How to Become a LaTeXpert

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Chapter 1

A Very Brief Introduction

This guide serves as an introduction to LaTeX. I have tried to make it concise and easy to follow. I am open to criticism (hopefully constructive).

Contact me via prabhavkumar10@gmail.com or LinkedIn.

Updates to this guide can be found on GitHub.

Chapter 2

LaTeX 101

2.1 TeX

Throughout history, mathematical symbols and equations were written on materials such as clay and paper. With the advent of technology, humans needed a way to write math on computers, so TeX (pronounced "Tech") was created. It is a computer program created by Donald E. Knuth and short for τέχνη, Greek for both "art" and "craft".

2.2 LaTeX

LaTeX (pronounced "Lah-Tech") is built on top of TeX and is much more user-friendly. It is created by Leslie Lamport. It is useful to think of TeX as a low-level language and LaTeX as a higher-level language.

2.2.1 The Light-Bulb Analogy

Understanding the difference between TeX and LaTeX can be quite tricky, so a simple light-bulb analogy can be used to explain the difference:

TeX and LaTeX can be thought of an electrical circuit and a switch, respectively. Both provide a similar function (lighting up a bulb), but it is much more convenient for the user to deal with the switch than the circuit.

2.2.2 Not a Word Processor

LaTeX is **not** a word processor. When using Microsoft Word, the final document automatically updates while typing on a .docx file. However, with LaTeX, the final document, which is usually a separate PDF file, only updates after typing and typesetting or compiling a .tex file.

2.3 Installing LaTeX

There are several ways to install LaTeX, but this is what I did:

1. Download MikTeX (a TeX distribution) .
2. Download Texmaker (a cross-platform LaTeX editor).
3. Watch this video for a guided walkthrough.

Chapter 3

Creating your First LaTeX Document

3.1 Before you Start: Typesetting & Troubleshooting

To compile a LaTeX file, the user must typeset it on Texmaker using the "Quick Build" button (other editors have a "Typeset" or "Compile" button). If a PDF file is outputted, the compilation was successful. If not, then do the following:

1. Click on the "abort" button.
2. Read the console output - it will include the line number and the command that caused the error.
3. Fix the error.
4. Typeset the file again.

As an example, after opening a new document, type the following code:

```
\documentclass[10pt]{article}

\begin{document}
Hello World!
\end{document}
```

Hello World!

As shown, the output should be Hello Word!.

3.2 \documentclass

\documentclass is the command that must appear at the start of a LaTeX document. The document class is specified within { }. Frequently used classes include:

- \article - for shorter documents (notes).
- \beamer - for presentation slides.
- \book - self-explanatory.
- \proc - for conference proceedings.
- \report - for longer documents (PhD thesis).

Document class options are specified within [ ]. Frequently used options include:

- $x$pt - main font size (default is 10pt).
- a4paper, a5paper, letterpaper, legalpaper - paper size.

3.3 The Preamble & The Body

Anything before \begin{document} is called the preamble and applies to the whole document.

The area between \begin{document} and \end{document} is called the body. This is where the content goes.

Text after \end{document} will be ignored.

3.3.1 \usepackage

Sometimes LaTeX cannot solve a problem, so external packages are added in the preamble using \usepackage. For example, dirtytalk allows users to deal with quotation marks.

```
\documentclass[10pt]{article}
\usepackage{dirtytalk}

\begin{document}
\say{Stay positive \& test negative!}
\end{document}
```

"Stay positive & test negative!"

You can find package documentation by googling "CTAN *insert package name*".

3.3.2 `\title, \author, \date, \maketitle`

When creating a title page, these 4 commands are used. For example, if Einstein (hypothetically) wrote a LaTeX document, he would type `\title{General Relativity}`, `\author{Albert Einstein}`, `\date{May 7, 1915}` and `\maketitle` in the body.

3.4 The Building Blocks of LaTeX: `\, [ ], { }, ␣`

The backslash is central to LaTeX because each LaTeX command starts with `\`.

3.4.1 Commands

A command is a special expression that instructs LaTeX to do a specific task. It is case-sensitive, i.e. `\large` and `\Large` are different commands. Commands are sometimes followed by declarations.

3.4.2 Declarations

A declaration is either optional `[ ]` or required `{ }`. For example, in `\documentclass[10pt]{article}`:

- `\documentclass` is the command.
- `[10pt]` is an optional declaration (can be omitted).
- `{article}` is a required declaration (something is needed within `{ }`).

Sometimes `{ }` provides spacing after a command:

```
\LaTeX  ample vs. \LaTeX{} ample
```

LaTeXample vs. LaTeX ample

3.4.3 Environments

An environment performs a specific action on a block of LaTeX code. It must have matching `\begin` and `\end` declarations. For example:

```
\begin{center}
Core-an is the official language at
    the center of Earth. \\
P.S. This is how you center text.
\end{center}
```

Core-an is the official language at the center of Earth.
P.S. This is how you center text.

3.4.4 Spaces

Spaces and tabs are treated as 1 space (␣). Any combination of consecutive spaces and tabs are also treated as 1 space. An empty line marks the end of a paragraph. Consecutive empty lines are treated as 1 empty line. For example:

```
1 space =    1 tab.
1 space =      consecutive spaces.

1 empty line = end of paragraph.


1+ empty lines = 1 empty line.
```

1 space = 1 tab. 1 space = consecutive spaces.
1 empty line = end of paragraph.
1+ empty lines = 1 empty line.

Use a tilde (~) for an unbreakable space

```
This is an unbreakable space.
Really? Oh Yes. \\
This is an unbreakable space.
Really? Oh~Yes.
```

This is an unbreakable space. Really? Oh Yes.
This is an unbreakable space. Really? Oh Yes.

3.4.5 Special Characters

Reserved Characters

The following characters (discussed elsewhere) have a special meaning in LaTeX:

```
# $ % & { } _ ~ ^ \
```

In order to print them, you must escape or prefix the character with a \:

```
\# \$ \% \& \{ \} \_ \~{} \^{}
\textbackslash
```

$ % & { } _ ~ ^ \

\\ means a newline so `\textbackslash` is used.

Symbols

There are over 18,000 symbols[1] in LaTeX. They are printed using specific commands. For example:

```
$\div$ \\
\copyright \\
$\clubsuit$
```

Sometimes the symbol must be placed between $ signs (refer to 7.2 on page 34).

Helpful Resources

1. Detexify - inputs a drawing of a symbol and outputs its LaTeX command (and the package required if needed).
2. CTAN - a comprehesive list of symbols.

3.5 Basic Organization (Section)

It is helpful to divide the LaTeX document into different sections.

3.5.1 Sectioning Commands (Subsection)

Different document classes have different sectioning commands:

`article` class (Subsubsection)

- `\section`
- `\subsection`
- `\subsubsection`
- `\paragraph`

[1] Some symbols require packages.

`book, report` class (Subsubsection)

- `\part`
- `\chapter`
- All of the `article` sectioning commands.

Sectioning commands automatically provide spacing (and numbering), so you do not need to add `\newline` or `\\` before the next sectioning command. Add a $*$ after the sectioning command for unnumbering. (Paragraph)

```
\section{This will be a numbered section.}
\section*{This will not.}
```

3.5.2 Labelling

Section commands can be labelled with `\label{labelname}`. When referring to a particular section, use `\ref{labelname}` (the section) or `\pageref{labelname}` (page number of the section). Using an example from this guide:

```
\label{symbols}
% Some Code
To learn about symbols, refer to
    \ref{symbols} on page
    \pageref{symbols}.
```

To learn about symbols, refer to 3.4.5 on page 13.

3.5.3 Footnotes

`\footnote` prints text at the bottom of the page[2]. Here is the code I used to create the footnote:

```
$\ldots$ at the bottom of the
    page\footnote{Footnotes are easy
    with \LaTeX{}!}.
```

... at the bottom of the page.

3.5.4 Comments

The % character is reserved for commenting. When used, the rest of the current line is ignored.

[2] Footnotes are easy with LaTeX!

```
% This text will be ignored.
Some text % will be ignored.
```

Some text

If multiple lines need to be commented, highlight the necessary text and use the keyboard shortcut for commenting[3].

Another way is to define a new command:

```
% Preamble
\newcommand{\comment}[1]{}

% Body
\comment{
You Can't See Me.

Just Like John Cena.
}
```

[3]Keyboard shortcuts for Texmaker; Texstudio.

Chapter 4

All About Text

4.1 Line Breaking

As mentioned previously, \\ or \newline performs a line break. * starts a new line without starting a new paragraph.

```
Text is broken here. \\*
The paragraph is not broken.
```

Text is broken here.
The paragraph is not broken.

4.2 Page Breaking

\newpage should suffice.

4.3 Keeping Words Together

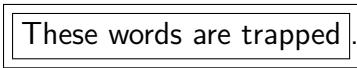
\mbox keeps words together in 1 line. No line breaks are allowed in the text.

```
These words are not grouped, but
    \mbox{these words are}.
```

These words are not grouped, but these words are.

\fbox draws a box around the grouped words.

```
\fbox{These words are trapped}.
```



4.4 Punctuation

4.4.1 Apostrophes, Colons, Commas, Periods, and Semi-Colons

Simply type these punctuation marks. It is useful but not necessary to type `\frenchspacing` in the preamble. This tells the document to treat spacing after commas and periods equally.

4.4.2 Dashes

There are 4 types of dashes:

```
hyphen (-): Pre-Christmas vibes. \\
en-dash (--): I work from 9--5. \\
em-dash (---): Yes --- or no? \\
minus sign ($-$): $-69$.
```

hyphen (-): Pre-Christmas vibes.
en-dash (–): I work from 9–5.
em-dash (—): Yes — or no?
minus sign (−): -69.

4.4.3 Ellipsis

As it has better spacing and line-break behavior, `\ldots` in between dollar signs is a better solution than typing 3 dots.

```
3 dots:  a b c... z \\
low dots: a b c $\ldots$ z
```

3 dots: a b c... z
low dots: a b c … z

4.4.4 Quotation Marks

The `dirtytalk` package is a comprehensive solution.

```
% Preamble
\usepackage{dirtytalk}

% Body
\say{I am surrounded!} \\
\say{Quotations can be \say{nested}
    as well!}
```

“I am surrounded!”
“Quotations can be ‘nested’ as well!”

If you want to define the primary and secondary set of quotation marks, type the following in the preamble:

```
\usepackage[
    left = ``,%
    right = '',%
    leftsub = `,%
    rightsub = ',%
]{dirtytalk}
```

You can find a table of primary and secondary quotation marks in several languages here.

4.4.5 Quotations

The `quotation` environment adds quotes to some text.

```
Walt Disney once said something
    interesting.
\begin{quotation}
The way to get started is to quit
    talking and begin doing.
\end{quotation}
It changed my life.
```

Walt Disney once said something interesting.

> The way to get started is to quit talking and begin doing.

It changed my life.

4.5 More Special Characters

Commands for accents, diacritics, and other characters can be found on Wikibooks. These commands may not be needed if the characters can be typed out from the keyboard.

4.6 Aligning Text

The `flushleft`, `center`, `flushright` environments align text to the left, center, and right, respectively.

```
\begin{flushleft}
Chairman Mao
\end{flushleft}

\begin{center}
Canada
\end{center}

\begin{flushright}
Hitler
\end{flushright}
```

Chairman Mao

Canada

Hitler

4.7 Coloring Text

Add color to the document using the `xcolor` package. Use `\textcolor` or `\color` to color text.

```
% Preamble
\usepackage{xcolor}

% Body
\textcolor{yellow}{Black} and
    {\color{black}yellow}.
```

Black and yellow.

If you want to highlight text, then use `\colorbox`.

```
% Preamble
\usepackage{xcolor}

% Body
\colorbox{yellow}{Black} \\
\colorbox{black}{\textcolor{yellow}{yellow}}
```

Black
yellow

The colors provided by `xcolor` can be found here. If you scroll down on the webpage, there are instructions to define more colors and set the page color.

4.8 Fonts

4.8.1 Font Sizes

LaTeX commands for font sizes:

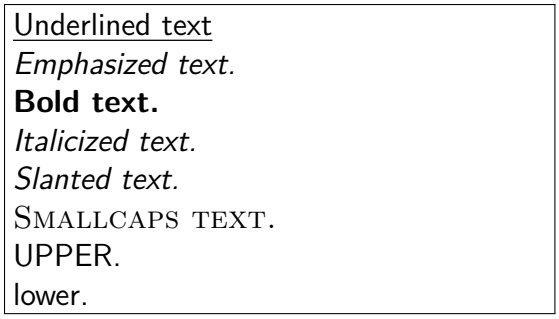
```
{\tiny tiny} \\
{\scriptsize scriptsize} \\
{\footnotesize footnotesize} \\
{\small small} \\
{\normalsize normalsize} \\
{\large large} \\
{\Large Large} \\
{\LARGE LARGE} \\
{\huge huge}
```

A more thorough tutorial on font sizes can be found at latex-tutorial.com.

4.8.2 Font Styles

Text can be type-faced in different ways. Popular commands include:

```
\underline{Underlined text} \\
\emph{Emphasized text.} \\
\textbf{Bold text.} \\
\textit{Italicized text.} \\
\textsl{Slanted text.} \\
\textsc{Smallcaps text.} \\
\uppercase{upper.} \\
\lowercase{LOWER.}
```



`\underline` does not break properly to the next line, so use the `ulem` pacakge to resolve the issue. This package also allows for underline styling and strikethroughs.

Note that although `\emph`, `\textit`, and `\textsl` have the same effect here, they render different effects with other fonts.

4.8.3 Font Families

The default font on a LaTeX document is Computer Modern, which is part of the serif family. The other 2 popular font families are sans serif and `monospace`.

Changing the Global Font Family

To change the default font family for the whole document to `monospace`, type the following in the preamble:

```
\renewcommand{\familydefault}{\ttdefault}
```

Replace `\ttdefault` with `\sfdefault` for sans serif. As serif is the default font family for a LaTeX document, nothing needs to be done to use it. However, if needed, use `\rmdefault`.

Temporarily Changing the Font Family

To use these font families temporarily, use the following commands:

```
\textrm{Serif text.} \\
\textsf{Sans Serif text.} \\
\texttt{Monospace text.}
```

Serif text.
Sans Serif text.
Monospace text.

4.9 More Fonts

To use other fonts, employ external packages.

4.9.1 Using Other Fonts Installed on your PC

Using the font globally

To use fonts installed on a local PC (e.g.Times New Roman), type the following in the preamble:

```
\usepackage{fontspec}
\setmainfont{Times New Roman}
```

Then, you must typeset the document using the XeLaTeX or LuaLaTeX compiler. The section between 2:52 to 3:16 of this video might help with the compilation.

Using the font temporarily

If you only need to use Times New Roman for some text, type:

```
\usepackage{fontspec}
\newfontfamily{\tnrm}{Times New
    Roman}
{\tnrm Times New Roman Text.}
```

Times New Roman Text.

`\tnrm` was my choice. It can be replaced with a command of your choice (just make sure it isn't already defined).

The user can download fonts for their PC at dafont.com.

4.9.2 Using The LaTeX Font Catalogue

More fonts and their instructions-for-use can be found on The LaTeX Font Catalogue[1]. For example, if you want to use Bookman[2] as the global font, type the following in the preamble:

```
\usepackage{bookman}
```

If you want to use Bookman only for some text:

```
Normal Text. \\
{\fontfamily{pbk}\selectfont Bookman
    Text.}
```

Normal Text.
Bookman Text.

