

Introduction to L^AT_EX

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What is L^AT_EX?

- A professional typesetting system for technical documents
- Widely used in Computer Science, Mathematics, Physics
- Ideal for documents with formulas, algorithms, references
- Not a word processor — you write source code that compiles into PDF

\LaTeX vs. Word Processors

Word:

$$KL(P \parallel Q) = E_{x \sim P} \log \frac{P(x)}{Q(x)}$$

Beamer (\LaTeX slides):

$$\text{KL}(P \parallel Q) = \mathbb{E}_{x \sim P} \log \frac{P(x)}{Q(x)}$$

Proper \LaTeX :

$$\text{KL}(P \parallel Q) = \mathbb{E}_{x \sim P} \log \frac{P(x)}{Q(x)}$$

Why \LaTeX ?

For academic writing:

- required by most CS conferences and journals;
- consistent, professional formatting;
- automatic numbering (sections, figures, equations, references);
- excellent math typesetting;
- reproducible builds from source.

In practice:

- Overleaf: collaborative online \LaTeX editor;
- local editors: TeXstudio, VS Code + LaTeX Workshop.

Workflow

1. Write .tex source file;
2. Compile with pdflatex (or xelatex, lualatex);
3. Run bibtex/biber for references;
4. Recompile (twice) to resolve cross-references;
5. Get PDF output.

Most editors handle this automatically.

Document Structure

Minimal Document

A minimal \LaTeX document:

```
\documentclass{article}
```

```
\begin{document}
```

Hello, World!

```
\end{document}
```

- `\documentclass{...}` — type of document (`article`, `report`, `book`, `beamer`);
- `\begin{document}... \end{document}` — the document body.

Preamble

Everything between `\documentclass` and `\begin{document}` is the **preamble**:

```
\documentclass[12pt, a4paper]{article}
```

```
\usepackage[utf8]{inputenc}  
\usepackage{amsmath}  
\usepackage{graphicx}  
\usepackage{hyperref}
```

```
\title{My First Paper}  
\author{Jane Doe}  
\date{\today}
```

```
\begin{document}  
\maketitle  
...  
\end{document}
```

Common Document Classes

- `article` — short documents, papers;
- `report` — longer documents with chapters;
- `book` — books, theses;
- `beamer` — presentations (slides);
- many conferences provide their own class (e.g., `llncs`, `acmart`).

Packages

Packages extend L^AT_EX functionality:

```
\usepackage{amsmath}           % advanced math
\usepackage{graphicx}          % include images
\usepackage{hyperref}          % clickable links
\usepackage{booktabs}           % professional tables
\usepackage{algorithm2e}         % algorithm pseudocode
\usepackage{listings}           % source code
\usepackage{tikz}                % diagrams
```

Load packages in the preamble with

```
\usepackage[options]{name}.
```

Sectioning

LATEX provides hierarchical sections:

```
\section{Introduction}  
\subsection{Background}  
\subsubsection{Details}  
\paragraph{Note}
```

- Sections are automatically numbered;
- `\section*{...}` — unnumbered version;
- `\tableofcontents` — generates table of contents automatically.

Text Formatting

Basic Text Formatting

```
\textbf{bold text}  
\textit{italic text}  
\texttt{monospace text}  
\underline{underlined text}  
  
\emph{emphasized} % italic in normal text,  
                  % normal in italic context
```

Result: **bold text**, *italic text*, monospace text

Lists

Itemized (bullet) list:

```
\begin{itemize}
    \item First item
    \item Second item
\end{itemize}
```

Enumerated (numbered) list:

```
\begin{enumerate}
    \item First item
    \item Second item
\end{enumerate}
```

Lists can be nested.

Special Characters

Some characters have special meaning in L^AT_EX:

```
\%  \$  &  #  _  {  }  
\textbackslash  \textasciitilde
```

- % — comment (rest of line is ignored);
- \$ — math mode delimiter;
- & — column separator in tables;
- \\ — line break;
- ~ — non-breaking space.

Whitespace and Line Breaks

- Multiple spaces are treated as one space;
- an empty line starts a new paragraph;
- `\\" forces a line break;`
- `\newpage` starts a new page;
- `\noindent` suppresses paragraph indentation.

