# LaTeX Workshop

QUT Maths Society

April 14, 2022

## Contents

# List of Figures



# List of Tables

# 1 Introduction

"LaTeX is a high-quality typesetting system; it includes features designed for the production of technical and scientific documentation. LaTeX is the de facto standard for the communication and publication of scientific documents. LaTeX is available as free software". [1]

One of the key differences between LaTeX and more common word processors such as MS Word, LibreOffice etc., is the separation of content and presentation. In LaTeX, the author describes the general structure of the document (i.e., section headings, paragraphs, equations, and figures), and the layout and typesetting is handled by LaTeX (or rather the underlying TeX backend).

There are several advantages to this:

- The author can focus on the actual content without worrying about layout and presentation
- The presentation can be modified without introducing major changes to the document
- LaTeX's standard format allows authors to easily conform to styles provided by external publishers

LaTeX is written in plaintext and processed by an external program to generate output files (usually PDFs).

## 1.1 Pronunciation and Spelling

LaTeX is pronounced *lah-tech* or *lay-tech*, but TeX is never pronounced *tecks*. It is typeset using the `\LaTeX{}` macro or with the capitalisation "LaTeX".

## 1.2 Language Structures

There are two major language structures that we encounter when using LaTeX; *macros* and *environments*.

### 1.2.1 Macros

Macros (or commands) tell LaTeX how to do things. They use the following syntax

```
\commandname
% or
\commandname[optional args]{required args}
```

Macros provide functionality for layouts, symbols, styles, etc. As shown below, common font styles can be invoked using macros.

**Bold face** `\textbf{Text}` — **Text**

**Italics** `\textit{Text}` — *Text*

**Emphasis** `\emph{Text}` — *Text* (either upright or italics depending on surrounding text)

**Underline** `\underline{Text}` — Text

We can also define custom macros that combine other macros or simplify repetitive instructions.

```
\newcommand{\commandname}[number_of_arguments]{command_body}
```

Arguments can be referenced inside the command body with the `#argument_number` syntax. For example

```
\newcommand{\boldanditalics}[1]{\textbf{\textit{#1}}}
\boldanditalics{Bold and italics text}
```

***Bold and italics text***

### 1.2.2 Environments

Environments are used to format large blocks of text which often contain many lines or multiple macros. Environments use opening `\begin` and closing `\end` tags so that everything inside those tags will be formatted in a special manner depending on the type of the environment.

```
\begin{environment_name}[optional_arguments]{required_arguments}
    ...
\end{environment_name}
```

Common environments include `figure`, `equation`, `itemize` (these will be discussed later), etc.

# 2 Basic Structure

## 2.1 Sections

Sections are used to divide the document into parts. A new section is started with the `\section {section_name}` macro. Section titles are formatted to be bold and larger than regular text. The number preceding the titles are automatically determined.

The table of contents (`\tableofcontents`) is also generated from these section macros, so that page numbers and section numbers are set automatically.

## 2.2 Subsections

We can split sections into smaller subsections `\subsection{Subsections}`,

### 2.2.1 Subsubsections

and also subsubsections `\subsubsection{Subsubsections}`.

## Unnumbered sections

We can remove section numbering by using the starred version of the section macro e.g. `\subsection*{Unnumbered sections}`.

As this also removes the section from the table of contents, we can manually add it using

```
\addcontentsline{toc}{subsection}{Unumbered sections}
```

remembering to place this immediately after the section macro so that the reference is set to the correct location.

## 2.3 Lists

Unordered (bullet) lists are produced by the `itemize` environment, where each list entry starts by using the `\item` command, which also generates the bullet symbol.

```
\begin{itemize}
    \item List entries ...
    \item We can ...
          \begin{itemize}
              \item We can ...
                    \begin{itemize}
                        \item The marker ...
                              \begin{itemize}
                                  \item List markers, ...
                              \end{itemize}
                    \end{itemize}
          \end{itemize}
\end{itemize}
```

- List entries start with the `\item` macro and are indicated by the black dot
- We can create multiple entries
  - We can nest lists by creating another `itemize` environment
    - The marker changes in each nested list to reflect the depth