Notice the code `pbk`. You need to know this code to access the font. The codes for the most common fonts can be found at Stack Exchange.

Sometimes the font does not appear. This is because it needs to be installed by LaTeX. For more information, read this guide.

[1] If you are writing mathematical expressions, use fonts with math support.
[2] Popular fonts can be found here.

Chapter 5

International Language Support

5.1 Using `polyglossia`

5.1.1 Languages Requiring Font Definitions

Arabic

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{arabic}
\newfontfamily{\arabicfont}[Script=Arabic]{Scheherazade}
```

`\arabicfont` is used to type Arabic: النص هذا عكس يمكن

You must download the Scheherazade font on your local PC. Other fonts that support Arabic can be found here.

Bengali

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{bengali}
\newfontfamily{\bengalifont}[Script=Bengali]{Kalpurush}
```

`\bengalifont` is used to type Bengali: আমি বাংলা বলি না।

You must download the Kalpurush font on your local PC. Other fonts that support Bengali can be found here.

Greek

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{greek}
\newfontfamily{\greekfont}[Script=Greek]{Linux Libertine}
```

`\greekfont` is used to type Greek: Θέλω να πάω στη Μύκονο.

You must download the Linux Libertine font on your local PC. Some other Greek fonts can be found here.

Hebrew

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble %
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{hebrew}
\newfontfamily{\hebrewfont}[Script=Hebrew]{IBM Plex Sans Hebrew}
```

`\hebrewfont` is used to type Hebrew: אינטליגנטים. אנשים אנחנו

You must download the IBM Plex Sans Hebrew font on your local PC. Other fonts that support Hebrew can be found here.

Hindi

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
```

```
\setotherlanguage{hindi}
\newfontfamily{\hindifont}[Script=Devanagari]{Lohit Devanagari}
```

`\hindifont` is used to type Hindi: विराट कोहली भगवान हैं।

You must download the Lohit Devanagari font on your local PC. Other fonts that support Hindi can be found here.

Thai

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{thai}
\newfontfamily\thaifont[Script=Thai]{Prompt}
```

`\thaifont` is used to type Thai: กุมารเป็นคนไทย

You must download the Prompt font on your local PC. Other fonts that support Thai can be found here.

Russian

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{russian}
\newfontfamily\russianfont[Script=Cyrillic]{Linux Libertine}
```

`\russianfont` is used to type Russian: Путин любит лошадей!

You must download the Linux Libertine font on your local PC. Some other Russian fonts can be found here.

If you set the default language as Russian, you can type it without `\russianfont`. However, you still need to define `\russianfont` using `\newfontfamily` in the preamble. The same applies to the other languages in 5.1.1.

5.1.2 Some Other Languages

Spanish

Use the `polyglossia` package with the XeLaTeX compiler as follows:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{spanish}

% Body
¡\today{} es mi cumpleaños!
```

¡December 24, 2021 es mi cumpleaños!

If you only need to use Spanish temporarily:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguage{spanish}

% Body
I speak Spanish. \\
\textspanish{\today{} es mi
    cumpleaños.}
```

I speak Spanish.
24 de diciembre de 2021 es mi cumpleaños.

French

If you also want to add French, make the following changes:

```
% Preamble
\usepackage{polyglossia}
\setdefaultlanguage{english}
\setotherlanguages{spanish, french}

% Body
I speak Spanish. \\
\textspanish{\today{} es mi
    cumpleaños.} \\
\textfrench{Je parle aussi français.}
```

I speak Spanish.
24 de diciembre de 2021 es mi cumpleaños.
Je parle aussi français.

German

You can simply replace `french` with `german` in the code above.

Read the `polyglossia` documentation for a full list of supported languages.

5.2 Languages Requiring Other Packages

Chinese

The most comprehensive solution is to use the `ctex` package.

```
% Preamble
\usepackage[UTF8]{ctex}

% Body
你好
```

你好

It is recommended to use the XeLaTeX compiler.

Japanese

The `xeCJK` package[1] takes care of Japanese.

```
% Preamble
\usepackage{xeCJK}

% Body
日本の首都は東京です
```

日本の首都は東京です

You must use the XeLaTeX compiler.

Helpful Resources

1. Language Fonts - a list of fonts that support different languages.
2. Wikibooks - a more comprehensive guide for typesetting different languages.
3. Overleaf - further reading.

[1] This package can also be used to typeset Chinese.

Chapter 6

Page Layout

6.1 Line Spacing

`\linespread` alters the space between lines. Type it in the preamble.

```
% Default Line Spacing
\linespread{1}

% One and a Half Line Spacing
\linespread{1.3}

% Double Line Spacing
\linespread{1.6}
```

`\setlength{\baselineskip}{1.6 \baselineskip}` temporarily alters the line spacing to double spacing:

```
{
\setlength{\baselineskip}{1.6
    \baselineskip}
A double spaced paragraph is a
    paragraph with twice the space
    between lines. Wow, that's meta!
\par} $\\$

This is a normal paragraph with
    normal spacing. Nothing special.
```

A double spaced paragraph is a paragraph with twice the space between lines. Wow, that's meta!

This is a normal paragraph with normal spacing. Nothing special.

`\par` ends a paragraph and is necessary[1].

[1] You can also use an empty line.

6.2 Paragraphs

6.2.1 Paragraph Indentation

Temporary Indentation

Sometimes paragraphs are indented. `\noindent` cancels the indent. If you want to indent a non-indented paragraph, use `\indent`.

Permanent Indentation

`\setlength{\parindent}{4em}` globally sets paragraph indentation to 4em. If you don't want any indentation in the document, use `\setlength{\parindent}{0em}`. Place the commands in the preamble, preferably before `\tableofcontents`.

6.2.2 Paragraph Spacing

`\setlength{\parskip}{1em}` globally sets spacing between 2 paragraphs to 1em.

More information of units such as em can be found here.

6.2.3 Paragraph Shape

Load the `shapepar` package. You can write paragraphs with cool shapes.

```
\heartpar{This paragraph is shaped as a
    heart because \LaTeX{} is powerful.
    There are many other shapes
    available. Just go through the
    documentation for
    \texttt{shapepar}. There are
    circles, squares, rectangles, and
    shapes you can't imagine. This is
    kind of cringe but oh well.}
```

This para-
graph
is shaped as a heart be-
cause LaTeX is powerful. There
are many other shapes available.
Just go through the documenta-
tion for shapepar. There are cir-
cles, squares, rectangles, and
shapes you can't imagine.
This is kind of cringe
but oh well.
♡

For more information, read the `shapepar` documentation. For irregular shapes, read this post.

More information on paragraph formatting can be found on Overleaf.

6.3 Page Elements

All documents classes except `book` (refer to 3.2 on page 11) are one-sided. In one-sided documents, each page is identical. In two-sided documents, odd and even pages have different margins. To create a two-sided document, use the `twoside` option.

```
% Books are two-sided documents
\documentclass{book}

% Use the two-sided option for other document classes
\documentclass[twoside]{article}
```

More information on one/two-sided documents can be found here.

6.3.1 Headers & Footers

Basic Customization

Use `\pagestyles` in the preamble.

```
% No Header, No Footer
\pagestyles{empty}

% No Footer, Header contains page number and some information
\pagestyles{headings}

% No Footer, Header for one-sided document
\pagestyles{myheadings}
\markright{Name \hfill Date \hfill} % Name is placed on the left, Date is
    placed in the center, page number on the right

% No Footer, Header for two-sided document
\pagestyles{myheadings}
\markboth{Hi}{Hello} % 'Hi' on even pages, 'Hello' on odd pages
```

Advanced Customization

Load the `fancyhdr` package and do the following:

```
% Preamble
\usepackage{fancyhdr}
\pagestyle{fancy} % Sets page style to fancy
\fancyhf{} % Clears the Header and Footer for customization
```

For a one-sided documents, use the following commands:

```
% Preamble
\rhead{Right Side of Header}
\chead{Header Center}
\lchead{Left Side of Header}
\rfoot{Right Side of Footer}
\cfoot{Footer Center}
\lfoot{Left Side of Footer}
```

For two-sided documents:

```
% Preamble
\fancyhead[LE,RO]{Outer}  % LE = Left Even; RO = Right Odd
\fancyhead[RE,LO]{Inner} % RE = Right Even; LO = Left Odd
\fancyfoot[CE,CO]{Center} % CE = Center Even; CO = Center Odd
\fancyfoot[LE,RO]{\thepage} % Prints the page number on the Footer center on
    even and odd pages
```

More commands include:

Description	Command
Page Number	\thepage
Chapter Number	\thechapter
Section Number	\thesection
Chapter Name	\chaptername
Current Chapter / Section Name & Number	\leftmark
Current Section / Subsection Name & Number	\rightmark

fancyhdr provides decorative lines for the header and footer. If you need to customize the lines, do the following:

```
% Preamble
\renewcommand{\headrulewidth}{2pt} % Header Line
\renewcommand{\footrulewidth}{2pt} % Footer Line
```

6.3.2 Page Numbers

Use \pagenumbering.

```
% Preamble
\pagenumbering{arabic}
```

The page numbers will be Arabic numerals. If you need lowercase (uppercase) Roman numerals, use roman (Roman) instead.

`\setcounter{page}` allows you to control the page counter.

```
\chapter{First Chapter}
\setcounter{page}{3} % 3 is assigned to the current page
```

More information on page numbering can be found here.

6.4 Page Margins

The `geometry` package allows you to change the margins.

```
% Preamble
\usepackage[margin=2in]{geometrty}
```

I have also used it to create help sheets.

```
% Preamble
\documentclass{article}
\usepackage[margin=1cm, landscape]{geometry}
\usepackage{multicol}

% Body
\begin{multicols}{3}
\section{Section 1}

\section{Section 2}

\section{Section 3}

\section{Section 4}
\end{multicols}
```

Helpful Resources

Frankly, I don't have much experience with page margins, so I direct you to the following resources.

1. CTAN - `geometry` package documentation.
2. Overleaf - an introduction to page size and margins.
3. Wikibooks - an advanced guide for page layout (page margins, page size, page background).

Chapter 7

Mathematics

This is where the heart of LaTeX lies.

7.1 $\mathcal{AMS}$-LaTeX packages

It is **strongly recommended** to load the packages in the $\mathcal{AMS}$-LaTeX bundle when typesetting math. Copy this into the document's preamble:

```
\usepackage{mathtools, amssymb, amsthm}
```

7.2 Math Mode

Math mode must be used when writing math. There are 2 modes: inline and display.

7.2.1 Inline (Text)

Inserts math in between text. Requires:

- an opening $ and closing $;
- or an opening \(and closing \);
- or a `math` environment.

```
$9+10=21$ is false. \\

\(3^2 + 4^2 = 5^2\) is true. \\

\begin{math}
\sin{x}=\pi \text{ has no solutions.}
\end{math}
```

$9+10=21$ is false.

$3^2 + 4^2 = 5^2$ is true.

$\sin x = \pi$ has no solutions.

`\text` inserts text in math mode. If not, this happens:

```
\begin{math}
\sin{x} = \pi has no solutions.
\end{math}
```

$\sin x = \pi has no solutions.$

7.2.2 Display (unnumbered)

Displays math in its own line and is unnumbered. Requires:

- an opening `\[` and closing `\]`;
- or an `equation*` environment;
- or a `displaymath` environment.

```
The Pythagorean theorem:
    \[a^2+b^2=c^2\]

Environments also work:
\begin{equation*}
a^2+b^2=c^2
\end{equation*}

Another environment:
\begin{displaymath}
a^2+b^2=c^2
\end{displaymath}
```

The Pythagorean theorem:

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

Environments also work:

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

Another environment:

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

Using an opening `$$` and closing `$$` also works but is **strongly discouraged**. Read this for more information.

7.2.3 Display (numbered)

Displays math in its own line and is automatically labelled. Requires:

- an `equation` environment.

```
A legend once said that
\begin{equation}
9+10=21
\end{equation}
```

A legend once said that

$$9 + 10 = 21 \tag{7.1}$$

7.2.4 Math Mode Fonts

The text and math fonts in a LaTeX document are independent. The default math font is Computer Modern. Math fonts compatible with LaTeX are rare. Refer to the footnote in 4.9.2 for more information.

If you need to use math fonts temporarily, LaTeX provides a few pre-defined commands:

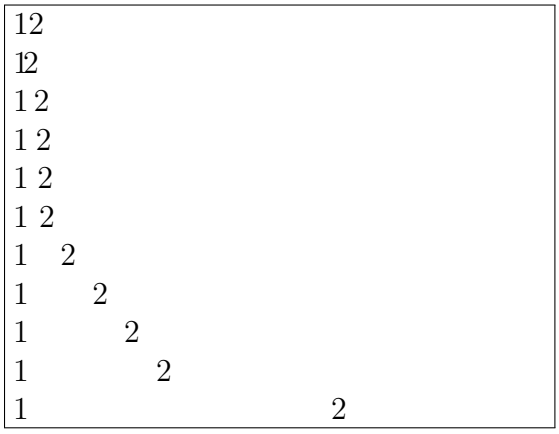
Description	Command	Output
Default	ABCabc123	$ABCabc123$
Roman	`\mathrm{ABCabc123}`	$\mathrm{ABCabc123}$
Bold	`\mathbf{ABCabc123}`	$\mathbf{ABCabc123}$
Italics	`\mathit{ABCabc123}`	$\mathit{ABCabc123}$
Typewriter	`\mathtt{ABCabc123}`	$\mathtt{ABCabc123}$
Fraktur	`\mathfrak{ABCabc123}`	$\mathfrak{ABCabc123}$
Blackboard Bold	`\mathbb{ABC}`	$\mathbb{ABC}$
Caligraphic	`\mathcal{ABC}`	$\mathcal{ABC}$

Note that `\mathbb` and `\mathcal` only work with capital letters.

7.2.5 Math Mode Spacing

LaTeX automatically spaces content in math mode. It ignores whitespace characters. If you want custom spacing, refer to this table. Here are a few examples:

```
$1     2 $ \\
$1 \! 2 $ \\
$1 \, 2 $ \\
$1 \: 2 $ \\
$1 \; 2 $ \\
$1 \  2 $ \\
$1 \quad 2 $ \\
$1 \qquad 2 $ \\
$1 \qquad \quad 2 $ \\
$1 \qquad \qquad 2 $ \\
$1 \hspace*{4cm} 2 $
```



\phantom acts like a whitespace character.

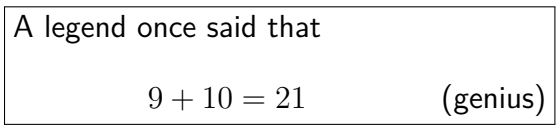
```
${}^{14}_{6}\mathrm{C}$ \\
${}^{14}_{\phantom{1}6}\mathrm{C}$
    % 1 space reserved
```

7.3 Equations

7.3.1 Labelling Equations

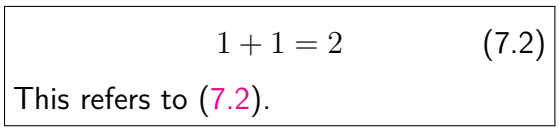
LaTeX automatically labels equations. Use \tag for a custom label.

