Scientific Writing with LaTeX

Part 2: Layout and Visuals

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Columns with `multicol`

Two-column document

```
% Option 1: entire document
\documentclass[twocolumn]{article}

% Option 2: specific sections
\usepackage{multicol}
\begin{multicols}{2}
  Text flows into two columns.
\end{multicols}
```

Side-by-side with minipage

```
\begin{minipage}{0.45\textwidth}
  Left content.
\end{minipage}
\hfill
\begin{minipage}{0.45\textwidth}
  Right content.
\end{minipage}
```

When to use which

multicol: flowing text.
minipage: placing specific blocks side-by-side.

Colors with `xcolor`

Basic usage

```
\usepackage{xcolor}

\textcolor{red}{Red text}
\textcolor{blue!50}{Light blue}
\colorbox{yellow}{Highlighted}
\fcolorbox{red}{yellow}{Framed}
```

Define custom colors

```
\definecolor{myblue}{RGB
    }{0,102,204}
\definecolor{mygray}{gray}{0.6}
\textcolor{myblue}{Custom blue}
```

Color models

- ▶ RGB — 0–255 per channel
- ▶ rgb — 0–1 per channel
- ▶ HTML — hex code
- ▶ gray — 0 (black) to 1 (white)

Color mixing

```
blue!30          % 30% blue
red!50!yellow    % 50-50 mix
green!20!black   % dark green
```

Boxes

Built-in

```
\fbox{Framed text}

\parbox{4cm}{A paragraph box
  with fixed width.}

\colorbox{yellow!30}{
  Highlighted note
}
```

Framed text
A paragraph box with
fixed width.
Highlighted note

Fancy: `tcolorbox`

```
\usepackage{tcolorbox}

\begin{tcolorbox}[
  colback=blue!5,
  colframe=gray,
  title={My Box}
]
  Nice framed content.
\end{tcolorbox}
```

Result

Nice framed content.

hyperref — Links and PDF Metadata

Setup (load last in preamble)

```
\usepackage{hyperref}
\hypersetup{
  colorlinks=true,
  linkcolor=black,
  citecolor=green!50!black,
  urlcolor=blue!70!black,
  pdftitle={My Paper},
  pdfauthor={Alice Smith}
}
```

Automatically makes TOC, refs, and cites clickable.

Manual links

```
\url{https://ctan.org}

\href{https://ctan.org}{CTAN}

\href{mailto:me@uni.pt}
    {me@uni.pt}
```

With labels

```
See Section~\ref{sec:intro}
% now clickable!

Equation~\eqref{eq:euler}
% parenthesized + clickable
```

Math Mode — Inline vs Display

Inline math

```
The equation $E = mc^2$ changed
physics. Variable $x \in \mathbb{R
    }$.
```

The equation $E = mc^2$ changed physics.

Display math (unnumbered)

```
\[ E = mc^2 \]
```

$$E = mc^2$$

Display math (numbered)

```
\begin{equation}
  E = mc^2
  \label{eq:einstein}
\end{equation}
```

$$E = mc^2 \qquad (1)$$

Never use \$\$...\$\$

Double-dollar is plain TeX and causes spacing issues. Always use \[...\] or equation.

Greek Letters

Lower		Upper	
\alpha	α	\Gamma	Γ
\beta	β	\Delta	Δ
\gamma	γ	\Theta	Θ
\delta	δ	\Lambda	Λ
\epsilon	ϵ	\Sigma	Σ
\theta	θ	\Omega	Ω
\lambda	λ	\Phi	Φ
\sigma	σ	\Psi	Ψ

Variants: \varepsilon (ε), \varphi (φ)

Common symbols

Command	Output
\infty	∞
\partial	∂
\nabla	∇
\forall	$\forall$
\exists	$\exists$
\in, \notin	$\in, \notin$
\leq, \geq	$\leq, \geq$
\neq, \approx	$\neq, \approx$
\times, \cdot	$\times, \cdot$
\rightarrow	$\rightarrow$

Fractions, Roots, Sub/Superscripts

Sub/superscripts

```
x^2     x^{2n+1}     a_i     a_{ij}
```

x^2 x^{2n+1} a_i a_{ij}

Fractions

```
\frac{a}{b}     \dfrac{a}{b}
\tfrac{a}{b}
```

$\frac{a}{b}$ $\dfrac{a}{b}$ $\tfrac{a}{b}$

\dfrac forces display size; \tfrac forces text size.