First paragraph text.

Second paragraph text.

`\noindent` Third paragraph, no indent.

Mathematics

Inline and Display Math

Inline math — within text:

The equation $\$E = mc^2\$$ is famous.

The equation $E = mc^2$ is famous.

Display math — centered on its own line:

$\backslash[E = mc^2 \backslash]$

$$E = mc^2$$

Numbered equation

Numbered equation:

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

The equation~\eqref{eq:einstein} is famous.

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

The equation (1) is famous.

Basic Math Notation

```
x^2          % superscript  
x_i          % subscript  
x_{i+1}^2    % grouped sub/superscript  
\frac{a}{b}   % fraction  
\sqrt{x}     % square root  
\sqrt[3]{x}   % cube root
```

$$x^2 \quad x_i \quad x_{i+1}^2 \quad \frac{a}{b} \quad \sqrt{x} \quad \sqrt[3]{x}$$

Greek Letters and Symbols

```
\alpha \beta \gamma \delta \epsilon  
\theta \lambda \mu \sigma \omega  
\Gamma \Delta \Theta \Lambda \Omega  
\infty \partial \nabla \forall \exists  
\in \notin \subset \cup \cap  
\leq \geq \neq \approx \equiv
```

$$\alpha \beta \gamma \delta \epsilon \quad \theta \lambda \mu \sigma \omega$$
$$\Gamma \Delta \Theta \Lambda \Omega \quad \infty \partial \nabla \forall \exists$$

Sums, Products, Integrals

\sum_{i=1}^n x_i

\prod_{i=1}^n x_i

\int_a^b f(x) \, dx

\lim_{n \rightarrow \infty} a_n

$$\sum_{i=1}^n x_i \quad \prod_{i=1}^n x_i \quad \int_a^b f(x) \, dx \quad \lim_{n \rightarrow \infty} a_n$$

Matrices

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

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

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

- `pmatrix` — round brackets;
- `bmatrix` — square brackets;
- `vmatrix` — determinant (vertical bars).

Aligned Equations

The align environment (from amsmath):

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

- & marks alignment point;
- \\ separates lines;
- align* for unnumbered version.

$$f(x) = x^2 + 2x + 1 \tag{2}$$

$$= (x + 1)^2 \tag{3}$$

Common Math Environments

- `equation` — single numbered equation;
- `align` — multiple aligned equations;
- `gather` — multiple centered equations;
- `cases` — piecewise definitions:

```
f(x) = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}
```

$$f(x) = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases} \quad (4)$$

Example: Machine Learning

A practical example — softmax function:

$$\text{softmax}(z_i) = \frac{e^{z_i}}{\sum_{j=1}^K e^{z_j}}$$

Cross-entropy loss:

$$\begin{aligned}\mathcal{L} = -\sum_{i=1}^N \sum_{c=1}^C & y_{i,c} \log(\hat{y}_{i,c})\end{aligned}$$

$$\text{softmax}(z_i) = \frac{e^{z_i}}{\sum_{j=1}^K e^{z_j}} \quad \mathcal{L} = - \sum_{i=1}^N \sum_{c=1}^C y_{i,c} \log(\hat{y}_{i,c})$$

Math Alphabets

Different letter styles carry different meaning:

```
\mathbb{R}      % blackboard bold  
\mathcal{L}   % calligraphic  
\mathbf{x}    % bold upright  
\boldsymbol{\theta} % bold italic  
\mathit{MSE}  % italic  
\mathrm{softmax} % upright roman
```

\mathbb{R} \mathcal{L} \mathbf{x} $\boldsymbol{\theta}$ MSE $\mathrm{softmax}$

Prefer `\DeclareMathOperator` over `\mathrm` for named functions.