```
A legend once said that
\begin{equation}
9+10=21 \tag{genius}
\end{equation}
```



\label and \eqref allow you to refer to an equation.

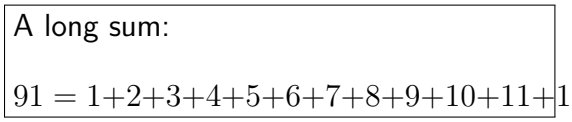
```
\begin{equation}
1+1=2  \label{babymath}
\end{equation}
This refers to \eqref{babymath}.
```



7.3.2 Long Equations

Sometimes equations are too long.

```
A long sum:
\[91=1+2+3+4+5+6+7+8+9+10+11+12+13\]
```



The `multline` environment resolves this.

```
A long sum:
\begin{multline}
91=1+2+3+4+5 \\
+6+7+8+9+10 \\
+11+12+13
\end{multline}
```

A long sum:

$$91 = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 + 11 + 12 + 13 \quad (7.3)$$

`multline*` removes the equation label.

7.3.3 Gathering Equations

The `multline` solution looks messy, so another solution is to gather equations. The `gather` environment brings equations together, centered.

```
Centered equations:
\begin{gather}
1+1=2 \\
xyz+x+y+z=w
\end{gather}
```

Centered equations:

$$1 + 1 = 2 \quad (7.4)$$

$$xyz + x + y + z = w \quad (7.5)$$

```
Centered (unnumbered) equations:
\begin{gather*}
1+1=2 \\
xyz+x+y+z=w
\end{gather*}
```

Centered (unnumbered) equations:

$$1 + 1 = 2$$

$$xyz + x + y + z = w$$

The `gathered` environment (**within display mode**) assigns 1 label to the gathered equations.

```
\begin{equation}
\begin{gathered}
1+1=2 \\
xyz+x+y+z=w
\end{gathered}
\end{equation}
```

$$\begin{gathered} 1 + 1 = 2 \\ xyz + x + y + z = w \end{gathered} \quad (7.6)$$

7.3.4 Aligning Equations

Another solution to long equations is to align equations on the relation symbol ($=$, $<$, etc.) using the `align` environment.

```
Aligned equations:
\begin{align}
1+1=2 \\
xyz+x+y+z=w
\end{align}
```

Aligned equations:

$$1+1=2 \tag{7.7}$$
$$xyz+x+y+z=w \tag{7.8}$$

```
Aligned (unnumbered) simplification:
\begin{align*}
1+2+3+4&=1+2+7 \\
&=1+9 \\
&=10
\end{align*}
```

Aligned (unnumbered) simplification:

$$\begin{aligned} 1+2+3+4 &= 1+2+7 \\ &= 1+9 \\ &= 10 \end{aligned}$$

Add text using && and \text.

```
Simplifying $1+2+3+4$:
\begin{align*}
1+2+3+4&=1+2+7 \\
&=1+9 && \text{(as $2+7=9$)} \\
&= 10
\end{align*}
```

Simplifying $1+2+3+4$:

$$\begin{aligned} 1+2+3+4 &= 1+2+7 \\ &= 1+9 && \text{(as } 2+7=9\text{)} \\ &= 10 \end{aligned}$$

Some more equations:

```
Aligned (unnumbered) equations:
\begin{align*}
x&=y & y&=z  \\
z&=x & y&=x  \\
z&=y & x&=z
\end{align*}
```

Aligned (unnumbered) equations:

$$\begin{aligned} x &= y & y &= z \\ z &= x & y &= x \\ z &= y & x &= z \end{aligned}$$

The aligned environment (**within display mode**) assigns 1 label to the aligned equations.

```
\begin{equation}
\begin{aligned}
1+1=2 \\
xyz+x+y+z=w
\end{aligned}
\end{equation}
```

$$\begin{aligned} 1+1 &= 2 \\ xyz+x+y+z &= w \end{aligned} \tag{7.9}$$

You can also use split instead of aligned. Read more about the differences here.

7.4 Math Environments

7.4.1 Theorems, Lemmas, Corollaries, Propositions, Definitions, Remarks, Examples, Exercises, Asides

These environments may be helpful when writing math. Define them in the preamble.

```
\newtheoremstyle{dotless}{}{}{}{}{\bfseries}{}{12pt}{}
\theoremstyle{dotless}
\newtheorem{thm}{Theorem}[section] % Theorem
\newtheorem*{thm*}{Theorem} % Theorem (unnumbered)
\newtheorem{lem}[thm]{Lemma} % Lemma
\newtheorem*{lem*}{Lemma} % Lemma (unnumbered)
\newtheorem{cor}[thm]{Corollary} % Corollary
\newtheorem*{cor*}{Corollary} % Corollary (unnumbered)
\newtheorem{prop}[thm]{Proposition} % Proposition
\newtheorem*{prop*}{Proposition} % Proposition (unnumbered)
\newtheorem{defn}[thm]{Definition} % Definition
\newtheorem*{defn*}{Definition} % Definition (unnumbered)
\newtheorem{rem}[thm]{Remark} % Remark
\newtheorem*{rem*}{Remark} % Remark (unnumbered)
\newtheorem{exa}[thm]{Example} % Example
\newtheorem*{exa*}{Example} % Example (unnumbered)
\newtheorem{exe}[thm]{Exercise} % Exercise
\newtheorem*{exe*}{Exercise} % Exercise (unnumbered)
\newtheorem{aside}[thm]{Aside} % Aside
\newtheorem*{aside*}{Aside} % Aside (unnumbered)
```

Implementing:

```
% Theorem
\begin{thm}
This is a theorem.
\end{thm}

% Example
\begin{exa}
$1+1=2$
\end{exa}

% Exercise (unnumbered)
\begin{exe*}
Does $2+2=4$?
\end{exe*}
```

Theorem 7.4.1 This is a theorem.

Example 7.4.2 $1+1=2$

Exercise Does $2+2=4$?

7.4.2 Proofs

The `proof` environment is provided by the `mathtools` package.

```
\begin{proof}
$1+1=2 \implies 1=1$
\end{proof}
```

Proof. $1+1=2 \implies 1=1$ □

Changing the QED symbol:

```
% Preamble
\renewcommand\qedsymbol{$\blacksquare$}
```

```
% Body
\begin{proof}
$1+1=2 \implies 1=1$
\end{proof}
```

Proof. $1+1=2 \implies 1=1$ ■

Changing the QED symbol (again):

```
% Preamble
\renewcommand\qedsymbol{QED}
```

```
% Body
\begin{proof}
$1+1=2 \implies 1 = 1$
\end{proof}
```

Proof. $1+1=2 \implies 1=1$ QED

You can also change the style of the `proof` environment.

```
% Preamble
\renewenvironment{proof}{{\bfseries
    Proof.}}{\hfill$\square$}
```

```
% Body
\begin{proof}
$1+1=2 \implies 1 = 1$
\end{proof}
```

Proof. $1+1=2 \implies 1=1$ □

Unlike the environments in 7.3, math mode must be used in the environments mentioned in 7.4.1 and 7.4.2.

7.5 Numbers

7.5.1 Reals ($\mathbb{R}$)

Integers ($\mathbb{Z}$)

Type out the integers. The font changes in math mode.

```
$-1, 0, 2, 4$ \\ % math mode font
-1, 0, 2, 4 % text mode font
```

$-1, 0, 2, 4$
-1, 0, 2, 4

Rationals ($\mathbb{Q}$)

`\frac` is used.

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

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

\[\frac{7}{10}\]
```

$\frac{1}{2}$

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

$$\frac{7}{10}$$

Use `\dfrac` for a **d**isplay mode sized fraction and `\tfrac` for a **t**ext mode sized fraction.

```
$\dfrac{69}{420}$
\[\tfrac{1}{1000}\]
```

$\dfrac{69}{420}$

$$\tfrac{1}{1000}$$

You can also use `^{1}/_{2}` to display ${}^{1}/_{2}$.

Irrationals($\mathbb{I}$)

A few famous irrationals:

Description	Command	Output
Pi	`\pi`	π
Euler's Number	`e`, `\mathrm{e}`	e, e
Logarithms	`\log_{2}{3}`	$\log_2 3$
Golden Ratio	`\phi`	ϕ
Unit Square Diagonal	`\sqrt{2}`	$\sqrt{2}$

```
The area of a unit circle is $\pi$.
```

The area of a unit circle is π.

7.5.2 Complex Numbers ($\mathbb{C}$)

```
Imaginary Unit: $i$, $\mathrm{i}$
```

Imaginary Unit: i, i

```
Complex number: $z=2+2i$
```

Complex number: $z=2+2i$

```
Conjugate: $z^{*}=2-2i$
```

Conjugate: $z^{*}=2-2i$

```
Real Part: $\Re(z)=2$ or
    $\mathrm{Re}(z)=2$
```

Real Part: $\Re(z)=2$ or $\mathrm{Re}(z)=2$

```
Imaginary Part: $\Im(z)=2$ or
    $\mathrm{Im}(z)=2$
```

Imaginary Part: $\Im(z)=2$ or $\mathrm{Im}(z)=2$

```
Absolute Value: $|z|=2\sqrt{2}$
```

Absolute Value: $|z|=2\sqrt{2}$

```
Argument: $\arg(z)=\frac{\pi}{2}$
```

Argument: $\arg(z)=\frac{\pi}{2}$

7.6 Variables

Variables are letters in math mode.

```
Find x vs. Find $x$
```

Find x vs. Find x

```
% Text Mode
abcdefghijklmnopqrstuvwxyz

% Math Mode
$abcdefghijklmnopqrstuvwxyz$
```

abcdefghijklmnopqrstuvwxyz
$abcdefghijklmnopqrstuvwxyz$

```
The solution to $ax^2+bx+c=0$ is
    \[x=\frac{-b \pm
    \sqrt{b^2-4ac}}{2a}.\]
```

The solution to $ax^2+bx+c=0$ is

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

7.6.1 Greek & Hebrew Letters

Command	Output	Command	Output	Command	Output	Command	Output
\alpha	α	\mu	μ	\upsilon	υ	\Upsilon	Υ
\beta	β	\nu	ν	\xi	ξ	\aleph	$\aleph$
\chi	χ	\omega	ω	\zeta	ζ	\beth	$\beth$
\delta	δ	\phi	ϕ	\Delta	Δ	\daleth	$\daleth$
\epsilon	ϵ	\varphi	φ	\Gamma	Γ	\gimel	$\gimel$
\varepsilon	ε	\pi	π	\Lambda	Λ		
\eta	η	\psi	ψ	\Omega	Ω		
\gamma	γ	\rho	ρ	\Phi	Φ		
\iota	ι	\sigma	σ	\Pi	Π		
\kappa	κ	\tau	τ	\Sigma	Σ		
\lambda	λ	\theta	θ	\Theta	Θ		

```
The cardinality of the natural
    numbers is $\aleph_0$.
```

The cardinality of the natural numbers is $\aleph_0$.

More Greek symbols can be found here.

7.7 Math Symbols

In this section, I will list some basic math symbols. However, if you need to find commands for symbols that are not included here, refer to 3.4.5 on page 13.

7.7.1 Basic Arithmetic

Description	Command	Output
Addition	+	$+$
Subtraction	-	$-$
Multiplication (times)	\times	$\times$
Multiplication (dot)	\cdot	$\cdot$
Division (sign)	\div	$\div$
Division (slash)	/	$/$
Exponentiation	a^{b}	a^b

```
$3 \times ((3^{3} \div
    3)+(((3+3)/3)+3-3+3+3+3+3))=69$
```

$3 \times ((3^3 \div 3) + (((3+3)/3) + 3 - 3 + 3 + 3 + 3 + 3)) = 69$

7.7.2 Basic Algebra

Description	Command	Output
Plus-Minus	`\pm`	$\pm$
Minus-Plus	`\mp`	$\mp$
Square Root	`\sqrt{x}`	$\sqrt{x}$
n^{th} Root	`\sqrt[n]{x}`	$\sqrt[n]{x}$
Absolute Value	`|x|`	$\|x\|$
Natural Log	`\ln{x}`, `\ln(x+y)`	$\ln x$, $\ln(x+y)$
Log	`\log_{2}{3}`, `\log_{2}(3+1)`	$\log_2(3+1)$
Factorial	`5!`	$5!$

```
$\sqrt{\sqrt{81}}=3$ \\
$\sqrt[2]{9}=3$ \\
$\sqrt[3]{27}=3$ \\
$|3|=3$ \\
$\ln{3}=\log_{e}{3} $ \\
$\ln(3)=\log_{e}(3)$
```

$\sqrt{\sqrt{81}}=3$
$\sqrt[2]{9}=3$
$\sqrt[3]{27}=3$
$|3|=3$
$\ln 3=\log_e 3$
$\ln(3)=\log_e(3)$

More operator symbols can be found here.

`polynom` package

You can divide and factorize polynomials with the `polynom` package.

```
% Long Division
$\polylongdiv{x^3+x^2+x+1}{x+1}$
```

$$\begin{array}{r|l} & x^2 \qquad +1 \\ \hline x+1 & x^3+x^2+x+1 \\ & -x^3-x^2 \\ \hline & \qquad\quad x+1 \\ & \qquad\quad -x-1 \\ \hline & \qquad\qquad 0 \end{array}$$

```
% Factorization
$x^5+x^4+x^3+x^2+x+1 = $
\[\polyfactorize{
x^5+x^4+x^3+x^2+x+1
}\]
```

$$x^5+x^4+x^3+x^2+x+1 = \left(x^4+x^2+1\right)\left(x+1\right)$$

`cancel` package

You can cancel fractions with the `cancel` package.

```
\[\frac{3 \cdot
    \cancel{2}}{\cancel{2} \cdot 4}
    = \frac{3}{4}\]
```

$$\frac{3 \cdot \cancel{2}}{\cancel{2} \cdot 4} = \frac{3}{4}$$

7.7.3 Comparison Symbols

Description	Command	Output
Equal to	`=`	$=$
Approximately Equal to	`\approx`	$\approx$
Not Equal to	`\neq`	$\neq$
Less Than	`<`	$<$
Less Than or Equal to	`\leq`	$\leq$
Less Than or Equal to (slant)	`\leqslant`	$\leqslant$
Much Less Than	`\ll`	$\ll$
Greater Than	`>`	$>$
Greater Than or Equal to	`\geq`	$\geq$
Greater Than or Equal to (slant)	`\geqslant`	$\geqslant$
Much Greater Than	`\gg`	$\gg$
Proportional To	`\propto`	$\propto$

```
$\pi \approx 3.14$, but $\pi \neq
    3.14$ and $\pi \geq 3.14$. In
    other words, $\pi > 3.14$.
```

$\pi \approx 3.14$, but $\pi \neq 3.14$ and $\pi \geq 3.14$. In other words, $\pi > 3.14$.

More Comparison symbols can be found here.

7.7.4 Su$_{\text{b}}^{\text{per}}$scripts

Description	Command	Output
Superscript	`a^{b}`	a^b
Subscript	`a_{0}`	a_0

^ and _ only impact the next character, so it's better to group the necessary characters with {}.

