

# L<sup>A</sup>T<sub>E</sub>X Workshop

QUT Maths Society

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# 1 Introduction

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

One of the key differences between  $\text{\LaTeX}$  and more common word processors such as MS Word, LibreOffice etc., is the separation of content and presentation. In  $\text{\LaTeX}$ , 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  $\text{\LaTeX}$  (or rather the underlying  $\text{\TeX}$  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
- $\text{\LaTeX}$ ’s standard format allows authors to easily conform to styles provided by external publishers

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

## 1.1 Pronunciation and Spelling

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

## 1.2 Language Structures

There are two major language structures that we encounter when using  $\text{\LaTeX}$ ; *macros* and *environments*.

### 1.2.1 Macros

Macros (or commands) tell  $\text{\LaTeX}$  how to do things. They use the following syntax

---

```
1 \commandname
2 % or
3 \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.

---

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

---

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

---

```
1 \newcommand{\boldanditalics}[1]{\textbf{\textit{#1}}}  
2 \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.

---

```
1 \begin{environment_name}[optional_arguments]{required_arguments}  
2     ...  
3 \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

---

```
1 \addcontentsline{toc}{subsection}{Unnumbered 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` macro, which also generates the bullet symbol.

---

```
1 \begin{itemize}
2   \item List entries ...
3   \item We can ...
4     \begin{itemize}
5       \item We can ...
6         \begin{itemize}
7           \item The marker ...
8             \begin{itemize}
9               \item List markers, ...
10              \end{itemize}
11            \end{itemize}
12          \end{itemize}
13 \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.

---

```

1 \begin{enumerate}
2   \item List entries ...
3   \item Nested lists ...
4     \begin{enumerate}
5       \item But use ...
6         \begin{enumerate}
7           \item Such as ...
8         \end{enumerate}
9     \end{enumerate}
10 \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.

---

```

1 \begin{enumerate}[label=label_specifier]
2   \item ...
3 \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  $\text{\LaTeX}$ 's strengths is how it formats mathematical expressions. There are two ways to format mathematical expressions; inline using  $\text{\textbackslash}(\text{ \textbackslash})$  and display style using  $\text{\textbackslash}[\text{ \textbackslash}]$ .

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

---

```
1 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:

---

```
1 \[
2   \lim_{\Delta t \rightarrow \infty} \frac{f(t + \Delta t) - f(t)}{\Delta t}
3 \]
```

---

$$\lim_{\Delta t \rightarrow \infty} \frac{f(t + \Delta t) - f(t)}{\Delta t}$$

Note that we commonly use  $\text{\textbackslash}equation$  environments for automatic vertical spacing and equation numbering (as with section headings).

---

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

---

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

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

---

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

---

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

#### 3.1 Paired Delimiters

Name	$\text{\LaTeX}$ Command	Inline	Display Style
Parentheses	$\text{\textbackslash}left( a \text{\textbackslash}right)$	$(a)$	$(a)$
Brackets	$\text{\textbackslash}left[ a \text{\textbackslash}right]$	$[a]$	$[a]$
Braces	$\text{\textbackslash}left\{ a \text{\textbackslash}right\}$	$\{a\}$	$\{a\}$
Angle brackets	$\text{\textbackslash}left\langle a \text{\textbackslash}right\rangle$	$\langle a \rangle$	$\langle a \rangle$
Pipes	$\text{\textbackslash}left  a \text{\textbackslash}right $	$ a $	$ a $
Double Pipes	$\text{\textbackslash}left  a \text{\textbackslash}right $	$\ a\ $	$\ a\ $
Ceiling	$\text{\textbackslash}left\lceil a \text{\textbackslash}right\rceil$	$\lceil a \rceil$	$\lceil a \rceil$
Floor	$\text{\textbackslash}left\lfloor a \text{\textbackslash}right\rfloor$	$\lfloor a \rfloor$	$\lfloor a \rfloor$

Table 1: Paired Delimiters in  $\text{\LaTeX}$ .

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

---

```

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

```

---

Here are a few suggestions

---

```

1 \DeclarePairedDelimiter{\ceil}{\lceil}{\rceil}
2 \DeclarePairedDelimiter{\floor}{\lfloor}{\rfloor}
3 \DeclarePairedDelimiter{\abracet}{\langle}{\rangle}
4 \DeclarePairedDelimiter{\abs}{\lvert}{\rvert}
5 \DeclarePairedDelimiter{\norm}{\lVert}{\rVert}

```

---

### 3.2 Arithmetic Operators

Name	L <sup>A</sup> T <sub>E</sub> X Command	Inline	Display Style
Addition	$a + b$	$a + b$	$a + b$
Subtraction	$a - b$	$a - b$	$a - b$
Multiplication	$a \cdot b$	$a \cdot (b \times c)$	$a \cdot (b \times c)$
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 L<sup>A</sup>T<sub>E</sub>X.