Auto-sizing Delimiters

Use `\left` and `\right` to make delimiters scale with content:

```
\left( \frac{a}{b} \right)  
\left[ \sum_{i=1}^n x_i \right]  
\left\{ x \in \mathbb{R} \mid x > 0 \right\}  
\left| A \right|_F  
\left| \sum_i \frac{1}{\sqrt{a_i}} \psi_i \right>
```

$$\left(\frac{a}{b} \right) \quad \left[\sum_{i=1}^n x_i \right] \quad \{x \in \mathbb{R} \mid x > 0\} \quad \left| \sum_i \frac{1}{\sqrt{a_i}} \psi_i \right>$$

Auto-sizing Delimiters

\middle scales a delimiter in the middle:

```
P\left( A \middle| B \right)  
\mathrm{KL}\left(P \middle\| Q\right)  
\left< \sum_i \psi_i \middle| \sum_i \phi_i \right>
```

$$P(A | B)$$

$$\mathrm{KL}(P \| Q)$$

$$\left\langle \sum_i \psi_i \middle| \sum_i \phi_i \right\rangle$$

\right. — invisible right delimiter.

Auto-sizing Delimiters

\left and \right automatically adjusts with nesting:

```
L(\theta) = \prod_j \left[ \frac{1}{Z_j} \left( \sum_i f_j \left( \frac{P(X)}{Q(X)} \right) \right) \right]
```

$$L(\theta) = \prod_j \left[\frac{1}{Z_j} \left(\sum_i f_j \left(\frac{P(X)}{Q(X)} \right) \right) \right]$$

Equation Annotations

Annotate parts of an equation with `\underbrace` and `\overbrace`:

```
\underbrace{x^\top W x}_{\text{quadratic form}}  
+ \overbrace{\lambda \|\theta\|^2}^{\text{regularizer}}
```

$$\underbrace{x^\top W x}_{\text{quadratic form}} + \overbrace{\lambda \|\theta\|^2}^{\text{regularizer}}$$

Equation Annotations

Place symbols above or below with \overset and \underset:

```
A \overset{\text{def}}{=} B  
x \underset{n \rightarrow \infty}{\longrightarrow} 0
```

$$A \stackrel{\text{def}}{=} B \quad x \underset{n \rightarrow \infty}{\longrightarrow} 0$$

Math Spacing

T_EX sometimes needs spacing hints inside math:

Command	Size	Typical use
\!	$-\frac{3}{18}$ mu	tighten adjacent symbols
\,	$\frac{3}{18}$ mu	before dx in integrals
\:	$\frac{4}{18}$ mu	binary operators
\;	$\frac{5}{18}$ mu	before/after text in math
\quad	1 em	separating cases or labels
\quad\quad	2 em	wide alignment gaps

Math Spacing: common patterns

```
\int_a^b f(x) \, dx           % thin space before dx  
\mathrm{d}x  
f : \mathbb{R}^n \rightarrow \mathbb{R}    % upright d  
P\left(A \mid B\right)          % colon in function type  
                                % \mid gives correct spacing
```

$$\int_a^b f(x) \, dx$$

$$f: \mathbb{R}^n \rightarrow \mathbb{R}$$

$$P(A \mid B)$$

Floats: Figures and Tables

Including Figures

```
\begin{figure}[htbp]
    \centering
    \includegraphics[width=0.8\textwidth]{image.png}
    \caption{Description of the figure.}
    \label{fig:example}
\end{figure}
```

- [htbp] — placement hints: here, top, bottom, page;
- \centering — center the figure;
- \caption — figure caption (auto-numbered);
- \label — for cross-referencing.

Tables: example

```
\begin{table}[htbp]
\centering
\caption{Comparison of optimization methods.}
\label{tab:optimizers}
\begin{tabular}{lccc}
\toprule
Optimizer & Learning Rate & Epochs & Test Acc. \\
\midrule
SGD & 0.01 & 100 & 0.88 \\
Adam & 0.001 & 50 & 0.91 \\
AdamW & 0.001 & 50 & \textbf{0.93} \\
\bottomrule
\end{tabular}
\end{table}
```

Use booktabs package for \toprule, \midrule, \bottomrule.

Tables: example

Table 1: Comparison of optimization methods.