Examples with {}[1]:

[1] `x^2^3` and `x_2_3` yield errors.

```
$x^{2} \quad x_{2}$ \\
$x^{10} \quad x_{10}$ \\
$x^{y^{2}} \quad x_{y_{2}}$ \\
$x^{y_{2}} \quad x_{y^{2}}$
```

$x^{2} \quad x_{2}$
$x^{10} \quad x_{10}$
$x^{y^{2}} \quad x_{y_{2}}$
$x^{y_{2}} \quad x_{y^{2}}$

Examples without {}:

```
$x^2 \quad x_2$ \\
$x^2z^3 \quad x_2z_3$ \\
$x  ^2 z^  3 \quad x  _2 z_   2$ \\
$x^10 \quad x _10$
```

$x^2 \quad x_2$
$x^2z^3 \quad x_2z_3$
$x^2z^3 \quad x_2z_2$
$x^10 \quad x_10$

Mixing things up:

```
$x^{420}_{69} - y \quad x_{69}^{420}
    - y$ \\
${}^{14}_{6}C \quad {}_{6}^{14}C$ \\
${}^1_1H \quad {}^1{}_1H$ \\
$A_1^2 \quad A{}_1{}^2$ \\
$A{}_1^2 \quad A_1{}^2$ \\
${}^{2}B^{2} \quad {}_2A_{1}$ \\
$x_1' \quad x''_2$
```

$x^{420}_{69} - y \quad x_{69}^{420} - y$
${}^{14}_{6}C \quad {}^{14}_{6}C$
${}^1_1H \quad {}^1{}_1H$
$A_1^2 \quad A_1{}^2$
$A{}_1^2 \quad A_1{}^2$
${}^{2}B^{2} \quad {}_2A_{1}$
$x_1' \quad x''_2$

7.7.5 Fences (Delimiters)

Description	Command	Output
Round Brackets	`(x)`	(x)
Square Brackets	`[x]`	$[x]$
Curly Brackets	`\{x\}`	$\{x\}$
Angled Brackets	`\langle x \rangle`	$\langle x \rangle$
Floor	`\lfloor x \rfloor`	$\lfloor x \rfloor$
Ceiling	`\lceil x \rceil`	$\lceil x \rceil$
Norm	`|x|`	$\|x\|$
Upper Corners	`\ulcorner x \urcorner`	$\ulcorner x \urcorner$
Lower Corners	`\llcorner x \lrcorner`	$\llcorner x \lrcorner$

If the fences are too small, use `\left` and `\right` before the left and right fence, respectively.

```
\[n \to \infty \implies \left(
    1+\frac{1}{n} \right)^{n} \to e\]
```

$$n \to \infty \implies \left(1+\frac{1}{n}\right)^{n} \to e$$

For bigger, custom fence sizes, use \big, \Big, \bigg, or \Bigg before both the left and right fence.

7.7.6 Dots

Description	Command	Output
Comma Separated List	`1, 2, \dotsc, 5`	$1, 2, \dotsc, 5$
Lower Dots	`1, 2, \ldots, 5`	$1, 2, \ldots, 5$
Multiplication Dots	`1 \cdot 2 \cdot 3 \dotsm 5`	$1 \cdot 2 \cdot 3 \cdots 5$
Binary Operation Dots	`1 + 2 + \dotsb + 5`	$1 + 2 + \cdots + 5$
Other Dots	`1, 2, \dotso, 5`	$1, 2, \dots, 5$
Vertical Dots	`\vdots`	$\vdots$
Diagonal Dots	`\ddots`	$\ddots$

7.7.7 Arrows

Description	Command	Output
Right Arrow	`\to`, `\rightarrow`	$\to$
Long Right Arrow	`\longrightarrow`	$\longrightarrow$
Not Right Arrow	`\nrightarrow`	$\nrightarrow$
Thick Right Arrow	`\Rightarrow`	$\Rightarrow$
Thick Long Right Arrow	`\Longrightarrow`	$\Longrightarrow$
Thick Not Right Arrow	`\nRightarrow`	$\nRightarrow$
Left Arrow	`\leftarrow`, `\gets`	$\leftarrow$
Long Left Arrow	`\longleftarrow`	$\longleftarrow$
Not Left Arrow	`\nleftarrow`	$\nleftarrow$
Thick Left Arrow	`\Leftarrow`	$\Leftarrow$
Thick Long Left Arrow	`\Longleftarrow`	$\Longleftarrow$
Thick Not Left Arrow	`\nLeftarrow`	$\nLeftarrow$
Left-Right Arrow	`\leftrightarrow`	$\leftrightarrow$
Not Left-Right Arrow	`\nleftrightarrow`	$\nleftrightarrow$
Thick Left-Right Arrow	`\iff`	$\iff$
Up Arrow	`\uparrow`	$\uparrow$
Thick Up Arrow	`\Uparrow`	$\Uparrow$
Down Arrow	`\downarrow`	$\downarrow$
Thick Down Arrow	`\Downarrow`	$\Downarrow$
Up-Down Arrow	`\updownarrow`	$\updownarrow$
Thick Up-Down Arrow	`\Updownarrow`	$\Updownarrow$
Maps To	`\mapsto`	$\mapsto$
Maps To (Long)	`\longmapsto`	$\longmapsto$
Leads To	`\leadsto`	$\leadsto$

7.7.8 Decorations

Description	Command	Output
Over-brace	`\overbrace{x+y}^{=y+x}`	$\overbrace{x+y}^{=y+x}$
Prime	`f'`	f'
Prime Prime	`f''`	f''
Dot	`\dot{x}`	$\dot{x}$
Dot Dot	`\ddot{x}`	$\ddot{x}$
Hat	`\hat{x}`	$\hat{x}$
Wide Hat	`\widehat{x+y}`	$\widehat{x+y}$
Tilde	`\tilde{x}`	$\tilde{x}$
Wide Tilde	`\widetilde{x+y}`	$\widetilde{x+y}$
Bar	`\bar{x}`	$\bar{x}$
Under-brace	`\underbrace{x+y}_{=y+x}`	$\underbrace{x+y}_{=y+x}$

7.7.9 Miscellaneous

Description	Command	Output
Asterisk	`\ast`	$\ast$
Bow Tie	`\bowtie`	$\bowtie$
Bullet	`\bullet`	$\bullet$
Dagger	`\dagger`	$\dagger$
Curly l	`\ell`	ℓ
Star	`\star`	$\star$
Surd	`\surd`	$\surd$
Tick	`\checkmark`	$\checkmark$
Tilde	`\sim`	$\sim$

7.8 Set Theory

7.8.1 Number Sets

Description	Command	Output
Boolean Numbers	`\mathbb{B}`	$\mathbb{B}$
Prime Numbers	`\mathbb{P}`	$\mathbb{P}$
Natural Numbers	`\mathbb{N}`	$\mathbb{N}$
Whole Numbers	`\mathbb{W}`	$\mathbb{W}$
Integers	`\mathbb{Z}`	$\mathbb{Z}$
Rationals	`\mathbb{Q}`	$\mathbb{Q}$
Algebraic Numbers	`\mathbb{A}`	$\mathbb{A}$
Irrationals	`\mathbb{I}`	$\mathbb{I}$
Reals	`\mathbb{R}`	$\mathbb{R}$
Complex Numbers	`\mathbb{C}`	$\mathbb{C}$
Quaternions	`\mathbb{H}`	$\mathbb{H}$
Octonions	`\mathbb{O}`	$\mathbb{O}$
Sedenions	`\mathbb{S}`	$\mathbb{S}$
Empty Set	`\emptyset`, `\varnothing`	$\emptyset$, $\varnothing$
Power Set	`\mathcal{P}`	$\mathcal{P}$

7.8.2 Set Notation

Description	Command	Output
Brackets	`\{3, 1, 4\}`	$\{3, 1, 4\}$
Cardinality	`\mathbf{card}(S), |S|`	$\mathbf{card}(S)$, $\|S\|$
Definition	`A:=B`	$A := B$
Element of	`\in`	$\in$
Not an Element of	`\notin`	$\notin$
Subset of	`\subset`	$\subset$
Subset of	`\subseteq`	$\subseteq$
Subset of but Not Equal to	`\subsetneq`	$\subsetneq$
Not a Subset of	`\not\subset`	$\not\subset$
Not a Subset of	`\nsubseteq`	$\nsubseteq$
Contains	`\supset`	$\supset$
Contains	`\supseteq`	$\supseteq$
Union	`\cup`	$\cup$
Big Union	`\bigcup_{n=1}^{10}{A_n}`	$\bigcup_{n=1}^{10} A_n$
Disjoint Union	`\sqcup`	$\sqcup$
Intersection	`\cap`	$\cap$
Big Intersection	`\bigcap_{n=1}^{10}{A_n}`	$\bigcap_{n=1}^{10} A_n$
Set Difference	`\setminus`	$\setminus$
Symmetric Difference	`\triangle`	$\triangle$
Set Complement	`A^{mathsf{c}}`	A^{c}
Set Complement	`\overline{A}`	$\overline{A}$
Cartesian Product	`\times`	$\times$

7.8.3 `braket` package

You can load the `braket` package when typesetting sets.

```
% Preamble
\usepackage{braket}

% Body
\[ \Set{x \in \mathbb{R} | 0 < x <
    \frac{1}{3}}\]
```

$$\left\{ x \in \mathbb{R} \,\middle|\, 0 < x < \frac{1}{3} \right\}$$

7.9 Logic

Description	Command	Output
Not	\neg, \sim	$\neg$, $\sim$
And	\land	$\land$
Or	\lor	$\lor$
Exclusive Or (XOR)	\oplus	$\oplus$
If... Then	\implies, \Longrightarrow	$\implies$
Only If	\Longleftarrow	$\Longleftarrow$
If and Only If	\iff	$\iff$
Equivalence	\equiv	$\equiv$
Therefore	\therefore	$\therefore$
Because	\because	$\because$
Exists	\exists	$\exists$
Exists Uniquely	\exists!	$\exists!$
There is No	\nexists	$\nexists$
For All	\for all	$\forall$
Top	\top	$\top$
Bottom	\bot	$\bot$

More logic symbols can be found on Wikipedia.

7.10 Algebra

7.10.1 Infinity

First, you ought to know the commands for ∞ and $-\infty$.

Description	Command	Output
Infinity	\infty	∞
Negative Infinity	-\infty	$-\infty$

7.10.2 Intervals

There are 9 types of intervals:

Description	Command	Output
Finite Open	`(a, b)`	(a, b)
Finite Closed	`[a, b]`	$[a, b]$
Finite Half Closed - Half Open	`[a, b)`	$[a, b)$
Infinite Half Closed - Half Open	`[a, \infty)`	$[a, \infty)$
Infinite Half Open - Half Closed	`(-\infty, b]`	$(-\infty, b]$
Infinite Open	`(a, \infty)`	(a, ∞)
Infinite Open	`(-\infty, b)`	$(-\infty, b)$
Reals	`(\infty, -\infty)`	$(\infty, -\infty)$

7.10.3 Functions

Description	Command	Output
Colon	`\colon`	$:$
Function	`\to`, `\rightarrow`	$\to$
Maps To	`\mapsto`	$\mapsto$
Injection	`\rightarrowtail`	$\rightarrowtail$
Injection	`\xhookrightarrow{}`	$\xhookrightarrow{}$
Injection	`\xrightarrow{\tiny 1:1}`	$\xrightarrow{\tiny 1:1}$
Injection	`\xrightarrow[\tiny 1:1]{}`	$\xrightarrow[\tiny 1:1]{}$
Surjection	`\twoheadrightarrow`	$\twoheadrightarrow$
Surjection	`\xrightarrow{\tiny \text{onto}}`	$\xrightarrow{\tiny \text{onto}}$
Bijection	`\xrightarrow{\tiny 1:1, \text{ onto}}`	$\xrightarrow{\tiny 1:1, \text{ onto}}$
Bijection	`\xrightarrow{\tiny\text{bij}}`	$\xrightarrow{\tiny\text{bij}}$
Composition	`\circ`	$\circ$
Restriction	`f|_{X}`	$f\vert_X$
Inverse	`f^{-1}`	f^{-1}
Convolution	`\ast`	$\ast$
Fourier Transform	`\hat{f}`	$\hat{f}$

While you could type out ":", `\colon` allows for proper spacing.

```
% :
$f \circ g: [0, 1] \to [0, 1]$ is a
    function. \\

% \colon
$f \circ g \circ h \colon A \to B$
    is a function.
```

$f \circ g : [0, 1] \to [0, 1]$ is a function.

$f \circ g \circ h \colon A \to B$ is a function.

Use the cases environment to define a piecewise function.

```
\[
f(x) = 1_{\mathbb{Q}}(x) =
\begin{cases}
1 & x \in \mathbb{Q} \\
0 & x \notin \mathbb{Q}
\end{cases}
\]
```

$$f(x) = 1_{\mathbb{Q}}(x) = \begin{cases} 1 & x \in \mathbb{Q} \\ 0 & x \notin \mathbb{Q} \end{cases}$$

If you need to include text, then:

```
\[
f(x) = 1_{\mathbb{Q}}(x) =
\begin{cases}
1 & \text{if $x \in \mathbb{Q}$} \\
0 & \text{if $x \notin \mathbb{Q}$}
\end{cases}
\]
```

$$f(x) = 1_{\mathbb{Q}}(x) = \begin{cases} 1 & \text{if } x \in \mathbb{Q} \\ 0 & \text{if } x \notin \mathbb{Q} \end{cases}$$

7.11 Geometry

7.11.1 Geometry Notation

Description	Command	Output
Line Segment	`\overline{AB}`	$\overline{AB}$
Ray	`\overrightarrow{AB}`	$\overrightarrow{AB}$
Line	`\overleftrightarrow{AB}`	$\overleftrightarrow{AB}$
Triangle	`\triangle{ABC}`	$\triangle ABC$
Square	`\square{ABC}`	$\square ABC$
Angle	`\angle{ABC}`	$\angle ABC$
Measured Angle	`\measuredangle{ABC}`	$\measuredangle ABC$
Degrees	`180^{\circ}`	180°
Congruent	`\cong`	$\cong$
Not Congruent	`\ncong`	$\ncong$
Similar	`\sim`	$\sim$
Not Similar	`\nsim`	$\nsim$
Parallel	`\parallel`	$\parallel$
Not Parallel	`\nparallel`	$\nparallel$
Perpendicular	`\perp`	$\perp$
Not Perpendicular	`\not\perp`	$\not\perp$

7.11.2 Trigonometry & Hyperbolic Functions

Description	Command	Output
Sine	`\sin{\pi}`, `\sin(\pi)`	$\sin \pi$, $\sin(\pi)$
Cosine	`\cos{\pi}`	$\cos \pi$
Tangent	`\tan{\pi}`	$\tan \pi$
Cosecant	`\csc{\pi}`	$\csc \pi$
Secant	`\sec{\pi}`	$\sec \pi$
Cotangent	`\cot{\pi}`	$\cot \pi$
Inverse Sine	`\arcsin{0}`	$\arcsin 0$
Inverse Cosine	`\arccos{0}`	$\arccos 0$
Inverse Tangent	`\arctan{0}`	$\arctan 0$
Hyperbolic Sine	`\sinh{0}`	$\sinh 0$
Hyperbolic Cosine	`\cosh{0}`	$\cosh 0$
Hyperbolic Tangent	`\tanh{0}`	$\tanh 0$

7.11.3 Sums

Sums are different in inline and display mode.

```
The harmonic series
$\sum_{n=1}^{\infty}{\frac{1}{n}}$
is divergent. \\

The harmonic series
\[\sum_{n=1}^{\infty}{\frac{1}{n}}\]
is divergent.
```

The harmonic series $\sum_{n=1}^{\infty} \frac{1}{n}$ is divergent.