- List markers, spacing, and other behaviour can be customised with the `enumitem` package

Numbered (ordered) lists use the same syntax as unordered lists but use the `enumerate` environment.

```
\begin{enumerate}
    \item List entries ...
    \item Nested lists ...
          \begin{enumerate}
              \item But use ...
                    \begin{enumerate}
                        \item Such as ...
                    \end{enumerate}
          \end{enumerate}
\end{enumerate}
```

1. List entries are numbered automatically
2. Nested lists are also numbered
   (a) But use a different number format
      i. Such as lowercase letters and roman numerals

We can change the top-level number format by specifying a value to the `label` parameter.

```
\begin{enumerate}[label=label_specifier]
    \item ...
\end{enumerate}
```

The following label specifiers can be used to override the default numbering format:

1. — `[label=\arabic*.]` (Default)

<I> — `[label=<\Roman*>]`

i — `[label=\roman*]`

(a) — `[label=(\alph*)]`

Part A: — `[label=Part \Alph*:]`

# 3 Mathematics

One of LaTeX's strengths is how it formats mathematical expressions. There are two ways to format mathematical expressions; inline using `\( \)` and display style using `\[ \]`.

Mathematical expressions can be contained "inline" (within) text and require less space:

```
Let \(\mathbb{N}\) denote the set of all natural numbers.
```

Let $\mathbb{N}$ denote the set of all natural numbers.

Mathematical expressions typeset outside paragraph text appear as standalone, display style math:

```
\[
    \lim_{\Delta{t} \to \infty} \frac{f\left( t + \Delta{t} \right) - f\left( t \right)}{\Delta{t}}
\]
```

$$\lim_{\Delta t \to \infty} \frac{f\left(t + \Delta t\right) - f\left(t\right)}{\Delta t}$$

Note that we commonly use `\equation` environments for automatic vertical spacing and equation numbering (as with section headings).

```
\begin{equation}
    a^2 + b^2 = c^2
\end{equation}
```

$$a^2 + b^2 = c^2 \tag{1}$$

We can use the starred version of this environment to remove the equation label.

```
\begin{equation*}
    a^2 + b^2 = c^2
\end{equation*}
```

$$a^2 + b^2 = c^2$$

## 3.1 Paired Delimiters

| Name | LaTeX Command | Inline | Display Style |
|---|---|---|---|
| Parentheses | `\left( a \right)` | $\left(a\right)$ | $\left(a\right)$ |
| Brackets | `\left[ a \right]` | $\left[a\right]$ | $\left[a\right]$ |
| Braces | `\left\{ a \right\}` | $\left\{a\right\}$ | $\left\{a\right\}$ |
| Angle brackets | `\left\langle a \right\rangle` | $\left\langle a\right\rangle$ | $\left\langle a\right\rangle$ |
| Pipes | `\left\lvert a \right\lvert` | $\left\lvert a\right\rvert$ | $\left\lvert a\right\rvert$ |
| Double Pipes | `\left\lVert a \right\lVert` | $\left\lVert a\right\rVert$ | $\left\lVert a\right\rVert$ |
| Ceiling | `\left\lceil a \right\rceil` | $\left\lceil a\right\rceil$ | $\left\lceil a\right\rceil$ |
| Floor | `\left\lfloor a \right\rfloor` | $\left\lfloor a\right\rfloor$ | $\left\lfloor a\right\rfloor$ |

Table 1: Paired Delimiters in LaTeX.

Note that we can declare custom paired delimiters for the final five examples using the following syntax:

```
\DeclarePairedDelimiter{\paired_delimiter_name}{left_delimiter}{right
   _delimiter}
```

Here are a few suggestions

```
\DeclarePairedDelimiter{\ceil}{\lceil}{\rceil}
\DeclarePairedDelimiter{\floor}{\lfloor}{\rfloor}
\DeclarePairedDelimiter{\abracket}{\langle}{\rangle}
\DeclarePairedDelimiter{\abs}{\lvert}{\rvert}
\DeclarePairedDelimiter{\norm}{\lVert}{\rVert}
```