### 3.3 Common Large Operators

Name	L <sup>A</sup> T <sub>E</sub> X Command	Inline	Display Style
Summations	$\sum_{i=1}^n i$	$\sum_{i=1}^n i$	$\sum_{i=1}^n i$
Limits	$\lim_{x \rightarrow 0} \frac{\sin x}{x}$	$\lim_{x \rightarrow 0} \frac{\sin x}{x}$	$\lim_{x \rightarrow 0} \frac{\sin x}{x}$
Derivatives	$\frac{df}{dx} \frac{\partial}{\partial t} F d\Omega$	$\frac{df}{dx} \frac{\partial}{\partial t} F d\Omega$	$\frac{df}{dx} \frac{\partial}{\partial t} F d\Omega$
Integrals	$\int_0^\infty e^{-x^2} dx$	$\int_0^\infty e^{-x^2} dx$	$\int_0^\infty e^{-x^2} dx$
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 L<sup>A</sup>T<sub>E</sub>X.



### 3.4 Common Mathematical Functions

Name	L <sup>A</sup> T <sub>E</sub> X Command	Inline	Display Style
Sine	<code>\sin{\left( x \right)}</code>	$\sin(x)$	$\sin(x)$
Inverse Sine	<code>\arcsin{\left( x \right)}</code>	$\arcsin(x)$	$\arcsin(x)$
Logarithm	<code>\log{\left( x \right)}</code>	$\log(x)$	$\log(x)$
Natural Logarithm	<code>\ln{\left( x \right)}</code>	$\ln(x)$	$\ln(x)$
Exponential	<code>\exp{\left( x \right)}</code>	$\exp(x)$	$\exp(x)$

Table 4: Common large operators in L<sup>A</sup>T<sub>E</sub>X.

### 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 `\\`.

---

```

1 \begin{gather}
2   \sum_{i = 0}^n f\left( i \right) =
3     f\left( 0 \right) + f\left( 1 \right)
4     + \cdots + f\left( n \right) \\
5   \prod_{i = 0}^n f\left( i \right) =
6     f\left( 0 \right) \times f\left( 1 \right)
7     \times \cdots \times f\left( n \right)
8 \end{gather}

```

---

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

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

### 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: `r l r l r l...`

---

```

1 \begin{align}
2 %   R & L & R & L & R & L & R & L
3   R & = L & R & = & = & L & R & = & L
4 \end{align}

```

---

$$R = L \qquad R = \qquad = L \qquad R = L \qquad (4)$$

This can be illustrated using a table.

Right		Left		Right		Left		Right		Left
$R&= L$		$&$		$R&=$		$&$		$=&L$		$&$
										$R =&L$

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

$$ax^2 + bx + c = 0 \qquad (5)$$

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

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

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

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

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

$\mathbf{v}_1 = \mathbf{w}_1$	$\mathbf{q}_1 = \frac{\mathbf{v}_1}{\ \mathbf{v}_1\ }$
$\mathbf{v}_2 = \mathbf{w}_2 - \text{proj}_{\mathbf{q}_1}(\mathbf{w}_2)$	$\mathbf{q}_2 = \frac{\mathbf{v}_2}{\ \mathbf{v}_2\ }$
$\mathbf{v}_3 = \mathbf{w}_3 - \text{proj}_{\mathbf{q}_1}(\mathbf{w}_3) - \text{proj}_{\mathbf{q}_2}(\mathbf{w}_3)$	$\mathbf{q}_3 = \frac{\mathbf{v}_3}{\ \mathbf{v}_3\ }$
$\vdots$	$\vdots$
$\mathbf{v}_i = \mathbf{w}_i - \sum_{j=1}^{i-1} \text{proj}_{\mathbf{q}_j}(\mathbf{w}_i)$	$\mathbf{q}_i = \frac{\mathbf{v}_i}{\ \mathbf{v}_i\ }$

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

---

```

1 \begin{align*}
2   \text{Text in text mode} \\
3   Text in math mode
4 \end{align*}

```

---

Text in text mode  
*Text in math mode*

Notice that spaces are ignored in math mode.

### 3.6 Additional Environments & Symbols

The `amsmath` package also allows us to use many matrix environments using:

- `matrix` for a matrix without any enclosing symbols
- `pmatrix` for parentheses
- `bmatrix` for brackets
- `Bmatrix` for braces
- `vmatrix` for vertical bars
- `Vmatrix` for double vertical bars

$$\begin{matrix} a & b \\ c & d \end{matrix} \quad \begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad \begin{bmatrix} a & b \\ c & d \end{bmatrix} \quad \left\{ \begin{matrix} a & b \\ c & d \end{matrix} \right\} \quad \left| \begin{matrix} a & b \\ c & d \end{matrix} \right| \quad \left\| \begin{matrix} a & b \\ c & d \end{matrix} \right\|$$

$\LaTeX$  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](#).