The harmonic series

$$\sum_{n=1}^{\infty} \frac{1}{n}$$

is divergent.

While the curly braces {} are not necessary, they make the code readable.

```
\[\sum_a^b \frac{1}{n}\]
```

$$\sum_a^b \frac{1}{n}$$

You can also typeset double sums.

```
\[\sum_{i=1}^{2}{\sum_{j=1}^{2}{i+j}}
    = 12\]
```

$$\sum_{i=1}^{2}{\sum_{j=1}^{2}{i+j}} = 12$$

Use `\substack` to write the limits over multiple lines.

```
\[\sum_{
\substack{
0 \leq i \leq 2 \\
0 \leq j \leq 2
}
}^{}{i+j}=12\]
```

$$\sum_{\substack{0\leq i\leq 2\\0\leq j\leq 2}} i+j=12$$

You can forcefully change the position of the limits for sums using `\limits` and `\nolimits`[2].

```
% Inline Mode
$\sum_{n=1}^{5}{n}$

% Inline Mode (placing limit
    position under sum)
$\sum\limits_{n=1}^{5}{n}$

% Inline Mode (placing limit
    position besides sum)
$\sum\nolimits_{n=1}^{5}{n}$

% Display Mode
\[\sum_{n=1}^{5}{n}\]

% Display Mode (placing limit
    position under sum)
\[\sum\limits_{n=1}^{5}{n}\]

% Display Mode (placing limit
    position besides sum)
\[\sum\nolimits_{n=1}^{5}{n}\]
```

$\sum_{n=1}^{5} n$
$\sum\limits_{n=1}^{5} n$
$\sum\nolimits_{n=1}^{5} n$

$$\sum_{n=1}^{5} n$$

$$\sum\limits_{n=1}^{5} n$$

$$\sum\nolimits_{n=1}^{5} n$$

7.11.4 Products

Refer to 7.11.3 on page 56 and replace `sum` with `prod`.

[2] This also applies for products, integrals, and limits.

```
% Inline Mode
$\prod_{n=1}^{50}{n}=50!$ \\

% Display Mode
The product \[\prod_{n=1}^{50}{n}\]
$=50!$
```

$\prod_{n=1}^{50} n = 50!$

The product

$$\prod_{n=1}^{50} n$$

$= 50!$

7.12 Calculus

7.12.1 Derivatives

You can write a derivative as follows:

```
% Leibniz Notation
If $f(x)=x^2$, then
\[\frac{df}{dx}=2x.\]

% Lagrange Notation
Using other notation:
\[f'(x)=2x\]
```

If $f(x) = x^2$, then

$$\frac{df}{dx} = 2x.$$

Using other notation:

$$f'(x) = 2x$$

Notice the slant in df. For an upright d, type the following in the preamble:

```
\newcommand{\dee}{\mathrm{d}}
```

\dee is my choice, so you can use something else.

```
\[\frac{\dee f}{\dee x} = 2x\]
```

$$\frac{\mathrm{d}f}{\mathrm{d}x} = 2x$$

If you need to evaluate derivatives:

```
\[\left.\frac{\dee f}{\dee
    x}\right|_{x=2}=4\]
```

$$\left.\frac{\mathrm{d}f}{\mathrm{d}x}\right|_{x=2} = 4$$

Partial derivatives are typeset using `\partial`.

```
\[\frac{\partial g}{\partial x
    \partial y}\]
```

$$\frac{\partial g}{\partial x \partial y}$$

`diffcoeff` package

`diffcoeff` with the `ISO` option also takes care of the upright d. It is also handy for higher-order and partial derivatives.

```
 % Preamble
\uspackage[ISO]{diffcoeff}
```

Typesetting ordinary derivatives:

```
\[\diff{f}{x}\]
\[\diff{f}/{x}\]
\[\diff[n]{f}{x}\]
\[\diff[n]{f}/{x}\]
\[\diff{\cos(\sin x)}{(\sin x)}\]
\[\diff[n]{\cos(\sin{x})}{\sin{x}}\]
\[\diff*{f(x)}{x}\]
\[\diff*{\diff{y}{x}}{x}\]
\[\diff[n]{f}{x}[x=0]\]
```

$$\frac{\mathrm{d}f}{\mathrm{d}x}$$
$$\mathrm{d}f/\mathrm{d}x$$
$$\frac{\mathrm{d}^n f}{\mathrm{d}x^n}$$
$$\mathrm{d}^n f/\mathrm{d}x^n$$
$$\frac{\mathrm{d}\cos(\sin x)}{\mathrm{d}(\sin x)}$$
$$\frac{\mathrm{d}^n \cos(\sin x)}{\mathrm{d}(\sin x)^n}$$
$$\frac{\mathrm{d}}{\mathrm{d}x} f(x)$$
$$\frac{\mathrm{d}}{\mathrm{d}x}\frac{\mathrm{d}y}{\mathrm{d}x}$$
$$\left(\frac{\mathrm{d}^n f}{\mathrm{d}x^n}\right)_{x=0}$$

Typesetting partial derivatives:

```
\[\diffp{f}{x}\]
\[\diffp{f}/{x}\]
\[\diffp[n]{f}{x}\]
\[\diffp[n]{f}/{x}\]
\[\diffp[n]{f(x,y)}{x}[(0,0)]\]
\[\diffp{f}{x, y, z}\]
\[\diffp[2, 3, 4, 1]{f(x, y, z,
    w)}{x, y, z, w}\]
```

$$\frac{\partial f}{\partial x}$$
$$\partial f/\partial x$$
$$\frac{\partial^n f}{\partial x^n}$$
$$\partial^n f/\partial x^n$$
$$\left(\frac{\partial^n f(x,y)}{\partial x^n}\right)_{(0,0)}$$
$$\frac{\partial^3 f}{\partial x\,\partial y\,\partial z}$$
$$\frac{\partial^{10} f(x,y,z,w)}{\partial x^2\partial y^3\partial z^4\partial w}$$

More package information can be found on CTAN.

7.12.2 Integration

Refer to 7.11.3 on page 56 and replace `sum` with `int`. To include the differential, add `\,\dee x`.

```
The integral $\int_{0}^{\infty}{e^x}
    \,\dee x$ diverges.
```

The integral $\int_0^\infty e^x \,\mathrm{d}x$ diverges.

```
\[\int_{0}^{2}{2x} \,\dee x =
    \left[x^2\right]^{2}_{0} = 4\]
```

$$\int_0^2 2x \,\mathrm{d}x = \left[x^2\right]_0^2 = 4$$

For multiple integrals, use `\int` multiple times.

```
If $I_1=I_2=[0, 2]$, then
\[\int_{I_1}{\int_{I_2}{xy \,\dee x}
    \,\dee y} = 4\]

Explicitly:
\[\int_{0}^{2}{\int_{0}^{2}{xy
    \,\dee x} \,\dee y} = 4\]
```

If $I_1 = I_2 = [0, 2]$, then

$$\int_{I_1}\int_{I_2} xy \,\mathrm{d}x\,\mathrm{d}y = 4$$

Explicitly:

$$\int_0^2\int_0^2 xy \,\mathrm{d}x\,\mathrm{d}y = 4$$

Different types of integrals:

```
% Integral with Specified Limits
    (Besides Integral)
\[\int_{-\infty}^{\infty} f = 0\]

% Integral with Specified Limits
    (Under Integral)
\[\int\limits_{-\infty}^{\infty} f =
    0\]

% Double / Surface Integral
\[\iint_A f = F\]

% Triple / Volume Integral
\[\iiint_V f = F\]

% Quadruple Integral
\[\iiiint_V f = F\]

% Multiple Integral
\[\idotsint_V f = F\]

% Line Integral
\[\oint_V f = F\]
```

$$\int_{-\infty}^{\infty} f = 0$$

$$\int\limits_{-\infty}^{\infty} f = 0$$

$$\iint_A f = F$$

$$\iiint_V f = F$$

$$\iiiint_V f = F$$

$$\int \cdots \int_V f = F$$

$$\oint_V f = F$$

7.12.3 Multivariable Calculus

Description	Command	Output
Gradient	`\nabla{f}`	∇f
Divergence	`\nabla\cdot{F}`	$\nabla \cdot F$
Divergence	`\nabla\times{f}`	$\nabla \times F$
Laplace Operator	`\Delta{f}`	Δf
D'Alembert Operator	`\square{f}`	$\square f$

7.13 Analysis

7.13.1 Sequences

Use `()` to denote sequences.

```
Let $(a_{n})=(1, 2, 3, 4, 5,
    \ldots)$ be a sequence.
Then \[n \to \infty \implies a_{n}
    \to \infty.\]
```

Let $(a_n) = (1, 2, 3, 4, 5, \ldots)$ be a sequence. Then

$$n \to \infty \implies a_n \to \infty.$$

7.13.2 Limits

Limits can also be typeset easily.

```
If the limit of $f(x)$ exists at
    $x=a$, then
    $(\forall\varepsilon>0)
    (\exists\delta>0)
    (0<|x-a|<\delta \implies
    |f(x)-f(a)|<\varepsilon)$. \\
```

If the limit of $f(x)$ exists at $x = a$, then $(\forall \varepsilon > 0)(\exists \delta > 0)(0 < |x - a| < \delta \implies |f(x) - f(a)| < \varepsilon)$.

```
% Inline Mode
$\lim_{n \to \infty}{\frac{1}{n}} =
    0$ \\

$\lim_{n \to 2^{+}}{\frac{1}{n}} =
    \frac{1}{2}$ \\

% Display Mode
\[\lim_{n \to \infty}{\frac{1}{n}} =
    0\]

\[f'(x) = \lim_{h \to
    0^{+}}{\frac{f(x+h) -
    f(x)}{h}}\] \\
```

$\lim_{n\to\infty} \frac{1}{n} = 0$

$\lim_{n\to 2^+} \frac{1}{n} = \frac{1}{2}$

$$\lim_{n\to\infty} \frac{1}{n} = 0$$

$$f'(x) = \lim_{h\to 0^+} \frac{f(x+h) - f(x)}{h}$$

`\substack` (refer to 7.11.3 on page 56) can also be applied to limits.

7.13.3 Infimum & Supremum

For limit inferior and superior, replace `\lim` with `\liminf` and `\limsup`, respectively.

```
% Limit Superior
\[\limsup_{n \to \infty}{x_{n}} = 1\]
\[\varlimsup_{n \to \infty}{x_{n}} =
    1\]

% Limit Inferior
\[\liminf_{n \to \infty}{x_{n}} =
    -1\]
\[\varliminf_{n \to \infty}{x_{n}} =
    -1\]
```

$$\limsup_{n\to\infty} x_n = 1$$

$$\varlimsup_{n\to\infty} x_n = 1$$

$$\liminf_{n\to\infty} x_n = -1$$

$$\varliminf_{n\to\infty} x_n = -1$$

Other important commands include:

Description	Command	Output
Minimum	`\min{A}`	$\min A$
Maximum	`\max{A}`	$\max A$
Infimum	`\inf{A}`	$\inf A$
Supremum	`\sup{A}`	$\sup A$

7.13.4 Big O Notation

Description	Command	Output
Small o	`o(g)`	$o(g)$
Big O	`\mathcal{O}(g)`	$\mathcal{O}(g)$
Big Theta	`\Theta(g)`	$\Theta(g)$
Big Omega	`\Omega(g)`	$\Omega(g)$
Small omega	`\omega(g)`	$\omega(g)$

7.14 Abstract Algebra

7.14.1 Equivalence Classes & Relations

Description	Command	Output
Equivalence Class	`[a]`	$[a]$
Equivalence Relation	`\sim`	$\sim$
Equivalence Relation	`\backsim`	$\backsim$

7.14.2 Group Theory

Description	Command	Output
Group Isomorphism	`\simeq`	$\simeq$
Direct Product	`\times`	$\times$
Semi-Direct Product	`\rtimes`	$\rtimes$
Wreath Product	`\wr`	$\wr$
Subgroup	`\leq`	$\leq$
Normal Subgroup	`\vartriangleleft`	$\vartriangleleft$
Not a Normal Subgroup	`\not\vartriangleleft`	$\not\vartriangleleft$
Quotient Group	`G / H`	G/H
Index of a Subgroup	`[G : H]`	$[G : H]$
Generator	`\langle X \rangle`	$\langle X \rangle$
Commutator	`[g, h]`	$[g, h]$

7.14.3 Field Theory

Description	Command	Output
Field Extension	`L : K`	$L : K$
Degree of Field Extension	`[L : K]`	$[L : K]$
Algebraic Closure	`\overline{K}`	$\overline{K}$

7.15 Discrete Mathematics

7.15.1 Number Theory

Description	Command	Output
Divides	`a \mid b`	$a \mid b$
Does Not Divide	`a \nmid b`	$a \nmid b$
Congruence With ()	`a \equiv b \pmod{n}`	$a \equiv b \pmod{n}$
Congruence Without ()	`a \equiv b \mod{n}`	$a \equiv b \mod{n}$
Greatest Common Divisor	`\gcd(100, 10)`	$\gcd(100, 10)$
Euler's Totient Function	`\phi(n)`	$\phi(n)$

7.15.2 Continued Fractions

`\cfrac` does the job. The options `[r]` or `[l]` determine the position of the numerator.

```
\begin{equation*}
x = x_{0} + \cfrac{y_{0}}{
x_{1} + \cfrac{y_{1}}{
x_{2} + \cfrac[l]{y_{2}}{
x_{3} + \cfrac[r]{y_{3}}{
x_{4} + \cdots}}}}
\end{equation*}
```

$$x = x_0 + \cfrac{y_0}{x_1 + \cfrac{y_1}{x_2 + \cfrac[l]{y_2}{x_3 + \cfrac[r]{y_3}{x_4 + \cdots}}}}$$

7.15.3 Combinatorics

Description	Command	Output
Factorial	`n!`	$n!$
Double Factorial	`n!!`	$n!!$
Derangement	`!n`	$!n$
Combination	`\binom{n}{k}`	$\binom{n}{k}$
Multinomial Coefficient	`\binom{n}{k_1, k_2, \ldots, k_r}`	$\binom{n}{k_1, k_2, \ldots, k_r}$
Multiset	`\left(\binom{n}{k}\right)`	$\left(\binom{n}{k}\right)$
Primorial	`n\#`	$n\#$

You can also use `\dbinom` for a **d**isplay mode sized binomial and `\tbinom` for a **t**ext mode sized binomial.

7.16 Stochastics (Probability & Statistics)

7.16.1 Probability

Description	Command	Output
Probability Measure	`P(E)`	$P(E)$
Conditional Probability	`P(A \mid B)`	$P(A \mid B)$
Expected Value	`E(X)`	$E(X)$
Variance	`\mathrm{Var}(X)`	$\mathrm{Var}(X)$
Standard Deviation	`\sigma(X)`	$\sigma(X)$
Covariance	`\mathrm{Cov}(X, Y)`	$\mathrm{Cov}(X)$
Correlation	`\rho(X, Y)`	$\rho(X, Y)$
Probability Distribution	`X \sim Y`	$X \sim Y$

7.16.2 Statistics

Description	Command	Output
Mean	\overline{x}	$\overline{x}$
Estimator	\hat{p}	$\hat{p}$

7.17 Linear Algebra

7.17.1 Vectors

Vectors are denoted using \vec.

```
$\vec{a}$
```

$\vec{a}$

Bold vectors require \boldsymbol. Typing this out can be cumbersome, so define a new command in the preamble.

```
\newcommand{\bvec}[1]{\boldsymbol{#1}}
```

Using the new command:

```
$\bvec{a}$
```

$\boldsymbol{a}$

Vectors are defined within a matrix[3], pmatrix, bmatrix, or Bmatrix environment.