### 3.2 Arithmetic Operators

| Name | LaTeX Command | Inline | Display Style |
|---|---|---|---|
| Addition | `a + b` | $a + b$ | $a + b$ |
| Subtraction | `a - b` | $a - b$ | $a - b$ |
| Multiplication | `a \cdot \left( b \times c \right)` | $a \cdot \left( b \times c \right)$ | $a \cdot \left( b \times c \right)$ |
| Inequalities | `a \ll b < c \leq d` | $a \ll b < c \leq d$ | $a \ll b < c \leq d$ |
| Fractions | `\frac{a}{b}` | $\frac{a}{b}$ | $\frac{a}{b}$ |
| Superscripts | `a^2` | $a^2$ | $a^2$ |
| Subscripts | `a_i` | $a_i$ | $a_i$ |
| Square root | `\sqrt{a}` | $\sqrt{a}$ | $\sqrt{a}$ |

Table 2: Arithmetic operators in LaTeX.

### 3.3 Common Large Operators

| Name | LaTeX Command | Inline | Display Style |
|---|---|---|---|
| Summations | `\sum_{i=1}^n i` | $\sum_{i=1}^{n} i$ | $\sum_{i=1}^{n} i$ |
| Limits | `\lim_{x \to 0} \frac{\sin{x}}{x}` | $\lim_{x \to 0} \frac{\sin x}{x}$ | $\lim_{x \to 0} \frac{\sin x}{x}$ |
| Derivatives | `\odv{f}{x} \pdv{}{t} \odif{\Omega}` | $\frac{\mathrm{d}f}{\mathrm{d}x} \frac{\partial}{\partial t} \mathrm{d}\Omega$ | $\frac{\mathrm{d}f}{\mathrm{d}x} \frac{\partial}{\partial t} \mathrm{d}\Omega$ |
| Integrals | `\int_0^\infty e^{-x^2} \odif{x}` | $\int_0^\infty e^{-x^2} \mathrm{d}x$ | $\int_0^\infty e^{-x^2} \mathrm{d}x$ |
| Union | `\bigcup_{i=1}^n S_i` | $\bigcup_{i=1}^{n} S_i$ | $\bigcup_{i=1}^{n} S_i$ |

Table 3: Common large operators in LaTeX.

## 3.4 Common Mathematical Functions

| Name | LaTeX Command | Inline | Display Style |
|---|---|---|---|
| Sine | `\sin{\left( x \right)}` | $\sin\left(x\right)$ | $\sin\left(x\right)$ |
| Inverse Sine | `\arcsin{\left( x \right)}` | $\arcsin\left(x\right)$ | $\arcsin\left(x\right)$ |
| Logarithm | `\log{\left( x \right)}` | $\log\left(x\right)$ | $\log\left(x\right)$ |
| Natural Logarithm | `\ln{\left( x \right)}` | $\ln\left(x\right)$ | $\ln\left(x\right)$ |
| Exponential | `\exp{\left( x \right)}` | $\exp\left(x\right)$ | $\exp\left(x\right)$ |

Table 4: Common large operators in LaTeX.

## 3.5 Multi-line Equations

As `equation` only allows single line equations, we can use other environments to group multiple equations into one environment.

### 3.5.1 Gather

The `gather` environment allows us to display a set of consecutive equations with multiple lines. New lines are separated using `\\`.

```
\begin{gather}
    \sum_{i = 0}^n f\left( i \right) =
        f\left( 0 \right) + f\left( 1 \right)
        + \cdots + f\left( n \right) \\
    \prod_{i = 0}^n f\left( i \right) =
        f\left( 0 \right) \times f\left( 1 \right)
        \times \cdots \times f\left( n \right)
\end{gather}
```

$$\sum_{i=0}^{n} f\left(i\right) = f\left(0\right) + f\left(1\right) + \cdots + f\left(n\right) \tag{2}$$

$$\prod_{i=0}^{n} f\left(i\right) = f\left(0\right) \times f\left(1\right) \times \cdots \times f\left(n\right) \tag{3}$$