Optimizer	Learning Rate	Epochs	Test Acc.
SGD	0.01	100	0.88
Adam	0.001	50	0.91
AdamW	0.001	50	0.93

Table Column Types

Column alignment specifiers in `\begin{tabular}{...}`:

- l — left-aligned;
- c — centered;
- r — right-aligned;
- p{width} — paragraph column with fixed width;
- | — vertical line (avoid in professional tables).

```
\begin{tabular}{l|cc|r}
  Name & Score 1 & Score 2 & Total \\
\hline
  Alice & 95 & 88 & 183 \\
\end{tabular}
```

Table Column Types

```
\begin{tabular}{l|cc|r}
  Name & Score 1 & Score 2 & Total \\
\hline
 Alice & 95 & 88 & 183 \\
\end{tabular}
```

Name	Score 1	Score 2	Total
Alice	95	88	183

Cross-references and Citations

Labels and References

\LaTeX can reference any numbered element:

```
\section{Introduction}  
\label{sec:intro}
```

As shown in Figure~\ref{fig:arch}
and Equation~\eqref{eq:loss}
(see Section~\ref{sec:intro}).

- `\label{...}` — place after `\caption`, `\section`, or in an equation;
- `\ref{...}` — produces the number;
- `\eqref{...}` — equation reference with parentheses;
- `~` — non-breaking space before the reference.

Bibliography with BibTeX

Create a .bib file:

```
@article{vaswani2017attention,  
    title={Attention is all you need},  
    author={Vaswani, Ashish and others},  
    journal={NeurIPS},  
    year={2017}  
}
```

In the document:

Transformers~\cite{vaswani2017attention}
have revolutionized NLP.

```
\bibliographystyle{plain}  
\bibliography{references}
```

Citation Commands

Basic commands:

- `\cite{key}` — [1] or (Author, Year);
- `\cite{key1, key2}` — multiple citations.

With `natbib` package:

- `\citet{key}` — textual: Author (Year);
- `\citep{key}` — parenthetical: (Author, Year);
- `\citep[see][]{key}` — (see Author, Year).

Compilation with References

To resolve all references:

pdflatex document

bibtex document

pdflatex document

pdflatex document

Multiple passes needed because:

1. first pass collects labels and citations;
2. bibtex generates bibliography;
3. second pass inserts references;
4. third pass resolves page numbers.

Useful Environments and Tips

Code Listings

Using the `listings` package:

```
\begin{lstlisting}[language=Python]
def hello():
    print("Hello, World!")
\end{lstlisting}
```

Or the `minted` package (requires Python's Pygments):

```
\begin{minted}{python}
def hello():
    print("Hello, World!")
\end{minted}
```

Theorem-like Environments

Define in the preamble:

```
\newtheorem{theorem}{Theorem}  
\newtheorem{lemma}{Lemma}  
\newtheorem{definition}{Definition}
```

Use in the document:

```
\begin{theorem}  
    For all  $n \geq 1$ :  
     $\sum_{i=1}^n i = \frac{n(n+1)}{2}.$   
\end{theorem}  
\begin{proof}  
    By induction on  $n$ ...  
\end{proof}
```

Theorem-like Environments

Theorem

For all $n \geq 1$: $\sum_{i=1}^n i = \frac{n(n+1)}{2}$.

Proof.

By induction on n ... □

Common Mistakes

Avoid these pitfalls:

- forgetting {} for multi-character sub/superscripts: x^{10} vs. $x^{\{10\}}$:
 - x^{10} vs. x^{10}
- using " instead of ' and '' for quotes;
- not escaping special characters: 50% should be 50\%;
- placing \label before \caption (label will be wrong);
- ignoring warnings about undefined references.

Useful Commands to Know

```
\phantom{text}          % invisible space
\vspace{1cm}           % vertical space
\hspace{1cm}            % horizontal space
\textcolor{red}{txt}    % colored text (xcolor)
\url{https://...}       % typeset URL (hyperref)
\footnote{text}         % footnote
\todo{Fix this}        % margin note (todonotes)
```

LATEX Programming

T_EX: the Engine

L^AT_EX is a **macro package** built on top of **T_EX**:

- **T_EX** — a Turing-complete macro expansion language + typesetting engine (Knuth, 1978);
- **L^AT_EX** provides a high-level API: `\begin{}`, `\newcommand`, `\usepackage`, ...;
- understanding **T_EX** fundamentals helps when **L^AT_EX** macros need to be more powerful.