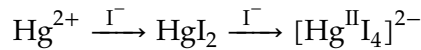
$$\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi\pi\varpi\rho\sigma\tau\upsilon\phi\chi\psi\omega$$

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

Bringing all of these together can give pretty equations like:

$$\Gamma(z) = \int_0^\infty t^{z-1} e^{-t} dt = \frac{e^{-\gamma z}}{z} \prod_{k=1}^\infty \left(1 + \frac{z}{k}\right)^{-1} e^{\frac{z}{k}}$$

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



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

## 4 Figures, Tables, and Code

### 4.1 Figures and Tables

$\text{\LaTeX}$  allows us to use figures and tables which can be added raw or by using floats. We generally use floats to allow  $\text{\LaTeX}$  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 contents, and also so that we can reference them using hyperlinks.



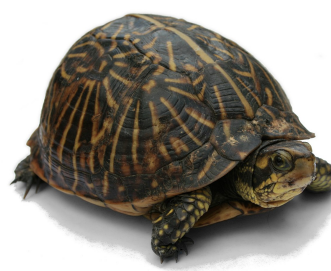
Figure 1: This is a caption for the figure. The figure numbering is automatic.



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

Note that we also use the `\centering` macro to horizontally center the figures and tables, and this macro can also be used in subfigures.

## 4.2 List of figures and tables

A list of figures and tables can be printed with `\listoffigures` and `\listoftables`. These are similar to the table of contents.

## 4.3 Code

Source code can be displayed using the `\lstlisting` environment and in addition to the environment, code can also be displayed inline with the `\lstinline` macro (this is how code has been formatted throughout this document).

Figure 4: An example listing.

---

```

1 #include <iostream>
2
3 int main() {
4     std::cout << "Hello World!" << std::endl;
5     return 0;
6 }
```

---

Example inline code:

---

```

1 Here is text formatted as code \lstinline{System.Double}.
```

---

Here is text formatted as code `System.Double`.

If the inline code contains braces (`{ }`), we need to delineate the argument using another symbol.

---

```

1 Example containing braces \lstinline|set = { 1, 2, 3 }|.
```

---

Example containing braces `set = { 1, 2, 3 }`.

The example illustrates how we must delineate the arguments with the same symbol, in this case, pipes (`|`), but we cannot use comment delimiters (`%`). For example, `\lstinline%code%` will not compile.

## 4.4 References & Labels

Throughout this document you may have noticed that everything is numbered (e.g. equations, sections, figures, tables, etc.).

It is incredibly easy to reference figures, equations, sections, or any element on a page with  $\LaTeX$ . Anything that is numbered (and some things that are not) can be marked using the `\label` macro. This marker can then be referenced anywhere in the document (even before it is defined) with the `\ref` macro, and its page number can be obtained with the `\pageref` macro.

Below are some examples of references.

---

```
1 Cat figure: Figure~\ref{fig:cat}
2 Turtle subfigure: Figure~\ref{fig:turtle}
3 Example table: Table~\ref{tab:table_example}
4 Schrödinger's equation: Equation~\ref{eq:schrodingers_equation}
5 Figures \& Tables subsection: Section~\ref{sec:figures_and_tables} on
   Page~\pageref{sec:figures_and_tables}
```

---

- Cat figure: Figure 1
- Turtle subfigure: Figure 3b
- Example table: Table 5
- Schrödinger's equation: Equation 3.6
- Figures & Tables subsection: Section 4.1 on Page 10

If we were to add an additional label,  $\LaTeX$  will automatically renumber all existing references the next time we compile the document. We can see this in action when we add a new numbered equation or section.

We recommend using the `hyperref` package to convert references into hyperlinks for easy navigation on a PDF viewer. This package also allows us to add custom text for references such as:

---

```
1 See the \LaTeX{} Project \href{https://www.latex-project.org/}{here}.
2 View \hyperref[eq:schrodingers_equation]{Schrödinger's Equation}.
```

---

See the  $\LaTeX$  Project [here](https://www.latex-project.org/).

View Schrödinger's Equation.

## 5 Diagrams

If we wish to generate simple plots of functions, or complex diagrams, we can do so with  $\text{\LaTeX}$  itself. The `tikz` library provides a multitude of packages for various kinds of diagrams.