### 3.5.2 Align

The `align` environment allows us to display consecutive equations that are also aligned. The alignment is determined by the placement of the `&` character. This alignment character breaks the equation into "columns" that are either right or left aligned, following the pattern: `rlrlrl`....

```
\begin{align}
%    R &   L   & R & L & R & L &   R   & L
     R & = L & R & = & = & L & R = & L
\end{align}
```

$$R = L \qquad R = \qquad =L \qquad R =L \tag{4}$$

This can be illustrated using a table.

| Right | Left | Right | Left | Right | Left | Right | Left |
|---|---|---|---|---|---|---|---|
| $R\&= L$ | & | $R\&=$ | & | $=\&L$ | & | $R =\&L$ | |

With this in mind, we can create aligned equations as shown below.

$$ax^2 + bx + c = 0 \tag{5}$$

$$a\left(x^2 + \frac{b}{a}x + \frac{c}{a}\right) = 0 \tag{6}$$

$$x^2 + \frac{b}{a}x + \left(\frac{b}{2a}\right)^2 + \frac{c}{a} = \left(\frac{b}{2a}\right)^2 \tag{7}$$

$$\left(x + \frac{b}{2a}\right)^2 = \frac{b^2}{4a^2} - \frac{c}{a} \tag{8}$$

$$x + \frac{b}{2a} = \frac{\pm\sqrt{b^2 - 4ac}}{2a} \tag{9}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{10}$$

$$\begin{aligned}
\mathbf{v}_1 &= \mathbf{w}_1 & \mathbf{q}_1 &= \frac{\mathbf{v}_1}{\|\mathbf{v}_1\|} \\
\mathbf{v}_2 &= \mathbf{w}_2 - \operatorname{proj}_{\mathbf{q}_1}(\mathbf{w}_2) & \mathbf{q}_2 &= \frac{\mathbf{v}_2}{\|\mathbf{v}_2\|} \\
\mathbf{v}_3 &= \mathbf{w}_3 - \operatorname{proj}_{\mathbf{q}_1}(\mathbf{w}_3) - \operatorname{proj}_{\mathbf{q}_2}(\mathbf{w}_3) & \mathbf{q}_3 &= \frac{\mathbf{v}_3}{\|\mathbf{v}_3\|} \\
&\vdots & &\vdots \\
\mathbf{v}_i &= \mathbf{w}_i - \sum_{j=1}^{i-1} \operatorname{proj}_{\mathbf{q}_j}(\mathbf{w}_i) & \mathbf{q}_i &= \frac{\mathbf{v}_i}{\|\mathbf{v}_i\|}
\end{aligned}$$

If we want to write normal text in math mode, we need to use the `\text` macro.

```
\begin{align*}
    \text{Text in text mode} \\
    Text in math mode
\end{align*}
```

$$\text{Text in text mode}$$
$$Textinmathmode$$

Notice that spaces are ignored in math mode.

### 3.6 Horizontal Spacing

If we want to add horizontal space we can use the following macros:

```
\begin{align*}
    A & \!      B \\
    A &         B \\
    A & \,      B \\
    A & \:      B \\
    A & \;      B \\
    A & \       B \\
    A & \quad   B \\
    A & \qquad B
\end{align*}
```

$$
\begin{aligned}
AB \\
AB \\
A\,B \\
A\,B \\
A\:B \\
A\;B \\
A\quad B \\
A\qquad B
\end{aligned}
$$

### 3.7 Additional Symbols

LaTeX provides lots of symbols that can be installed from the Comprehensive TeX Archive Network that are used in math mode, including the greek alphabet (shown below). A short (but extensive) list can be found at The Great, Big List of LaTeX Symbols.

$$\alpha\beta\gamma\delta\epsilon\varepsilon\zeta\eta\theta\vartheta\iota\kappa\lambda\mu\nu\xi\pi\varpi\rho\varrho\sigma\varsigma\tau\upsilon\phi\varphi\chi\psi\omega$$

$$\Gamma\Delta\Theta\Lambda\Xi\Pi\Sigma\Upsilon\Phi\Psi\Omega$$

Bringing all of these together can give pretty equations like:

$$\Gamma\left(z\right) = \frac{e^{-\gamma z}}{z}\prod_{k=1}^{\infty}\left(1+\frac{z}{k}\right)^{-1}e^{\frac{z}{k}}.$$