Engine family: pdfT_EX · XeT_EX · LuaT_EX — all extend the original T_EX engine.

Macro packages: plain T_EX, L^AT_EX, ConT_EXt — different macro layers on the same engine.

Tokens and Category Codes

TeX reads input character by character and assigns each a **category code** (catcode):

- **catcode 0** — escape character \: starts a control sequence;
- **catcode 1/2** — begin/end group { }: creates a local scope;
- **catcode 3** — math shift \$: enters/exits math mode;
- **catcode 11** — letter: part of a control sequence name;
- **catcode 14** — comment %: rest of line is ignored.

A **control sequence** like `\frac` is a single token regardless of its length.

Catcodes can be changed — this is how `\verb` works: it temporarily makes \ an ordinary character.

Groups and Scoping

{ } create a **local group** — all assignments inside are reverted on exit:

```
{\color{red} red text}      % color reverts after }
{\large big text}        % font size reverts after }
{\def\x{local}}          % \x is undefined after }
```

All T_EX assignments are **local by default**:

- `\setlength`, `\def`, font commands, color, etc.;
- `\global` prefix makes an assignment permanent (use sparingly).

This is why font/color commands are typically written as `{\large text}` — no explicit reset needed.

\def: the TeX Primitive

The primitive \def defines macros directly:

```
\def\R{\mathbb{R}}                                % no arguments  
\def\norm#1{\left\| #1 \right\|}            % one argument  
\def\pair#1#2{\langle #1, #2 \rangle}        % two arguments
```

\def vs \newcommand:

- \def silently **overwrites** any existing command — dangerous;
- \newcommand **errors** if the command already exists — safe;
- \renewcommand explicitly signals the intent to redefine.

Use \newcommand in L^AT_EX documents; \def in low-level macro code.

Expansion

T_EX processes tokens in two phases:

1. **Expansion**: expandable tokens (macros, `\if...`) are replaced by their definition, repeatedly, until only unexpandable tokens remain;
2. **Execution**: unexpandable tokens are executed (assignments, typesetting).

`\expandafter` expands the token *after* the next one first:

```
\def\hello{world}
\expandafter\MakeUppercase\expandafter{\hello}
% equivalent to: \MakeUppercase{world}
```

`\noexpand`: suppresses expansion of the following token.

\edef: Expanding Definition

\edef expands the replacement text **at definition time**:

```
\newcommand{\myname}{Alice}  
\edef\greeting{Hello, \myname!}  
% \greeting is now literally "Hello, Alice!"
```

```
\renewcommand{\myname}{Bob}  
\greeting      % still outputs: Hello, Alice!
```

Compare with \def / \newcommand — expands at **use time**:

```
\newcommand{\greeting}{Hello, \myname!}  
\renewcommand{\myname}{Bob}  
\greeting      % outputs: Hello, Bob!  
  
\xdef = \global\edef (global expanding def).
```

Box Model

Everything in \TeX is a **box** with width, height, and depth:

- `\hbox{...}` (`\mbox`) — horizontal box, no line breaks inside;
- `\vbox{...}` (`minipage`, `parbox`) — vertical box;
- boxes can be nested, measured, and positioned freely.

```
\makebox[3cm]{c}{centered}          % fixed-width centered box  
\framebox{framed content}         % box with visible border  
\raisebox{0.5ex}{raised text}     % shift box up/down
```

\LaTeX builds lines from **horizontal lists** of boxes and **glue** (stretchable/shrinkable space). Tables, columns, and figures are all composed of boxes.

Low-level Conditionals

T_EX primitives for conditionals (no package needed):

```
\ifnum\value{page} > 1
```

Not the first page.

```
\fi
```

```
\ifdim\textwidth > 10cm
```

Wide page.

```
\else
```

Narrow page.

```
\fi
```

```
\ifx\myvar\undefined
```

\myvar is not defined.

```
\fi
```

Low-level Conditionals

- `\ifnum`: integer comparison (`<`, `>`, `=`);
- `\ifdim`: dimension comparison;
- `\ifx`: tests if two tokens identical;
- `\if`: compare character codes of two tokens;
- every conditional must end with `\fi`.