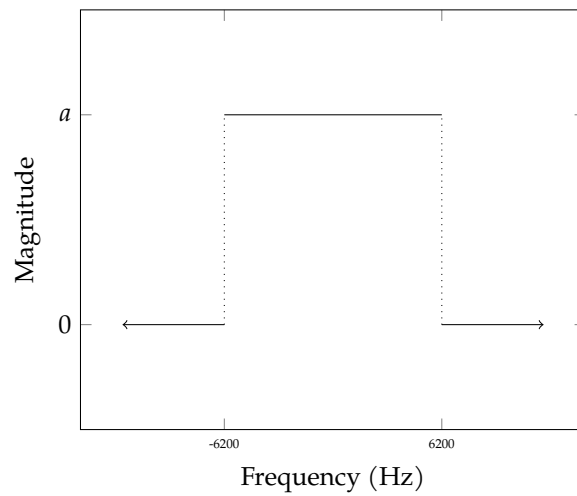


Figure 5: Band pass filter.

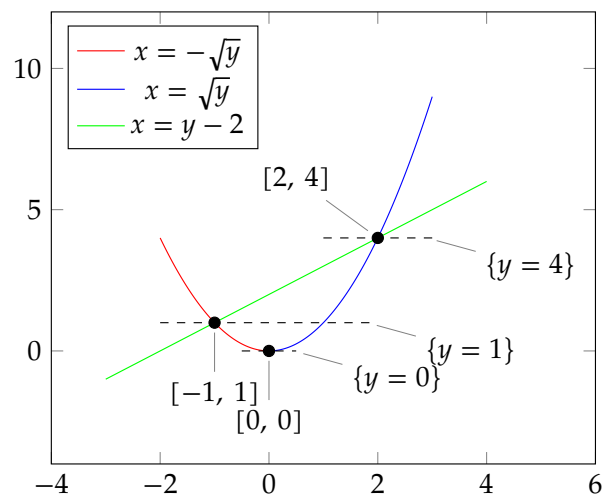


Figure 6: Graph of three functions.

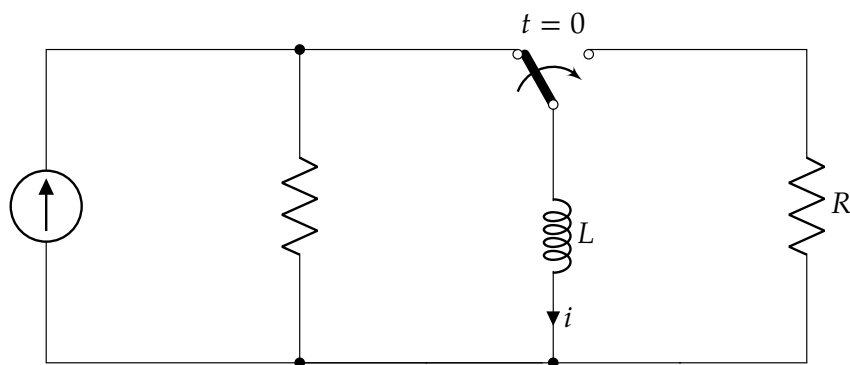


Figure 7: RL circuit.

## 6 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.bib}`.

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.



## 7 Miscellaneous

### 7.1 Horizontal Spacing

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

---

```
1 \begin{align*}
2   A & \& \! B \& \& \\
3   A & \& B \& \& \\
4   A & \& \, B \& \& \\
5   A & \& \: B \& \& \\
6   A & \& \; B \& \& \\
7   A & \& \quad B \& \& \\
8   A & \& \qquad B \\
9 \end{align*}
```

---

$AB$   
 $AB$   
 $A\,B$   
 $A\,B$   
 $A\,B$   
 $A\,B$   
 $A\quad B$   
 $A\qquad B$

### 7.2 Managing Large Documents

If we want to organise large L<sup>A</sup>T<sub>E</sub>X project files, we can split our source code into the preamble, body and even sections, using the `\input` macro.

The following example requires the file: `src\extras.tex`. If we place the following code in the document (right after this text), then we should see an additional section appear.

---

```
1 \input{src/extras.tex}
```

---

### 7.3 Extra Section

Congrats you found the extra section! Here's a bonus equation:

$$\psi^{(m)}(z) = \frac{d^{m+1}}{dz^{m+1}} \ln(\Gamma(z)) = (-1)^{m+1} \int_0^\infty \frac{t^m e^{-zt}}{1 - e^{-t}} dt \quad (11)$$

---

The **red** horizontal rules have been placed for clarity. The content inside those rules was taken from another file.

We can even reference the labels from an external file:

---

```
1 Reference to marker in another file: Equation~\ref{eq:bonus}.
```

---

Reference to marker in another file: Equation 11.

## 8 Other Resources

- Wikibooks — Reference documentation and guides
- Overleaf — Reference documentation and guides
- The T<sub>E</sub>X Stack Exchange — Q&A site for both L<sup>A</sup>T<sub>E</sub>X and typesetting issues
- The Comprehensive T<sub>E</sub>X Archive Network (CTAN) — Package database

## 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.