$$\mathbf{G}_{\mu\nu} + \mathbf{\Lambda}\mathbf{g}_{\mu\nu} = \kappa\mathbf{T}_{\mu\nu}$$

$$\mathrm{Hg}^{2+} \xrightarrow{\mathrm{I}^-} \mathrm{HgI}_2 \xrightarrow{\mathrm{I}^-} [\mathrm{Hg}^{\mathrm{II}}\mathrm{I}_4]^{2-}$$

$$i\hbar\frac{\partial}{\partial t}\Psi\left(x,\,t\right) = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi\left(x,\,t\right) + V\left(x,\,t\right)\Psi\left(x,\,t\right)$$

# 4 Figures, Tables, and Code

LaTeX allows us to use figures and tables which can be added raw or by using floats. We generally use floats to allow LaTeX to algorithmically place figures on a page, and move to the next page if it encounters a vertical overflow.

The float environment for figures is `figure` and `table` for tables. Floats are containers for objects that cannot be displayed over multiple pages. They should always have a descriptive caption (`\caption`) so that the reader does not have to rely on the text, and also so that we can reference them using hyperlinks.

If we wish to give the object we want to reference a marker, we can use the `label` macro.

```
\caption{This is a caption for the figure. The figure numbering is automatic.}\label{fig:cat}
```

see the source code for the cat figure for this implementation.

Note that labels or reference markers should always be placed immediately after the object we want to reference. This ensures that we maintian correct page references.

We can reference figures using the following syntax:

```
Figure~\ref{fig:cat} shows a cat, and Figure~\ref{fig:turtle} shows a turtle.
```

Figure 1 shows a cat, and Figure 3b shows a turtle.

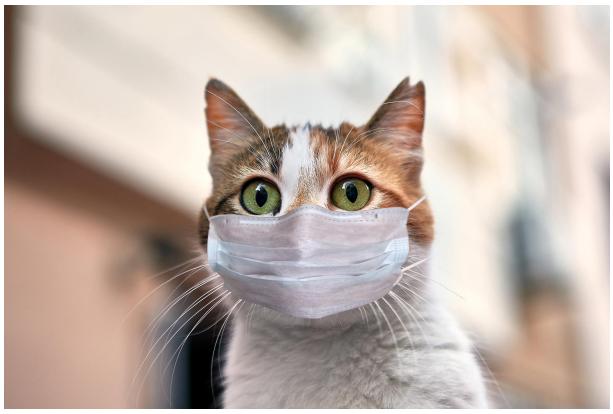

Figure 1: This is a caption for the figure. The figure numbering is automatic.

Figure 2: Providing a second dimension may skew the image.

(a) The first subfigure.

(b) The second subfigure.

Figure 3: A caption for both subfigures.

Table 5: An example of a table. Captions are placed above tables.

| | Column 1 | Column 2 |
|---|---|---|
| Row 1 | 7 | 2 |
| Row 2 | 8 | 9 |
| Row 3 | 2 | 0 |
| Row 4 | 4 | 1 |

Lists of figures and tables can be printed similarly to a table of contents with `\listoffigures` and `\listoftables`

Source code can also be included with the `listing` environment. In addition to the environment, code can also be included with the `\lstinline` macro (this is what I have been doing for all the macros in this document)

Figure 4: An example listing

```
#include <iostream>

int main() {
    std::cout << "Hello World!" << std::endl;
    return 0;
}
```

### 4.1 References & Labels

Throughout this document you may have noticed that everything is numbered (e.g. equations, sections, figures, tables). It is incredibly easy to refer to these things with the label and reference system in LaTeX. Everything that is numbered (and some things that are not) can have a label attached with the `\label{labelname}` macro. The number can then be later referred to with the `\ref{labelname}` macro. This means that if you go back and add a figure, all your reference to later figures will be automatically updated to reflect the new figure names.

Even better, when the `hyperref` package is included (by `\usepackage{hyperref}` in the preamble), all of these references are turned into hyperlinks to the item. This means that you can click on a reference and go straight to the related equation, figure, or table. This package also turns all the entries in the table of contents and table of figures into a link, to allow for easy navigation of the document

If you want to reference the page that a label is on, you can do that with the `\pageref{labelname}` macro. Below are some examples of references.