Roots

```
\sqrt{x}     \sqrt[3]{x}
\sqrt{x^2 + y^2}
```

$\sqrt{x}$ $\sqrt[3]{x}$ $\sqrt{x^2 + y^2}$

Binomial and dots

```
\binom{n}{k}
\ldots  \cdots  \vdots  \ddots
```

$\binom{n}{k}$ $a_1, \ldots, a_n$ $a_1 + \cdots + a_n$

Sums, Integrals, Limits

```
\sum_{i=1}^{n} x_i      \quad    \prod_{j=1}^{m} a_j
\int_{0}^{\infty} e^{-x}\, dx      \quad    \lim_{n \to \infty} \frac{1}{n}
```

$$\sum_{i=1}^{n} x_i \qquad \prod_{j=1}^{m} a_j \qquad \int_0^\infty e^{-x}\, dx \qquad \lim_{n\to\infty} \frac{1}{n}$$

Spacing trick

Use \, before dx: compare $\int f(x)dx$ vs $\int f(x)\, dx$.

Aligned Equations

`align` environment

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

$$f(x) = x^2 + 2x + 1 \qquad (2)$$
$$= (x + 1)^2 \qquad (3)$$

Use align* for no numbering. The & marks the alignment point.

Piecewise with `cases`

```
f(x) = \begin{cases}
  x^2  & \text{if } x \geq 0 \\
  -x   & \text{if } x < 0
\end{cases}
```

$$f(x) = \begin{cases} x^2 & \text{if } x \geq 0 \\ -x & \text{if } x < 0 \end{cases}$$

Matrices

```
\begin{pmatrix}
  a & b \\ c & d
\end{pmatrix}

\begin{bmatrix}
  1 & 0 \\ 0 & 1
\end{bmatrix}

\begin{vmatrix}
  a & b \\ c & d
\end{vmatrix}
```

Rendered:

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \qquad \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad \begin{vmatrix} a & b \\ c & d \end{vmatrix}$$

Large matrix with dots:

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

Math Fonts and Decorations

Font commands

Command	Result
`\mathbb{R}`	$\mathbb{R}$
`\mathcal{L}`	$\mathcal{L}$
`\mathbf{x}`	$\mathbf{x}$
`\mathrm{Var}`	Var
`\boldsymbol{\mu}`	$\boldsymbol{\mu}$

Use `\mathbb{}` for $\mathbb{N}, \mathbb{Z}, \mathbb{Q}, \mathbb{R}, \mathbb{C}$.

Accents and decorations

Command	Result
`\hat{x}`	$\hat{x}$
`\bar{x}`	$\bar{x}$
`\tilde{x}`	$\tilde{x}$
`\vec{x}`	$\vec{x}$
`\dot{x}`, `\ddot{x}`	$\dot{x}, \ddot{x}$
`\overline{abc}`	$\overline{abc}$
`\underbrace{a+b}_{c}`	$\underbrace{a+b}_{c}$

Theorems, Proofs, and Math Tips

Theorems (preamble setup)

```
\usepackage{amsthm}
\newtheorem{theorem}{Theorem}
\newtheorem{lemma}[theorem]{Lemma}
```

Usage

```
\begin{theorem}[Pythagoras]
  $a^2 + b^2 = c^2$
\end{theorem}
\begin{proof}
  Left as an exercise.
\end{proof}
```

Auto-sizing delimiters

```
\left( \frac{a}{b} \right)
\left[ \sum_i x_i \right]
\left. \frac{d}{dx} \right|_{x=0}
```

$$\left(\frac{a}{b} \right) \qquad \left. \frac{d}{dx} \right|_{x=0}$$

Custom operators

```
\DeclareMathOperator{\argmax}
  {arg\,max}
```

Basic Tables with `tabular`

```
\begin{tabular}{l c r}
  \hline
  Name  & Grade & Score \\
  \hline
  Alice & A     & 95    \\
  Bob   & B+    & 87    \\
  Carol & A-    & 91    \\
  \hline
\end{tabular}
```

Name	Grade	Score
Alice	A	95
Bob	B+	87
Carol	A-	91

Column specifiers

l	left-aligned
c	centered
r	right-aligned
p{3cm}	paragraph (fixed width)
|	vertical line

`&` separates columns, `\\` ends a row, `\hline` draws a line.

Professional Tables with `booktabs`

```
\usepackage{booktabs}

\begin{table}[htbp]
  \centering
  \caption{Student Results}
  \label{tab:results}
  \begin{tabular}{lcc}
    \toprule
    Name  & Grade & Score \\
    \midrule
    Alice & A     & 95    \\
    Bob   & B+    & 87    \\
    Carol & A-    & 91    \\
    \bottomrule
  \end{tabular}
\end{table}
```

Result:

Name	Grade	Score
Alice	A	95
Bob	B+	87
Carol	A-	91

Golden rule

Never use vertical lines. Use only three horizontal rules: \toprule, \midrule, \bottomrule.

`multicolumn` **and** `multirow`

```
\usepackage{multirow}

\begin{tabular}{llcc}
  \toprule
  & & \multicolumn{2}{c}
      {\textbf{Scores}} \\
  \cmidrule(lr){3-4}
  \textbf{Group} & \textbf{Name}
    & \textbf{T1} & \textbf{T2} \\
  \midrule
  \multirow{2}{*}{A}
    & Alice & 95 & 88 \\
    & Bob   & 87 & 92 \\
  \midrule
  \multirow{2}{*}{B}
    & Carol & 91 & 85 \\
    & Dave  & 78 & 90 \\
  \bottomrule
\end{tabular}
```

Result:

		Scores	
Grp	**Name**	**T1**	**T2**
A	Alice	95	88
	Bob	87	92
B	Carol	91	85
	Dave	78	90

\cmidrule(lr){3-4} draws a partial rule under columns 3–4.