Row vectors:

```
% Row Vector (no fences)
\begin{equation*}
\begin{matrix}
1 & 2 & 3
\end{matrix}
\end{equation*}
```

$$1 \quad 2 \quad 3$$

```
% Row Vector (round brackets)
\begin{equation*}
\begin{pmatrix}
1 & 2 & 3
\end{pmatrix}
\end{equation*}
```

$$\begin{pmatrix} 1 & 2 & 3 \end{pmatrix}$$

[3] The array environment does the same thing but is not preferred.

```
% Row Vector (square brackets)
\begin{equation*}
\begin{bmatrix}
1 & 2 & 3
\end{bmatrix}
\end{equation*}
```

$$\begin{bmatrix} 1 & 2 & 3 \end{bmatrix}$$

```
% Row Vector (curly braces)
\begin{equation*}
\begin{Bmatrix}
1 & 2 & 3
\end{Bmatrix}
\end{equation*}
```

$$\begin{Bmatrix} 1 & 2 & 3 \end{Bmatrix}$$

Column vectors:

```
% Column Vector (no delimiters)
\begin{equation*}
\begin{matrix}
1 \\
2 \\
\vdots \\
3
\end{matrix}
\end{equation*}
```

$$\begin{matrix} 1 \\ 2 \\ \vdots \\ 3 \end{matrix}$$

```
% Column Vector (round brackets)
\begin{equation*}
\begin{pmatrix}
1 \\
2 \\
\vdots \\
3
\end{pmatrix}
\end{equation*}
```

$$\begin{pmatrix} 1 \\ 2 \\ \vdots \\ 3 \end{pmatrix}$$

```
% Column Vector (square brackets)
\begin{equation*}
\begin{bmatrix}
1 \\
2 \\
\vdots \\
3
\end{bmatrix}
\end{equation*}
```

$$\begin{bmatrix} 1 \\ 2 \\ \vdots \\ 3 \end{bmatrix}$$

```
% Column Vector (curly braces)
\begin{equation*}
\begin{Bmatrix}
1 \\
2 \\
\vdots \\
3
\end{Bmatrix}
\end{equation*}
```

$$\begin{Bmatrix} 1 \\ 2 \\ \vdots \\ 3 \end{Bmatrix}$$

7.17.2 Matrices

Use the exact same environments mentioned in 7.17.1.

```
% Matrix (no delimiters)
\begin{equation*}
\begin{matrix}
1 & 2 & 3 \\
4 & 5 & 6
\end{matrix}
\end{equation*}
```

$$\begin{matrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{matrix}$$

```
% Matrix (round brackets)
\begin{equation*}
\begin{pmatrix}
a_{11} & \cdots & a_{1n} \\
\vdots & \ddots & \vdots \\
a_{m1} & \cdots & a_{mn}
\end{pmatrix}
\end{equation*}
```

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$$

```
% Matrix (square brackets)
\begin{equation*}
\begin{bmatrix}
1 & 2 \\
4 & 5
\end{bmatrix}
\end{equation*}
```

$$\begin{bmatrix} 1 & 2 \\ 4 & 5 \end{bmatrix}$$

```
% Matrix (curly braces)
\begin{equation*}
\begin{Bmatrix}
1 & 2 \\
3 & 4 \\
5 & 6
\end{Bmatrix}
\end{equation*}
```

$$\begin{Bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{Bmatrix}$$

If you need matrices with different delimiters, then you add them to a plain `matrix` using `\left` and `\right`.

```
% Matrix (custom delimiters)
$
\left(
\begin{matrix}
1 & 2 \\
3 & 4
\end{matrix}
\right]
$,
$
\left\lceil
\begin{matrix}
1 & 2 \\
3 & 4
\end{matrix}
\right\rfloor
$
```

$$\left(\begin{matrix}1 & 2\\ 3 & 4\end{matrix}\right], \left\lceil\begin{matrix}1 & 2\\ 3 & 4\end{matrix}\right\rfloor$$

Even in inline mode, matrices are in display style. For smaller matrices, use `smallmatrix`, `psmallmatrix`, or `bsmallmatrix`.

```
% Small Matrix (no delimiters)
$
\begin{smallmatrix}
1 & 2 \\
3 & 4
\end{smallmatrix}
$ is a $2 \times 2$ matrix.

% Small Matrix (round brackets)
$
\begin{psmallmatrix}
1 & 2 \\
3 & 4
\end{psmallmatrix}
$ is a $2 \times 2$ matrix.

% Small Matrix (square brackets)
$
\begin{bsmallmatrix}
1 & 2 \\
3 & 4
\end{bsmallmatrix}
$ is a $2 \times 2$ matrix.
```

$\begin{smallmatrix}1 & 2\\ 3 & 4\end{smallmatrix}$ is a 2×2 matrix.

$\left(\begin{smallmatrix}1 & 2\\ 3 & 4\end{smallmatrix}\right)$ is a 2×2 matrix.

$\left[\begin{smallmatrix}1 & 2\\ 3 & 4\end{smallmatrix}\right]$ is a 2×2 matrix.

```
% Small Matrix (custom brackets)
$
\left(
\begin{smallmatrix}
1 & 2 \\
3 & 4
\end{smallmatrix}
\right\}
$ is a $2 \times 2$ matrix.
```

$\left(\begin{smallmatrix} 1 & 2 \\ 3 & 4 \end{smallmatrix}\right\}$ is a 2×2 matrix.

7.17.3 Determinants

Use the `vmatrix` environment.

```
\begin{equation*}
\begin{vmatrix}
1 & 2 \\
3 & 4
\end{vmatrix}
= 1 \cdot 4 - 2 \cdot 3 = -2
\end{equation*}
```

$$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix} = 1 \cdot 4 - 2 \cdot 3 = -2$$

An alternative is:

```
\begin{equation*}
\left|
\begin{matrix}
1 & 2 \\
3 & 4
\end{matrix}
\right|
= 1 \cdot 4 - 2 \cdot 3 = -2
\end{equation*}
```

$$\left|\begin{matrix} 1 & 2 \\ 3 & 4 \end{matrix}\right| = 1 \cdot 4 - 2 \cdot 3 = -2$$

You can also use `\det`.

```
The determinant of $A$ is
\begin{equation*}
\det{\left(
\begin{pmatrix}
1 & 2 \\
3 & 4
\end{pmatrix}
\right)}
= 1 \cdot 4 - 2 \cdot 3 = -2
\end{equation*}
```

The determinant of A is

$$\det\left(\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}\right) = 1 \cdot 4 - 2 \cdot 3 = -2$$

7.17.4 Matrix Norm

Use the `Vmatrix` environment.

```
\begin{equation*}
\begin{Vmatrix}
1 & 2 \\
3 & 4
\end{Vmatrix}
\end{equation*}
```

$$\begin{Vmatrix} 1 & 2 \\ 3 & 4 \end{Vmatrix}$$

An alternative is:

```
\begin{equation*}
\left\|
\begin{matrix}
1 & 2 \\
3 & 4
\end{matrix}
\right\|
\end{equation*}
```

$$\left\| \begin{matrix} 1 & 2 \\ 3 & 4 \end{matrix} \right\|$$

7.17.5 Vector Calculus

Description	Command	Output
Dot Product	`v \cdot w`	$v \cdot w$
Inner Product	`\langle v, w \rangle`	$\langle v, w \rangle$
Cross Product	`v \times w`	$v \times w$
Triple Product	`(u, v, w)`	(u, v, w)
Dyadic Product	`v \otimes w`	$v \otimes w$
Unit Vector	`\hat{v}`	$\hat{v}$

7.17.6 Matrix Operations

Description	Command	Output
Matrix Multiplication	`A \cdot B`	$A \cdot B$
Hadamard Product	`A \circ B`	$A \circ B$
Kronecker Product	`A \otimes B`	$A \otimes B$
Matrix Transpose	`A^{T}`	A^{T}
Conjugate Transpose	`A^{*}`	A^{*}
Inverse Matrix	`A^{-1}`	A^{-1}
Trace	`\mathrm{tr}(A)`	$\mathrm{tr}(A)$
Determinant	`\det(A)`	$\det(A)$
Determinant	`|A|`	$\|A\|$
Matrix Norm	`\\|A\\|`	$\\|A\\|$
Rank	`\mathrm{rank}(A)`	$\mathrm{rank}(A)$
Span	`\mathrm{span}(A)`	$\mathrm{span}(A)$

7.17.7 Vector Spaces

Description	Command	Output
Kernel	`\ker{W}`	$\ker W$
Dimension	`\dim{W}`	$\dim W$
Degree	`\deg{P(x)}`	$\deg P(x)$
Direct Sum	`V \oplus W`	$V \oplus W$
Direct Product	`V \times W`	$V \times W$
Tensor Product	`V \otimes W`	$V \otimes W$
Quotient Space	`V / W`	V / W
Orthogonal Complement	`W^{\perp}`	$A^{\perp}$
Dual Space	`V^{*}`	V^{*}
Linear Hull	`\langle X \rangle`	$\langle X \rangle$

7.18 Overriding Default Math Styles

Suppose you want a display mode style sum in between text. How do you do that? Fortunately, LaTeX provides commands to override the default style that math is typeset.

- `\textstyle` - inline math style.
- `\displaystyle` - display math style.

- `\scriptstyle` - sub/superscript math style.
- `\scriptscriptstyle` - second order sub/superscript math style.

These commands are useful with sums, products, integral, and limits.

```
% Display Mode
\[\sum_{n=1}^{10}{n}\]

% Text Style in Display Mode
\[\textstyle\sum_{n=1}^{10}{n}\]

% Other Styles
$\scriptscriptstyle\sum_{n=1}^{10}
{n}$,
$\scriptstyle\sum_{n=1}^{10}{n}$,
$\sum_{n=1}^{10}{n}$,
$\displaystyle\sum_{n=1}^{10}{n}$
```

$$\sum_{n=1}^{10} n$$

$$\textstyle\sum_{n=1}^{10} n$$

$\scriptscriptstyle\sum_{n=1}^{10} n$, $\scriptstyle\sum_{n=1}^{10} n$, $\sum_{n=1}^{10} n$, $\displaystyle\sum_{n=1}^{10} n$

7.19 Coloring Math

Coloring math is similar to coloring text (refer to 4.7 on page 20).

```
\[\frac{\textcolor{blue}{5}}{10}=
    \frac{1}{\textcolor{red}{10}}\]
```

$$\frac{\textcolor{blue}{5}}{10}=\frac{1}{\textcolor{red}{10}}$$

7.20 Homework

There are a few templates for homework assignments that I have uploaded to GitHub. More templates can be found on Overleaf.

Helpful Resources

1. Wikibooks - a thorough guide for typesetting mathematics.
2. AMS Math Guide for LaTeX - a guide to LaTeX by the American Mathematical Society.
3. The Grammar of Mathematics - how to write math.

Chapter 8

Structures

8.1 Lists

Different environments render different lists.

- `itemize` - unordered list (bullet points).
- `enumerate` - ordered list (numbers).
- `description` - description list (words).

```
Grocery list:
\begin{itemize}
  \item Pineapples
  \item More Pineapples
  \item Even More Pineapples
\end{itemize}
```

Grocery list:

- Pineapples
- More Pineapples
- Even More Pineapples

```
Premier League Top 4:
\begin{enumerate}
  \item Manchester United
  \item Manchester City
  \item Liverpool
  \item Chelsea
\end{enumerate}
```

Premier League Top 4:

1. Manchester United
2. Manchester City
3. Liverpool
4. Chelsea

```
Bull's Starting Line-up:
\begin{description}
  \item[PG] Lonzo Ball
  \item[SG] Zach Lavine
  \item[SF] DeMar DeRozan
  \item[PF] Javonte Green
  \item[C] Nikola Vučević
\end{description}
```

Bull's Starting Line-up:

PG Lonzo Ball

SG Zach Lavine

SF DeMar DeRozan

PF Javonte Green

C Nikola Vučević

You can also nest lists.

```
Bull's Starting Line-up:
\begin{description}
  \item[PG] Lonzo Ball
    \begin{description}
      \item Bench
        \begin{itemize}
          \item[\textbf{\#6}] Alex
    Caruso
          \item Coby White
        \end{itemize}
      \end{description}
  \item[SG] Zach Lavine
  \item[SF] DeMar DeRozan
  \item[PF] Javonte Green
  \item[C] Nikola Vučević
\end{description}
```

Bull's Starting Line-up:

PG Lonzo Ball

Bench

#6 Alex Caruso

- Coby White

SG Zach Lavine

SF DeMar DeRozan

PF Javonte Green

C Nikola Vučević

More information on lists can be found here.

8.2 Tables

The `table` and `tabular` environments are used to create tables.

8.2.1 The `table` environment

```
\begin{table}[c] % t = top of the
    page; c = center of the page b =
    bottom of the page

% Title of the table
\caption{Basic Table}

% Centers table (table is aligned to
    left by default)
\centering
\end{table}
```

Table 8.1: Basic Table

- c specifies the position of the table within the page.
- To place table at precisely the location in the LaTeX code, load the `float` package and use `H` instead of `c`.
- To right align the table, place the code in a `flushright` environment.

To fill in the table contents, start a `tabular` environment.

```
\begin{center} % You can also use
    the center environment
\begin{table}[c]
\caption{Basic Table}

% 3 columns: l = left justified
    contents; c = centered column
    contents; r = right justified
    contents
\begin{tabular}{l c r}
1 & 2 & 3 \\
4 & 5 & 6 \\
\end{tabular}
\end{table}
\end{center}
```

Table 8.2: Basic Table

1	2	3
4	5	6

- Column widths and spacing are automatically defined.
- & separates columns.
- \\ separates rows.
- For simple tables, you may only need the `tabular` environment.

Notice the small gap between the table contents and title. The `caption` package solves this. Add the following to the preamble.

```
\usepackage{caption}
\captionsetup[table]{skip=10pt}
```

The `caption` package provides more customization options. Read this tutorial for more information.

8.2.2 The `tablular` environment

The `tablular` environment was introduced in the last section. Let's continue adding features to it.

```
\centering

\begin{tabular}[c]{|| l | c | r ||}
\hline
Col 1 & Col 2 & Col 3 \\ [0.2ex] %
    Headings
1 & 2 & 3 \\
\hline
4 & 5 & 6 \\
\hline
7 & 8 & 9 \\
\hline\hline
\end{tabular}
```

Col 1	Col 2	Col 3
1	2	3
4	5	6
7	8	9

- | adds a vertical line between columns.
- || adds a double vertical line between columns.
- `\hline` adds a horizontal line between rows.
- `\hline\hline` adds a double horizontal line between rows.
- There is no need \\ after `\hline`.
- Add space between rows with square brackets []

```
\centering

\begin{tabular}[c]{l c r}
\hline
Col 1 & Col 2 & Col 3 \\ [0.2ex]
\cline{2-2}
1 & 2 & 3 \\
\cline{2-3}
4 & 5 & 6 \\
\hline
7 & 8 & 9 \\
\hline
\end{tabular}
```

Col 1	Col 2	Col 3
1	2	3
4	5	6
7	8	9

- `\cline{m-n}` adds a horizontal line between columns `m` and `n`.

```
\centering

\begin{tabular}[c]{| l | c | r |
    p{2.5cm} |}
\hline
Col 1 & Col 2 & Col 3 & Text \\
    [0.2ex]
1 & 2 & 3 & Numbers from 1-3. \\
\hline
4 & 5 & 6 & Numbers from 4-6. \\
\hline
7 & 8 & 9 & Numbers from 7-9. \\
\hline
\end{tabular}
```

Col 1	Col 2	Col 3	Text
1	2	3	Numbers from 1-3.
4	5	6	Numbers from 4-6.
7	8	9	Numbers from 7-9.

