

Introduction to L^AT_EX

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What is \LaTeX ?

–

- 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):

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

Proper \LaTeX :

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

Why L^AT_EX?

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 L^AT_EX 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., `llncls`, `acmart`).

Packages

Packages extend L^AT_EX functionality:

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

Load packages in the preamble with

`\usepackage[options]{name}.`

Sectioning

L^AT_EX 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 \LaTeX :

```
\% \ $ \& \# \_ \{ \}  
\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:

`\[E = mc^2 \]`

$$E = mc^2$$

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 \\
      &= (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:

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

Cross-entropy loss:

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

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

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

L^AT_EX 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 ...



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

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

L^AT_EX Programming

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]{\left\langle #1, #2 \right\rangle}
```

Usage:

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

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

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.

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}`

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

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

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).

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

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

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

L^AT_EX 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.

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: <code>\grade{95}</code>	Score 95: A
Score 72: <code>\grade{72}</code>	Score 72: C

Also available: `\ifdefined`, `\ifx` (low-level T_EX 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*}
\loss(\theta) &= \mathbb{E}_{(x,y) \sim \text{dataset}}
               \|\text{model}(x) - y\|^2; \\
\theta^* &= \operatorname{argmin}_{\theta} \loss(\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

\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.