

# **Introduction to L<sup>A</sup>T<sub>E</sub>X**

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# What is L<sup>A</sup>T<sub>E</sub>X?

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- 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

# $\text{\LaTeX}$ vs. Word Processors

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Word:

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

Beamer ( $\text{\LaTeX}$  slides):

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

Proper  $\text{\LaTeX}$ :

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

# Why $\text{\LaTeX}$ ?

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## 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  $\text{\LaTeX}$  editor;
- local editors: TeXstudio, VS Code + LaTeX Workshop.

# Workflow

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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**

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# Minimal Document

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A minimal  $\text{\LaTeX}$  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

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- `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

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Packages extend L<sup>A</sup>T<sub>E</sub>X 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

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$\text{\LaTeX}$  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**

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## Basic Text Formatting

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```
\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

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**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

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Some characters have special meaning in L<sup>A</sup>T<sub>E</sub>X:

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

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

## Whitespace and Line Breaks

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- 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**

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# Inline and Display Math

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**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

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**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

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```
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

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```
\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

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\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

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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

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- `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

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A practical example — softmax function:

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

Cross-entropy loss:

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

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

## **Floats: Figures and Tables**

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# Including Figures

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```
\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

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**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	<b>0.93</b>

## 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**

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## Labels and References

---

$\text{\LaTeX}$  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

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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

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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

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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**

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## Code Listings

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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

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## Avoid these pitfalls:

- forgetting {} for multi-character sub/superscripts:  $x^{10}$  vs.  $x^{\{10\}}$ :
  - $x^10$  vs.  $x^{10}$
- using " instead of ' 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**

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

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|\begin{array}{l} #2 \end{array}\right|_{\#1}}%
```

$\$\\norm{f}\\$$   $\Rightarrow \left|\begin{array}{l} f \end{array}\right|_{L^2}$

$\$\\norm[L^\\infty]{f}\\$$   $\Rightarrow \left|\begin{array}{l} f \end{array}\right|_{L^\\infty}$

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

- #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

---

$\text{\LaTeX}$  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  $\text{\TeX}$  conditionals) and the `etoolbox` package for modern alternatives.

## Loops with pgffor

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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

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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

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With the preamble above, you write concise math:

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

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# Summary

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$\text{\LaTeX}$  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.