- `\p{2.5cm}` specifies a paragraph column with text vertically aligned at the top.

More complex tables involving merging rows and columns. Use `\multicolumn` to merge cells over multiple columns.

```
\centering

\begin{tabular}[c]{| l | c | r |}
\hline
Col 1 & Col 2 & Col 3 \\ [0.2ex]
\hline
1 & \multicolumn{2}{c}{2, 3} \\
\hline
\multicolumn{3}{c}{4, 5, 6} \\
\hline
\multicolumn{1}{l}{7} &
    \multicolumn{1}{c}{8} &
    \multicolumn{1}{r}{9} \\
\hline
\end{tabular}
```

Col 1	Col 2	Col 3
1	2, 3	
4, 5, 6		
7	8	9

- `\multicolumn` removes the vertical lines, so specify them.

```
\centering

\begin{tabular}[c]{| l | c | r |}
\hline
Col 1 & Col 2 & Col 3 \\ [0.2ex]
\hline
1 & \multicolumn{2}{| c |}{2, 3} \\
\hline
\multicolumn{3}{| c |}{4, 5, 6} \\
\hline
\multicolumn{1}{| l |}{7} &
    \multicolumn{1}{| c |}{8} &
    \multicolumn{1}{| r |}{9} \\
\hline
\end{tabular}
```

Col 1	Col 2	Col 3
1	2, 3	
4, 5, 6		
7	8	9

Load the `multirow` package and use `\multirow` to merge cells over multiple rows.

```
\centering

\begin{tabular}{| c | c | c |}
\hline
\multicolumn{3}{| c |}{Bulls Roster}
    \\
\hline
\multirow{2}{*}{Point Guards}
& PG1 & Lonzo B. \\
& PG2 & Alex C. \\
\hline
\multirow{2}{*}{Shooting Guards}
& SG1 & Zach L. \\
& SG2 & Ayo D. \\
\hline
\multirow{2}{*}{Small Forwards}
& SF1 & DeMar D. \\
& SF2 & Derrick J. \\
\hline
\multirow{2}{*}{Power Forwards}
& PF1 & Patrick W. \\
& PF2 & Javonte G. \\
\hline
\multirow{2}{*}{Centers}
& C1 & Nikola V. \\
& C2 & Tony B. \\
\hline
\end{tabular}
```

Bulls Roster		
Point Guards	PG1	Lonzo B.
	PG2	Alex C.
Shooting Guards	SG1	Zach L.
	SG2	Ayo D.
Small Forwards	SF1	DeMar D.
	SF2	Derrick J.
Power Forwards	PF1	Patrick W.
	PF2	Javonte G.
Centers	C1	Nikola V.
	C2	Tony B.

- $*$ tells LaTeX that the column width is determined by its content.

Helpful Resources

1. Table to LaTeX generators - converts drawn table to LaTeX.
2. Overleaf - positioning tables.
3. Wikibooks - an advanced guide for tables.

8.3 Images

1. Save the image in the folder your document is saved in (as a EPS, JPEG, PDF, or PNG).

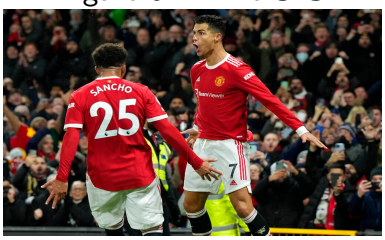
2. Load the `graphicx` package.
3. Use `\includegraphics`.

```
\begin{center}
\includegraphics[width=5cm,
    height=3cm, angle=0,
    scale=1]{ronaldo.jpeg}
\end{center}
```

Sometimes images and text do not work well together, so images must be placed in a `figure` environment. It is similar to the `table` environment in some ways.

```
\begin{center}
\begin{figure}
\caption{The \textbf{SIU}}
\includegraphics[width=5cm,
    height=3cm, angle=0,
    scale=1]{ronaldo.jpeg}
\end{figure}
\end{center}
```

Figure 8.1: The **SIU**



More information on inserting images can be found here.

Chapter 9

Navigation

9.1 Table of Contents

Use `\tableofcontents` in the body of the document.

9.2 List of Tables & Figures

Use `\listoftables` and `\listoffigures` in the body of the document.

9.3 Abstract

Add the following code to the document body:

```
\chapter*{Abstract}

% Adding Abstract to Table of Contents
\addcontentsline{toc}{chapter}{Abstract}
```

An alternative solution is to use the `abstract` environment.

```
\begin{abstract}
This guide serves as an introduction to \LaTeX{}. I hope new users find it
    useful.
\end{abstract}
```

9.4 Acknowledgements

Add the following code to the document body:

```
\chapter*{Acknowledgements}

% Adding Acknowledgements to Table of Contents
\addcontentsline{toc}{chapter}{Acknowledgements}
```

9.5 Appendix

Load the appendix package as follows:

```
% Preamble
\usepackage[toc]{appendix} % Includes appendices in Table of Contents

% Body
\begin{appendices}
\chapter{Riemann Hypothesis Proof}
Sir Michael Atiyah claims the proof for the Riemann Hypothesis is as follows...
\end{appendices}
```

9.6 Bibliography

Watch this video. A few things to remember:

- Run the compilers below in the order stated:
  1. LaTeX[1]
  2. BibTeX
  3. LaTeX ($\times 2$)
- Other bibliography styles can be found here.
- When you use `\bibliography`, the .bib file name must be within the `{}`.
- When you use `\cite`, the name must within `{}` must match the name in the .bib file.

[1] You can use XeLaTeX or LuaLaTeX instead.

9.7 Index

Load the `imakeidx` package and type the following code:

```
% Preamble
\usepackage{imakeidx}

% Alphabetical Index
\begin{filecontents*}{\jobname.mst}
headings_flag 1
heading_prefix   "\\par\\penalty-50\\textbf{"
heading_suffix   "}\\\\\*\~\\\\\*"
symhead_positive "Symbols"
symhead_negative "symbols"
numhead_positive "Numbers"
numhead_negative "numbers"
delim_0 ",\~"
\end{filecontents*}

% Making the Index
\makeindex[intoc]

% Body

% Making an Index entry
This is the first index\index{first entry} entry.

% Printing the Index
\printindex
```

Next, run the compilers below in the order stated:

1. LaTeX[2]
2. MakeIndex
3. LaTeX ($\times 2$)

To change the style of index entries, refer to this table.

9.8 Hyperlinks

Load the `href` package.

[2] Refer to the footnote in 9.6

```
% Preamble
\usepackage[colorlinks, urlcolor=blue]{href}
```

Use \href to add a link.

```
This is a
    \href{https://www.google.com}
{link}.
```

This is a link.

If you just want a URL, then use \url.

```
\url{https://www.google.com}
    provides a pretty good search
    engine.
```

https://www.google.com provides a pretty good search engine.

You can also add your email address.

```
\href{mailto:prabhavkumar10@gmail.com}
{Say Hi!}
```

Say Hi!

More information about hyperlinks can be found here.

Chapter 10

Drawing

TikZ is the most powerful graphics tool in LaTeX. While it is quite complex, I introduce the basics.

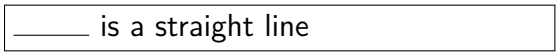
10.1 Lines

Load the `tikz` package.

```
% Preamble
\usepackage{tikz}
```

Use `\tikz...;` to draw inline. **; marks the end of the instruction and is necessary**.

```
\tikz \draw (0, 0) - - (1, 0); is a
    straight line
```



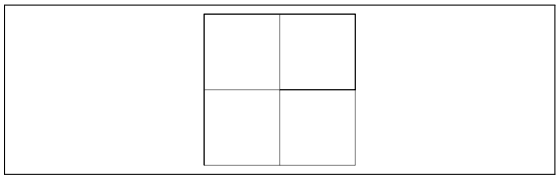
Use the `tikzpicture` environment for larger pictures.

```
\centering
\begin{tikzpicture}

% Drawing Grid Lines
\draw[help lines] (-1, -1) grid (1,
    1);

% Drawing a Path
\draw (0, 0) - - (1, 0) -- (1, 1) --
    (0, 1) -- (-1, 1) -- (-1, 0) --
    (-1, -1);

\end{tikzpicture}
```

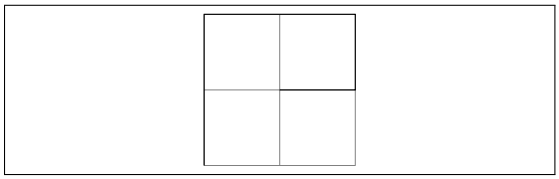


Drawing the same path using |:

```
\centering
\begin{tikzpicture}
\draw[help lines] (-1, -1) grid (1,
    1);

% Drawing Same Path
\draw (0, 0) -| (1, 1) -| (-1, -1);

\end{tikzpicture}
```



10.2 Points

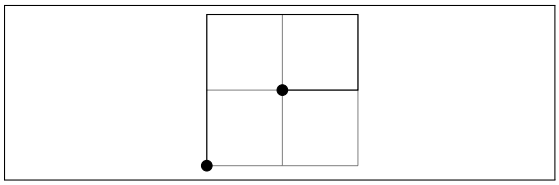
```
\centering
\begin{tikzpicture}

% Drawing Grid Lines
\draw[help lines] (-1, -1) grid (1,
    1);

% Drawing a Path
\draw (0, 0) -| (1, 1) -| (-1, -1);

% Starting & Ending Points
\filldraw (0,0) circle (2pt);
\filldraw (-1, -1) circle (2pt);

\end{tikzpicture}
```



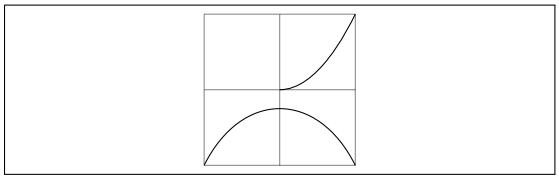
10.3 Curved Lines

```
\centering
\begin{tikzpicture}
\draw[help lines] (-1, -1) grid (1,
    1);

% Drawing a Parabola
\draw (0, 0) parabola (1, 1);

% Drawing a Curved Line
\draw (-1, -1) .. controls (-0.5, 0)
    and (0.5, 0) .. (1, -1);

\end{tikzpicture}
```

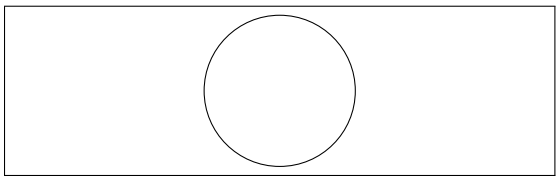


`(-1, -1)` and `(1, -1)` are the start and end points, respectively. `(-0.5, 0)` and `(0.5, 0)` act like magnets. Make sure there is no whitespace between the 2 periods before and after `controls`.

10.4 Shapes

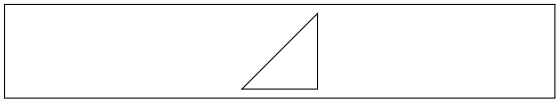
A circle centered at the origin of radius 1:

```
\centering
\begin{tikzpicture}
\draw (0, 0) circle (1);
\end{tikzpicture}
```



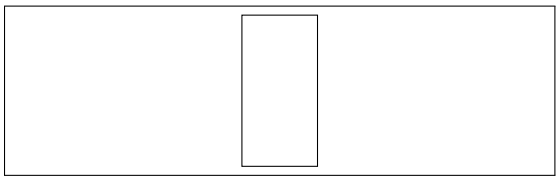
A triangle:

```
\centering
\begin{tikzpicture}
\draw (0, 0) -- (1, 0) -- (1, 1) --
    cycle;
\end{tikzpicture}
```



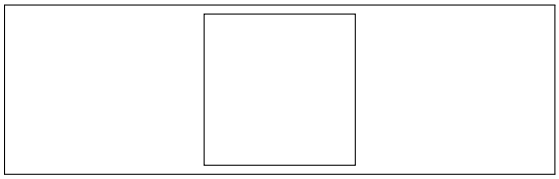
A rectangle:

```
\centering
\begin{tikzpicture}
\draw (0, 0) rectangle (1, 2);
\end{tikzpicture}
```



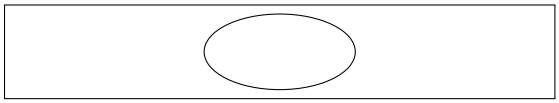
A square:

```
\centering
\begin{tikzpicture}
\draw (0, 0) rectangle (2, 2);
\end{tikzpicture}
```



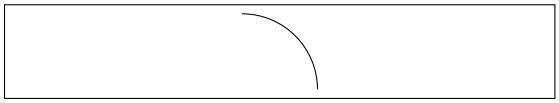
An ellipse centered at the origin with x and y-direction radii of 1 and 0.5:

```
\centering
\begin{tikzpicture}
\draw (0, 0) ellipse (1 and 0.5);
\end{tikzpicture}
```



An arc of radius 1 from 0 to 90 degrees:

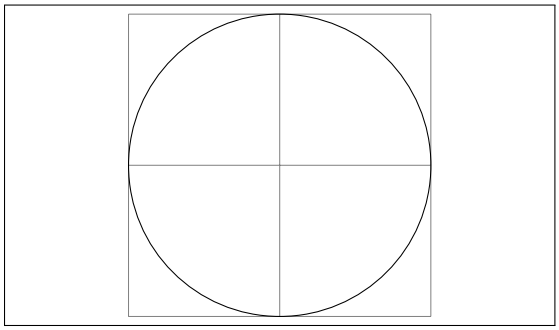
```
\centering
\begin{tikzpicture}
\draw (0, 0) arc (0:90:1);
\end{tikzpicture}
```



10.5 Scaling

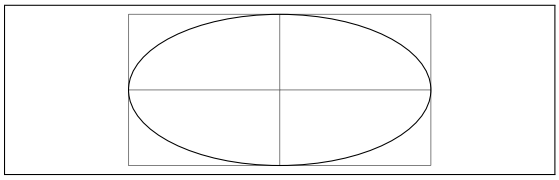
Scaling a drawing by a factor of 2:

```
\centering
\begin{tikzpicture}[scale=2]
\draw[help lines] (-1, -1) grid (1,
    1);
\draw (0, 0) circle (1);
\end{tikzpicture}
```



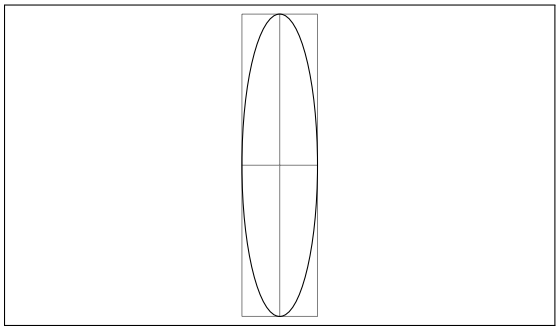
Scaling across the x-dimension:

```
\centering
\begin{tikzpicture}[xscale=2]
\draw[help lines] (-1, -1) grid (1,
    1);
\draw (0, 0) circle (1);
\end{tikzpicture}
```