Custom Commands: `\newcommand`

Define reusable shorthands, especially useful for math notation:

```
\newcommand{\R}{\mathbb{R}}
\newcommand{\N}{\mathbb{N}}
\newcommand{\norm}[1]{\left| #1 \right|} 
\newcommand{\inner}[2]{\langle #1, #2 \rangle}
```

Usage:

Let $f : \mathbb{R}^n \rightarrow \mathbb{R}$ and $x \in \mathbb{R}^n$.

Then $\|\mathbf{x}\| = \sqrt{\langle \mathbf{x}, \mathbf{x} \rangle}$.

Let $f : \mathbb{R}^n \rightarrow \mathbb{R}$ and $x \in \mathbb{R}^n$. Then $\|x\|_{L^2} = \sqrt{\langle x, x \rangle}$.

Define once in the preamble, use everywhere, change notation
globally by editing one line.

amsmath Operator Commands

\DeclareMathOperator defines named operators typeset in upright font:

```
\DeclareMathOperator{\argmax}{arg\!,max}  
\DeclareMathOperator{\rank}{rank}  
\DeclareMathOperator{\tr}{tr}  
\DeclareMathOperator{\diag}{diag}  
\DeclareMathOperator{\KL}{KL}
```

$$\arg \max_{\theta} \mathcal{L}(\theta) \quad \text{rank}(A) \quad \text{tr}(M) \quad \text{KL}(P \| Q) \quad (5)$$

amsmath Operator Commands

The * variant allows limits above/below in display math:

```
\DeclareMathOperator*{\mathbb{E}}{\mathbb{E}}
\DeclareMathOperator*{\argmin}{arg\_,min}
```

$$\mathbb{E}_{x \sim p} f(x) \quad \arg \min_{\theta \in \Theta} \mathcal{L}(\theta)$$

Use `\DeclareMathOperator` instead of `\mathrm{mathrm}` or `\text`, it handles spacing around the operator correctly:

```
\DeclareMathOperator \mathrm{mathrm};  
arg\max_{\theta \in \Theta} \mathcal{L}(\theta) \quad arg\max_{\theta \in \Theta} \mathcal{L}(\theta);  
arg\min_{\theta \in \Theta} \mathcal{L}(\theta) \quad arg\min_{\theta \in \Theta} \mathcal{L}(\theta);  
\mathbb{D}_{x \sim p} f(x) \quad \mathbb{D}_{x \sim p} f(x).
```

Custom Commands: optional arguments

\newcommand supports optional arguments with defaults:

% [1] = 1 argument, [L^2] = default value

```
\newcommand{\norm}[2][L^2]{%
    \left|\!| #2 \right|\!\!|_{#1}}%
```

$\$\\norm{f} \$ \Rightarrow \left|\!| f \right|\!\!|_{L^2}$

$\$\\norm[L^\\infty]{f} \$ \Rightarrow \left|\!| f \right|\!\!|_{L^\\infty}$

$$\|f\|_{L^2} \quad \|f\|_{L^\infty}$$

- #1 — first argument (optional, with default);
- #2 — second argument (mandatory);
- % at end of line, suppress unwanted whitespace.

\renewcommand

Override existing commands:

```
% Change equation numbering to include section
```

```
\renewcommand{\theequation}{%
    \thesection.\arabic{equation}}%
```

```
}
```

```
% Redefine abstract name
```

```
\renewcommand{\abstractname}{Executive Summary}
```

- Use `\renewcommand` for commands that already exist;
- use `\newcommand` for new commands, it errors if the command already exists (safety check).

Custom Environments

```
\newenvironment{name}[args]{begin-code}{end-code}:

\newenvironment{important}{%
    \begin{center}
    \begin{minipage}{0.9\textwidth}
    \textbf{Important:} \itshape
    }{%
    \end{minipage}
    \end{center}
}
```

Custom Environments

Usage:

```
\begin{important}
```

Always compile twice to resolve references.

```
\end{important}
```

Result:

Important: *Always compile twice to resolve references.*

Custom Environments with Arguments

Environments can also accept arguments:

```
\newenvironment{method}[1]{%
    \begin{block}{Method: #1}
}{%
    \end{block}
}
```

Custom Environments with Arguments

```
\begin{method}{Gradient Descent}
  Update rule:  $\theta \leftarrow \theta - \alpha \nabla_{\theta} \mathcal{L}$ 
\end{method}
```

Method: Gradient Descent

Update rule: $\theta \leftarrow \theta - \alpha \nabla_{\theta} \mathcal{L}$

Combine with `\newcommand` to build a consistent notation system for your paper or thesis.

