d|, \|e\|, \langle f \rangle,$
$\lfloor g \rfloor, \lceil h \rceil, \ulcorner i \urcorner$

- Brackets can be resized dynamically to fit whatever is between them by using `\left` and `\right` (useful for vectors and matrices):

```
% ugly!
$(\frac{1}{2})$
\\[0.5em]
% better!
$\left( \frac{1}{2} \right)$
```

$(\frac{1}{2})$

$\left(\frac{1}{2}\right)$

Interlude: Packages

- Packages provide extensions to basic LaTeX, such as new commands and environments, e.g. the **graphics** package is needed to include images in your document.
- The amsmath package provides lots of handful of options for writing mathematics.
- To use the amsmath package, we simply add the following line to the preamble of the document (after the documentclass but before the \begin{document})

```
\usepackage{amsmath}
```

- You will need the **amsmath** package for much of what follows

Mathematical symbols

- There are a HUGE number of commands for inserting mathematical symbols into your document
- Greek letters: `\alpha` α, `\beta` β, `\gamma` γ, `\delta` δ, `\Gamma` Γ, `\Delta` Δ, ...
- Arrows: `\rightarrow` $\rightarrow$, `\Rightarrow` $\Rightarrow$, `\Leftrightarrow` $\Leftrightarrow$, `\mapsto` $\mapsto$
- Misc symbols: `\infty` ∞, `\forall` $\forall$, `\exists` $\exists$, `\nabla` ∇, `\partial` ∂, `\emptyset` $\emptyset$
- Operators and relations: `\times` $\times$, `\div` $\div$, `\cap` $\cap$, `\cup` $\cup$, `\neq` $\neq$, `\geq` $\geq$, `\leq` $\leq$, `\in` $\in$, `\perp` $\perp$, `\approx` $\approx$, `\equiv` $\equiv$
- See the references at the end for a list of symbols.

Multi-line equations

Long equations can be broken apart using the `multline` environment by inserting a double backslash to set the point to be broken:

```
\begin{multline*}
(x+y)^3 = x^3 + 3x^2y \\+ 3xy
^2 + y^3
\end{multline*}
```

$$(x+y)^3 = x^3 + 3x^2y \\ + 3xy^2 + y^3$$

NB: The asterisk `*` following `multiline` is used to suppress equation numbers. You can do the same with `equation` and `align`.

```
\begin{multline*}
(x+y)^3 = x^3 + 3x^2y \\+ 3xy
^2 + y^3
\end{multline*}
```

$$(x+y)^3 = x^3 + 3x^2y \\ + 3xy^2 + y^3 \quad (2)$$

Multi-line equations II

- We can align a sequence of equations at the equals sign (or anywhere really) using `align`:

```
\begin{align*}
(x+1)^3 &= (x+1)(x+1)(x+1) \\
        &= (x+1)(x^2+2x+1) \\
        &= x^3 + 3x^2 + 3x + 1
\end{align*}
```

$$
\begin{aligned}
(x+1)^3 &= (x+1)(x+1)(x+1) \\
&= (x+1)(x^2+2x+1) \\
&= x^3 + 3x^2 + 3x + 1
\end{aligned}
$$

- The ampersand `&` separates the left column (before the =) from the right column (after the =).
- We use double backslash `\\` to start a new line of equations.

Fractions and binomials

```
Fractions can be used
alongside the text, for
example $\frac{1}{2}$, and in
a mathematical
display style like the one
below:

\[\frac{1}{2}\]

The binomial coefficient is
defined by the next expression
:

\[
    \binom{n}{k} = \frac{n!}{k
!(n-k)!}
\]
```

Fractions can be used alongside the text, for example $\frac{1}{2}$, and in a mathematical display style like the one below:

$$\frac{1}{2}$$

The binomial coefficient is defined by the next expression:

$$\binom{n}{k} = \frac{n!}{k!\,(n-k)!}$$

Common functions

- We get square (and nth) roots using `\sqrt`:

```
$\sqrt{\frac{a}{b}}$\\
$\sqrt[n]{1+x+x^2+x^3+\ldots}$
```

$$\sqrt{\frac{a}{b}}$$
$$\sqrt[n]{1+x+x^2+x^3+\ldots}$$

- Common functions like log, sin, and exp all have their own predictably-named commands:

```
$\cos(2\theta) = \cos^2\theta
- \sin^2\theta$\\

$\lim_{x \to \infty} \exp(-x)
= 0$
```

$$\cos(2\theta) = \cos^2\theta - \sin^2\theta$$
$$\lim_{x\to\infty} \exp(-x) = 0$$