- Reference to a figure – Figure 1

Table 6: Placement specifiers for floats. Multiple of these can be specified

| Spec. | Location |
|---|---|
| h | Place *approximately* here |
| t | Place at top of page |
| b | Place at bottom of page |
| p | Place on page for only floats |
| ! | Override internal placement parameters (force placement) |

- Reference to a subfigure – Figure 3b
- Reference to table – Table 6
- Reference to a section (with pageref) – Section **??** on page **??**

### 4.2 LaTeX (usually) knows better than you

A mistake many people new to LaTeX make is trying to force images to go in particular places. This is often very hard and not necessary. LaTeX is very good at placing floats in places that look good, and do not break the flow or layout of the document too much.

There are several placement specifiers that we can provide to the float commands in order to give LaTeX hints on where we want the float to go. These go right after begin float macro. e.g. `\begin{figure}[placement specifier] ... \end{figure}`. Table 6 shows all of the available placement specifiers.

## 5 Citations

There are many ways to manage bibliographies, citations, and reference lists in LaTeX, and many of them are outdated or have been superseded by newer alternatives. The method that I use is with a combination of BibLaTeX and Biber. BibLaTeX is the frontend in LaTeX that handles citations and printing the bibliography. Biber is the backend which manages the database of all the references. The `biblatex` package needs to be included with `\usepackage[style=ieee]{biblatex}` in the preamble. The IEEE style can be replaced with others, such as APA. This changes both the citation and bibliography style.

References are stored in a database file with a `.bib` extension. An example database file for the sources used in this document is shown below. Each entry in the database file refers to an source, with the necessary fields filled. In the preamble, the database file needs to be added with `\addbibresource{references.bibF}`.

These sources can be cited with `\cite{referencename}` (no parentheses) or `\parencite{referencename}` (with parentheses). For example [2] [3]

At the end of the document, the bibliography can be printed with `\printbibliography`. It will only print sources that are actually cited in the document.

## 6 Other Use Cases

### 6.1 In-Place Diagrams

In cases where it may be convenient/elegant to draw simple plots/diagrams with LaTeX itself, the `tikz` packages provides support for this. In addition, the plots shown in Figures **??** and **??** also require the `pgfplots` package.

### 6.2 Circuit Diagrams

It may be useful at some point to be able to construct circuit diagrams in LaTeX, and so the `circuitikz` package can be used in order to implement this functionality. Shown below in Figure **??** is an example of a circuit diagram one might construct.

### 6.3 Matrices/Vectors

It may also be convenient at some point to be able to express matrices and vectors in MATLAB. These have their own environments which come from the `amsmath` package, and can be used to produce the following:

$$\begin{bmatrix} x_1'(t) \\ x_2'(t) \\ x_3'(t) \\ x_4'(t) \end{bmatrix} = \begin{bmatrix} -0.1 & 0.05 & 0 & 0 \\ 0.05 & -0.2 & 0.05 & 0.05 \\ 0.05 & 0.05 & -0.2 & 0.05 \\ 0 & 0 & 0.05 & -0.1 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \\ x_4(t) \end{bmatrix} + \begin{bmatrix} 500 \\ 250 \\ 100 \\ 10 \end{bmatrix}$$

# 7 Other Resources

- The LaTeX Wikibook – Good reference documentation and guides – `https://en.wikibooks.org/wiki/LaTeX`
- The TeX Stack Exchange – Answers to most of your questions – `https://tex.stackexchange.com/`
- Comprehensive TeX Archive Network (CTAN) – Package database – `https://ctan.org/`

## References


[1] L. Project. "LaTeX - a document preparation system." (2018), [Online]. Available: `https://www.latex-project.org/` (visited on 03/19/2018).

[2] C. Columbus, *How I Discovered America*. Barcelona: Hispanic Press, 1492.

[3] T. P. Phillips, "Possible influence of the magnetosphere on American history," *J. Oddball Res.*, vol. 98, pp. 1000–1003, 1999.