Scaling across the x and y-dimensions:

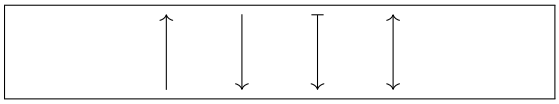
```
\centering
\begin{tikzpicture}[xscale=0.5,
    yscale=2]
\draw[help lines] (-1, -1) grid (1,
    1);
\draw (0, 0) circle (1);
\end{tikzpicture}
```



10.6 Decorating Lines

10.6.1 Arrows

```
\centering
\begin{tikzpicture}
\draw [->] (0, 0) -- (0, 1);
\draw [<-] (1, 0) -- (1, 1);
\draw [<-|] (2, 0) -- (2, 1);
\draw [<->] (3, 0) -- (3, 1);
\end{tikzpicture}
```



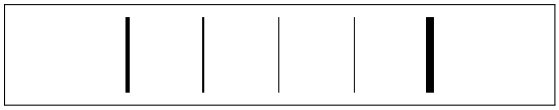
10.6.2 Line Thickness

```
\centering
\begin{tikzpicture}

% Pre-defined Thickness %
\draw [ultra thick] (0, 0) -- (0, 1);
\draw [thick] (1, 0) -- (1, 1);
\draw [thin] (2, 0) -- (2, 1);
\draw [very thin] (3, 0) -- (3, 1);

% Custom Thickness %
\draw [line width=3pt] (4, 0) -- (4,
    1);

\end{tikzpicture}
```



10.6.3 Line Styles

```
\centering
\begin{tikzpicture}
\draw [dashed, ultra thick] (0, 0)
    -- (0, 1);
\draw [dashed, thick] (1, 0) -- (1,
    1);
\draw [dotted] (2, 0) -- (2, 1);
\end{tikzpicture}
```

10.6.4 Line Color

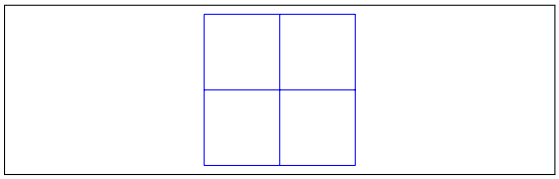
```
\centering
\begin{tikzpicture}
\draw [red, dashed, ultra thick] (0,
    0) -- (0, 1);
\draw [blue, dashed, thick] (1, 0)
    -- (1, 1);
\draw [magenta] (2, 0) -- (2, 1);
\end{tikzpicture}
```

Refer to 4.7 to use different colours.

10.6.5 Grid Lines

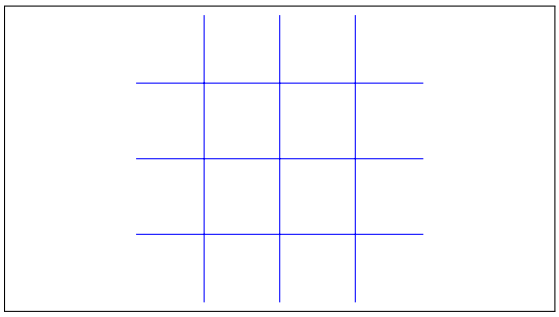
Custom grid lines:

```
\centering
\begin{tikzpicture}
\draw[step=1, blue, thin] (-1, -1)
    grid (1, 1);
\end{tikzpicture}
```



Removing outer border:

```
\centering
\begin{tikzpicture}
\draw[step=1, blue, thin] (-1.9,
    -1.9) grid (1.9, 1.9);
\end{tikzpicture}
```



10.7 Repetition

If you need to reuse lines of code to draw similar things, use `\foreach`.

```
\centering
\begin{tikzpicture}

% Vertical or Horizontal Parallel
    Lines?
\foreach \x in {0,...,100} {
\draw [red, dashed, ultra thin] (\x
    * 0.015, 0) -- (\x * 0.015, 1);
};

\end{tikzpicture}
```

You don't need to enter math mode to do math with `\x`.

Helpful Resources

I have only scratched the surface of TikZ, so please use these resources, especially if you want to create art.

1. My Favorite TikZ Manual - learn TikZ visually.
2. Minimal Introduction TiKZ - a very minimal introduction to TikZ.
3. Another TikZ Manual - a comprehensive guide for TikZ.
4. Examples - learn TikZ through examples.
5. STEM-related Drawings - STEM-related TikZ drawings and their code.

Chapter 11

Extending LaTeX

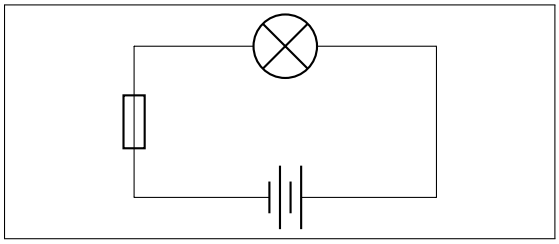
11.1 Physics

Physics has a lot of diagrams, so TikZ is important. The rest is basically math[1]. Refer to resource 5 in 10.7.

11.1.1 Circuits

My favorite physics-related package is `circuitikz`.

```
\centering
\begin{circuitikz}
\draw (0,0) to [lamp] (4,0);
\draw (4,0) to (4, -2);
\draw (4, -2) to [battery] (0, -2);
\draw (0, -2) to [fuse] (0, 0);
\end{circuitikz}
```



More information can be found here.

11.2 Chemistry

11.2.1 Basics

Load the `mhchem` package and use `\ce` in math mode to write formulae.

[1] Open to debate.

```
$\ce{H2O}$ \\
$\ce{Cl-}$ \\
$\ce{CrO4^{2}-}$ \\
$\ce{(C3H4O2)2}$
```

$\ce{H2O}$ \\
$\ce{Cl-}$ \\
$\ce{CrO4^{2}-}$ \\
$\ce{(C3H4O2)2}$

Add the amount before the formula.

```
$\ce{2O2}$ \\
$\ce{3/4Cl2}$
```

$\ce{2O2}$ \\
$\ce{3/4Cl2}$

Displaying isotopes:

```
$\ce{^{14}_{6}C}$ \\
$\ce{^{17}_{6}C+}$
```

$\ce{^{14}_{6}C}$ \\
$\ce{^{17}_{6}C+}$

11.2.2 Reactions

```
$\ce{H2 + O -> H2O}$ \\
$\ce{H2 + O ->[\text{heat}] H2O}$ \\
$\ce{H2 + O <- H2O}$ \\
$\ce{CO2 + C <=> 2CO}$
```

$\ce{H2 + O -> H2O}$ \\
$\ce{H2 + O ->[\text{heat}] H2O}$ \\
$\ce{H2 + O <- H2O}$ \\
$\ce{CO2 + C <=> 2CO}$

More information on `mhchem` can be found here.

11.2.3 Drawing Chemical Formulae

Load the `chemfig` package and use `\chemfig`.

Bonds

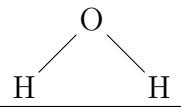
```
$\chemfig{O - H}$ \\
$\chemfig{O = H}$ \\
$\chemfig{O ~ H}$ \\
$\chemfig{O > H}$ \\
$\chemfig{O >: H}$ \\
$\chemfig{O >| H}$ \\
$\chemfig{O < H}$ \\
$\chemfig{O <: H}$ \\
$\chemfig{O <| H}$
```

$\chemfig{O - H}$ \\
$\chemfig{O = H}$ \\
$\chemfig{O ~ H}$ \\
$\chemfig{O > H}$ \\
$\chemfig{O >: H}$ \\
$\chemfig{O >| H}$ \\
$\chemfig{O < H}$ \\
$\chemfig{O <: H}$ \\
$\chemfig{O <| H}$

Bond Angles

```
\centering
Water ($\ce{H2O}$) \vspace{.5cm} \\
\chemfig{H-[1] O-[7] H} \\
```

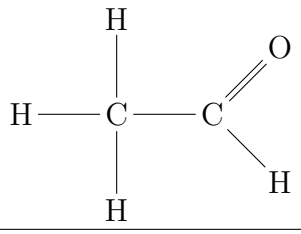
Water (H_2O)



`[x]` represents $(x * 45)^\circ$.

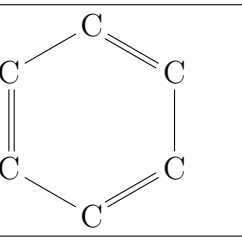
A more complex example:

```
\centering
\chemfig{H-C(-[2] H)(-[6] H)-C(=[1]
    O)-[7] H}
```



Rings

```
\centering
\chemfig{C*6(-C=C-C=C-C=)}
```



`C` is the first atom. `*6` is the number of atoms. `()` contains the rest of the atoms.

More information on `chemfig` can be found here.

11.3 Poetry

Use the `verse` package.

```
\centering
\begin{verse}
Roses are Red, \\
Violets are Blue, \\
This guide with help you.
\end{verse}
```

Roses are Red,
Violets are Blue,
This guide with help you.

More information can be found here.

11.4 Programming Languages

You may need to type out programming languages in LaTeX.

11.4.1 `verbatim` environment

The `verbatim` environment outputs text or code in monospace font.

```
\begin{verbatim}
def add(x, y):
    return x + y
\end{verbatim}
```

```
def add(x, y):
    return x + y
```

To type code inline, use `\verb`.

```
\verb|add()| returns the sum of 2
    numbers.
```

`add()` returns the sum of 2 numbers.

There should be no space between `\verb` and `|`. Any character except a letter or `*` can be used instead of `|` as a delimiter.

11.4.2 `listings` package

For more customization, use the `listings` package and the `lstlisting` environment. For example,

```
\begin{lstlisting}[language=Python, caption=Python Example]
def add(x, y):
    return x + y
\end{lstlisting}
```

produces

Listing 11.1: Python Example

```
def add(x, y):
    if x >= y:
        print(x)
    else:
        print(y)
    return x + y
```

You can also highlight code, add line numbers, and do many more things. Read this guide for more information.

Code highlighting can also be done via the `minted` package. Read about it here. **Warning**: `minted` can cause errors. However, solutions to the most common errors can be found here.

11.5 PDF Forms

Use the `Form` environment.

```
\begin{Form}[action={path/to/submit}]
\begin{tabular}{l}
    \TextField{Name} \\\\
    \CheckBox[width=1em]{Male}
    \CheckBox[width=1em]{Female}
    \CheckBox[width=1em]{Other} \\\\
    \Submit{Submit} \quad
    \Reset{Reset}\\
\end{tabular}
\end{Form}
```

Name

Male Female Other

Submit Reset

More information can be found here. A more thorough example can be found here. **Warning**: making PDF forms in LaTeX can be buggy, so it's probably better to use Adobe Acrobat.

11.6 Emojis

11.6.1 Using LuaLaTeX

Use `\emoji` provided by the `emoji` package with the LuaLaTeXcompiler as follows:

```
% Preamble
\usepackage{emoji}

% Body
\emoji{flexed-biceps-medium-dark-skin-tone}
```

A list of emojis provided by the `emoji` package can be found here.

11.6.2 Using XeLaTeX

If you need to use the XeLaTeXcompiler, download the Symbola font on your local PC and do the following:

```
I am {\fontspec{Symbola}\char"1F600}!
```

I am 😀!

Here is a list of emoji codes.

11.6.3 Using Images

Another option is to insert emojis at images. Read this article for more details.

11.7 Writing a CV

If you want to write your CV with LaTeX, choose one of the templates and edit accordingly. I have also uploaded a template on GitHub.

11.8 Writing a Thesis

If you don't know how to write a thesis, read this guide. If you want to write your thesis with LaTeX, choose one of the templates and edit accordingly. If you want a video walkthrough, these are the best videos I have come across.

11.9 Presentations

`beamer` is the document class for presentations. I learnt `beamer` using Overleaf's tutorials. You can find examples of aesthetically pleasing presentations here. A list of `beamer` themes can be found here.

Chapter 12

Clever Tricks

Here is a list of LaTeX hacks:

1. `\today` - prints today's date (December 24, 2021).
2. `\TeX` - prints TeX.
3. `\LaTeX` - prints LaTeX.
4. **Negations** - place `n` or `\not` before a math symbol command to get its negation: `\in` prints $\in$ and `\not\in` prints $\notin$ (doesn't always work).
5. **One Bracket** - use `\left.` (or `\right.`) if you only need 1 delimiter: `\left.\frac{1}{2}\right)` yields $\frac{1}{2}\Big)$.

Chapter 13

Common Errors

1. **Too few braces** - `\section{I am missing a closing brace!`
2. **Too many braces** - `\section{I have an extra brace}}`
3. **Non-matching braces** - `\section[My braces don't match}`
4. **Missing environment end** - `\begin{enumerate} \item Don't forget to add \end{enumerate}`
5. `hbox` **errors** - read this.
6. **Forgetting to use \ to escape** - `$` does not print $.
7. **Forgetting to use math mode** - `a^2 + b^2 = c^2` will cause an error, but `$a^2 + b^2 = c^2$` will not (remember to place mathematical symbols, expressions, and statements in math mode).
8. `\\` **error** - if you get a "There's no line here to end" error, try `$\\$`.
9. **URL error** - if you can't open a URL, try adding `http://` or `https://`
10. **Compiler error** - If you use external packages and get an error, you may be using the wrong compiler: e.g. `fontspec` needs XeLaTeX or LuaLaTeX.
11. **Footnote / Index / References / Labels / Links not showing** - recompile the document multiple times to typeset successfully.
12. **Declaring packages in wrong order** - declare the `hyperref` package last (as it causes most of the issues). A more comprehensive list of package conflicts can be found here.

Chapter 14

More Resources

As LaTeX is open-source, resources are infinite. Popular resources include:

1. **Big Resources**
   - Search Engine - Google.
   - CTAN - LaTeX's humble abode.
   - Stack Exchange - ask questions.
   - LaTeX Forum - ask questions.
   - LaTeX Subreddit - for reddit fans.
2. **Learn LaTeX**
   - Overleaf - learn and write LaTeX online (highly recommended).
   - Wikibooks - a more comprehensive LaTeX online guide (highly recommended).
   - LaTeX Playlist - learn LaTeX on YouTube.
   - Dr Trefor Bazett - learn LaTeX from a mathematician.
   - The Art of LaTeX - book to learn LaTeX.
   - The Not So Short Introduction to LaTeX - Bible of LaTeX.
   - LaTeX Gallery - LaTeX templates (highly recommended).
3. **Cheat Sheets**
   - LaTeX Cheat Sheet - 2-page cheat sheet.
   - LaTeX Math Cheat Sheet - Math cheat sheet.
   - LaTeX Quick Guide - 2-page guide.
4. **Some Pretty Cool Stuff**
   - Mathpix Snip Notes - convert images and pdf documents to LaTeX.

More Resources

- LaTeX + Vim - writing LaTeX in Vim.
- LaTeX + Notion - writing LaTeX in Notion.
- `logicpuzzle` - create puzzles (sudoku, battleship etc.) with LaTeX.
- For Coffee Lovers - place coffee stains on LaTeX documents.
- Even more resources - an awesome list of LaTeX resources.

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