Integrals, sums and limits

```
% A simple integral
$$\int_{a}^{b} x^2 dx$$
% A multiple integral
$$\iint_V \mu(u,v) \,du\,dv$$
% Sum
$$\sum_{n=1}^{\infty} 2^{-n} =
 1$$
% Product
$$\prod_{i=a}^{b} f(i)$$
% Limit
$$\lim_{x\to\infty} f(x)$$
```

$$\int_a^b x^2 dx$$

$$\iint_V \mu(u,v)\,du\,dv$$

$$\sum_{n=1}^{\infty} 2^{-n} = 1$$

$$\prod_{i=a}^{b} f(i)$$

$$\lim_{x\to\infty} f(x)$$

Matrices and vectors

- There isn't a specific matrix/vector command, instead we must use the more general `array` environment which we then enclose between brackets
- Like `align`ing equations, we use `&` to align the columns of the matrix and `\\` to start a new row.
- NB: The `{c c c}` argument indicates we want 3 columns, each centre aligned.

```
$
\left[
  \begin{array}{c c c}
     1 & 2 & 3\\
     4 & 5 & 6\\
     7 & 8 & 9\\
  \end{array}
 \right]
 $
```

$$\left[\begin{array}{c c c} 1 & 2 & 3\\ 4 & 5 & 6\\ 7 & 8 & 9\\ \end{array}\right]$$

Theorems and proofs

- `amsmath` provides the `theorem` and `proof` environments for inserting theorems and proofs into your document.
- You can customise it to similar entities such as lemmas, propositions, corollaries; to number your theorems; etc.

```
\begin{theorem}
Let $f$ be a function whose
derivative exists in every
point, then $f$
is a continuous function.
\end{theorem}
\begin{proof}
Here is my important proof
\end{proof}
```

Theorem
Let f be a function whose derivative exists in every point, then f is a continuous function.

Proof.
Here is my important proof □

Mathematical fonts

Sometime we need particular font typefaces to denote special quantities, e.g. $\mathbb{R}$

```
Normal maths font:\\
$NRQZ$ \\
Calligraphic or `curly' font
:\\
$\mathcal{NRQZ}$ \\
Blackboard bold font:
$\mathbb{NRQZ}$\\
Fraktur font:\\
$\mathfrak{NRQZ}$ \\
```

Normal maths font:
$NRQZ$
Calligraphic or ‘curly’ font:
$\mathcal{NRQZ}$
Blackboard bold font:
$\mathbb{NRQZ}$
Fraktur font:
$\mathfrak{NRQZ}$

SUMMARY AND FURTHER READING

In summary

- LaTeX is a great tool for producing documents including good-quality and well-presented mathematics
- Getting started can be tricky, so find a good user interface and try a few exercises
- There are a huge number of commands you might need – keep the cheat sheet close by!
- We've barely scratched the surface!
- LaTeX 'drop-in' sessions 15th and 16th June, 2-4pm, in CG93

  Please come along if you want to practice some of what you've seen today, try some exercises, or to have any LaTeX problems or questions

Extra stuff

- Figures and tables using `figure` and `table` environments
- Cross-references using `\label` and `\ref`
- Referencing sources using `\cite` and BibTeX to produce a bibliography
- Using the `tikz` package for making graphics inside Latex
- Using `beamer` to produce slides for presentations
- Using the `listings` package to format code fragments

Online references:

- *The Not So Short Introduction to LaTeX 2ε* – an excellent PDF reference for doing most things in LaTeX
  https://tobi.oetiker.ch/lshort/lshort.pdf
- *ITS Guide 190: Introduction to LaTeX using TeXnic Center* – using LaTeX on university machines
  https://www.dur.ac.uk/resources/its/info/guides/190latex.pdf
- *Wikibooks LaTeX/Mathematics article* – http://en.wikibooks.org/wiki/LaTeX/Mathematics – good guide to maths in LaTeX
- *Getting to Grips with LaTeX* – helpful online web guide for most LaTeX features
  http://www.andy-roberts.net/writing/latex
- *The LaTeX Cheat Sheet* – summarises most of the useful bits of LaTeX in 2 sides of A4
  http://maths.dur.ac.uk/Ug/projects/resources/latex/latexsheet-a4.pdf
- *The Great Big List of LaTeX symbols*
  http://www.rpi.edu/dept/arc/training/latex/LaTeX_symbols.pdf