Table Placement and Generators

Float placement

```
\begin{table}[htbp]
  \centering
  ...
\end{table}
```

h = here, t = top, b = bottom, p = own page.

Use [H] from the float package to force position (use sparingly).

Online generators

- ▶ https://www.tablesgenerator.com
  Paste from Excel/CSV, get LaTeX

- ▶ https://www.latex-tables.com
  Visual editor with booktabs

From CSV

The csvsimple or pgfplotstable packages can read CSV files directly into tables.

Including Images

```
\usepackage{graphicx}

\includegraphics{photo.png}

\includegraphics[
  width=0.8\textwidth
]{photo.png}

\includegraphics[
  width=5cm,
  keepaspectratio,
  angle=45,
  trim=1cm 2cm 1cm 0cm,
  clip
]{photo.png}
```

Common options

Option	Effect
width=	Set width
height=	Set height
scale=0.5	Scale factor
angle=90	Rotate
keepaspectratio	No distortion
trim=L B R T	Crop edges

Formats

pdflatex: PDF, PNG, JPG
Use PDF for plots, PNG for screenshots, JPG for photos.

The `figure` Environment

```latex
\begin{figure}[htbp]
  \centering
  \includegraphics[
    width=0.7\textwidth
  ]{diagram.pdf}
  \caption{System overview.}
  \label{fig:architecture}
\end{figure}

See Figure~\ref{fig:architecture}.
```

Key points

- ▶ `\centering` centers the image
- ▶ `\caption{...}` adds a numbered caption
- ▶ `\label{...}` must be **after** caption
- ▶ `[htbp]` controls placement

Common mistake

Placing `\label` before `\caption` gives wrong reference numbers.

Side-by-Side Figures

```latex
\usepackage{subcaption}

\begin{figure}[htbp]
  \centering
  \begin{subfigure}[b]{0.45\textwidth}
    \centering
    \includegraphics[width=\textwidth]{before.png}
    \caption{Before treatment}
    \label{fig:before}
  \end{subfigure}
  \hfill
  \begin{subfigure}[b]{0.45\textwidth}
    \centering
    \includegraphics[width=\textwidth]{after.png}
    \caption{After treatment}
    \label{fig:after}
  \end{subfigure}
  \caption{Treatment comparison.}
  \label{fig:comparison}
\end{figure}
```

Image Tips

Set a graphics path

```
\graphicspath{{images/}{figures/}}

% Now just write:
\includegraphics{photo.png}
```

Vector vs raster

- ▶ **PDF**: diagrams, plots (vector)
- ▶ **PNG**: screenshots (lossless)
- ▶ **JPG**: photographs (lossy)

Export plots as PDF

Python: `plt.savefig('plot.pdf')`
R: `ggsave('plot.pdf')`
Vector graphics look sharp at any zoom.

Wrap figures

The wrapfig package lets text flow around images:
`\begin{wrapfigure}{r}{0.3\textwidth}`

Table of Contents

```
\begin{document}
\maketitle
\tableofcontents
\newpage

\section{Introduction}
...
\subsection{Background}
...
\section{Methods}
...
```

LaTeX builds the TOC from your sections. Needs two compilations.

Related commands

- ▶ \listoffigures
- ▶ \listoftables
- ▶ \setcounter{tocdepth}{2}

Manual entries

```
\addcontentsline{toc}
  {section}{Custom Entry}
```

Starred sections (\section*{}) need this to appear in the TOC.

Splitting Documents: \input and \include

Project structure

```
thesis/
  main.tex
  preamble.tex
  chapters/
    01-intro.tex
    02-methods.tex
    03-results.tex
  figures/
  references.bib
```

main.tex

```
\documentclass[12pt]{report}
\input{preamble}

\begin{document}
\maketitle
\tableofcontents

\input{chapters/01-intro}
\input{chapters/02-methods}
\input{chapters/03-results}

\printbibliography
\end{document}
```

\input{file}: pastes content, no page break, can nest. \include{file}: adds page breaks, supports \includeonly{}.

\input vs. \include

Feature	\input	\include
Analogy	"Copy-Paste"	"Chapter Manager"
Page Break?	No	Yes (Always)
In Preamble?	Yes	No
Nesting?	Yes	No
Speed?	Standard	Fast (via includeonly)

Use \input for:

Small snippets, tables, and preamble settings.

Use \include for:

Large structural blocks like Chapters or Appendices.

End of Part 2

Next: Graphics (Ti*k*Z and PGFplots)

(More coffee!)