Counters

\LaTeX uses counters for automatic numbering:

```
\newcounter{example}[section] % reset per section  
  
\newcommand{\example}{%  
    \stepcounter{example} %  
    \textbf{Example~\thesection.\theexample} %  
}
```

Useful counter commands:

- `\newcounter{name}[parent]` — create a counter;
- `\setcounter{name}{value}` — set value;
- `\stepcounter{name}` — increment by 1;
- `\arabic{name}`, `\roman{name}` — display formats.

Lengths

Control spacing and sizes with length registers:

```
\newlength{\mywidth}  
\setlength{\mywidth}{0.45\textwidth}  
\addtolength{\mywidth}{-1cm}
```

- `\newlength` — define a length register;
- `\setlength` — assign a value;
- `\addtolength` — add to current value;
- units: pt, cm, em, ex, or relative like `0.5\textwidth`.

Conditionals

The `ifthen` package provides readable conditionals:

```
\usepackage{ifthen}

\newcommand{\grade}[1]{%
  \ifthenelse{#1 > 89}{A}{%
    \ifthenelse{#1 > 79}{B}{%
      \ifthenelse{#1 > 69}{C}{F}}}}%
}
```

Score 95: `\grade{95}`
Score 72: `\grade{72}`

Score 95: A
Score 72: C

Also available: `\ifdefined`, `\ifx` (low-level \TeX conditionals) and the `etoolbox` package for modern alternatives.

Loops with pgffor

The pgffor package (part of TikZ/PGF) provides \foreach:

```
\usepackage{pgffor}

\foreach \x in {1,2,...,5} {
    Item \x;|,
}

\foreach \name/\score in {
    Alice/95, Bob/87, Carol/91} {
    \name: \score\\
}
```

Item 1; Item 2; Item 3; Item 4; Item 5;

Useful for generating repetitive content: tables, TikZ diagrams, lists.

Practical Example: Paper Preamble

A real-world preamble with custom commands:

```
% Number sets
\newcommand{\R}{\mathbb{R}}
% Operators
\DeclareMathOperator*{\E}{\mathbb{E}}
\DeclareMathOperator*{\argmin}{arg\!,min}
\DeclareMathOperator{\KL}{KL}
% Shortcuts
\newcommand{\loss}{\mathcal{L}}
\newcommand{\model}{f_{\theta}}
\newcommand{\dataset}{\mathcal{D}}
% Norms and brackets
\newcommand{\norm}[1]{\left| #1 \right|} 
\newcommand{\abs}[1]{\left| #1 \right|}
```

Practical Example: Usage

With the preamble above, you write concise math:

```
\begin{align*}
\text{\textbackslash loss}(\text{\textbackslash theta}) &= \text{\textbackslash E\_}\{(x,y) \sim \text{\textbackslash dataset}\} \\
&\quad \text{\textbackslash norm}\{\text{\textbackslash model}(x) - y\}^2; \\
\theta^* &= \text{\textbackslash argmin\_}\text{\textbackslash theta} \text{\textbackslash loss}(\text{\textbackslash theta}). \\
\end{align*}
```

$$\mathcal{L}(\theta) = \mathbb{E}_{(x,y) \sim \mathcal{D}} \|f_\theta(x) - y\|_{L^2}^2;$$

$$\theta^* = \arg \min_{\theta} \mathcal{L}(\theta).$$

Readable source, beautiful output — and easy to change notation globally.

Conclusion

Summary

\LaTeX is essential for academic CS writing:

- **document structure**: `\documentclass`, preamble, environments;
- **math typesetting**: inline `$...$`, display `\[...\]`, `align`;
- **floats**: figure, table with `\caption` and `\label`;
- **references**: `\label/\ref`, BibTeX for citations;
- **packages**: extend functionality as needed.