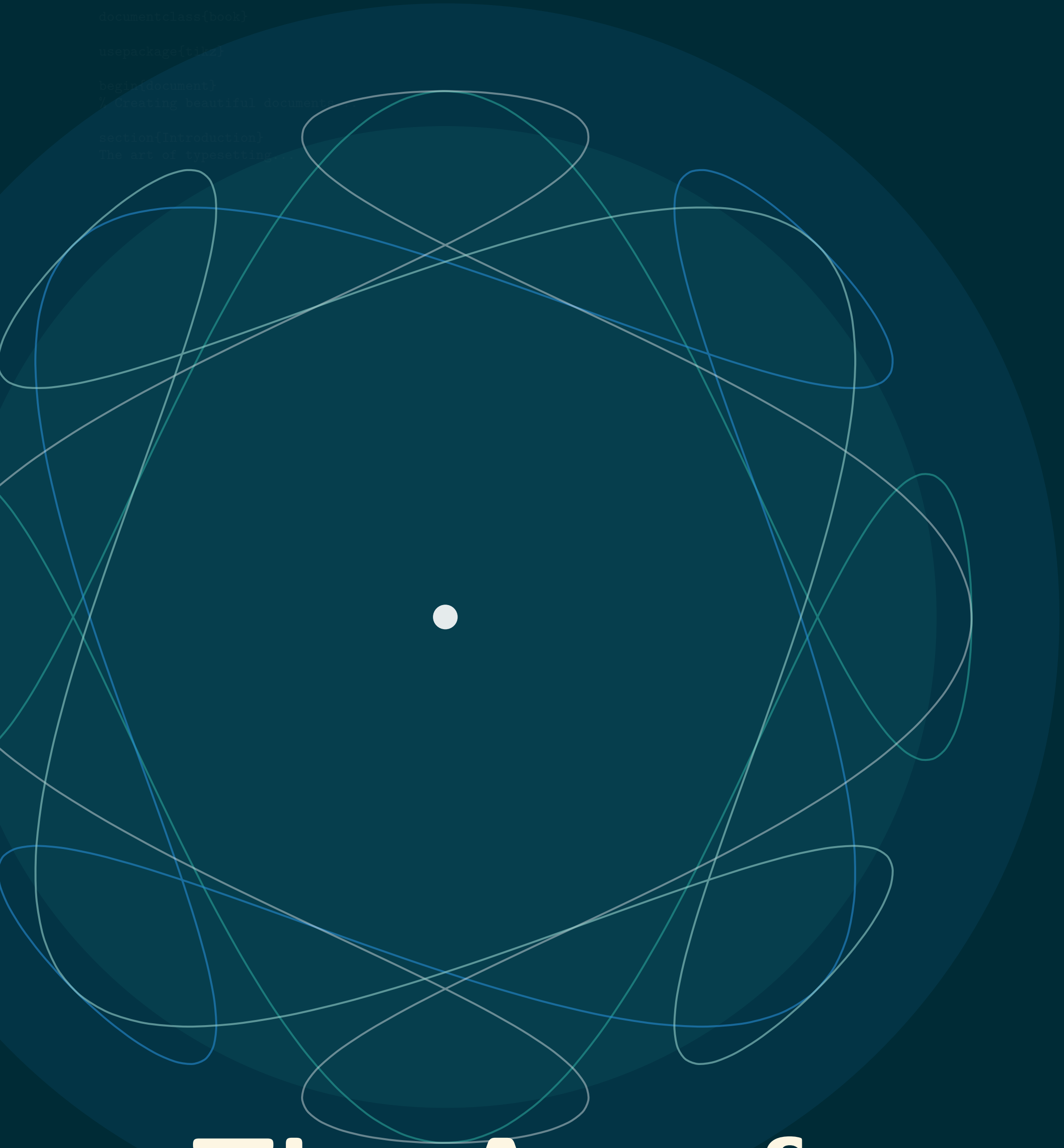
LECTURE NOTES



```
documentclass{book}

usepackage{tikz}

begin{document}
% Creating beautiful documents...

section{Introduction}
The art of typesetting...
```

The Art of Modern LaTeX

Professional Typesetting & Vector Graphics

From Standard Documents to Advanced TikZ

Ji, Yonghyeon

A Comprehensive Guide to LaTeX

The Art of Modern LaTeX

Professional Typesetting & Vector Graphics

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1 Introduction to LaTeX

LaTeX (often pronounced "Lay-tek" or "Lah-tek") is a high-quality typesetting system widely used for professional scientific and technical documents.

Instead of formatting text by hand (like in a word processor), we write a plain-text source file and then *compile* it into a polished PDF.

1.1 What is LaTeX?

> What is LaTeX?
>
> LaTeX is a document preparation system based on TeX, designed for producing beautifully typeset documents, especially those containing complex mathematical expressions.

A helpful way to think about LaTeX is:

- We write *content* and *structure* (sections, theorems, figures, references).
- The compiler applies consistent typography and layout rules automatically.

This separation makes long documents easier to maintain: if we change the structure (add sections, figures, equations), numbering and references can update automatically when compiled again.

What TeX and LaTeX Do

- TeX is the underlying typesetting engine (it focuses on high-quality layout and spacing).
- LaTeX is a set of macros and conventions on top of TeX that provides document structure: chapters/sections, figures, tables, bibliographies, and many more.

We usually write LaTeX source and let the engine produce the final PDF.

Why Use LaTeX? People choose LaTeX because it is strong where word processors often become difficult:

- **Professional-quality typography** with consistent formatting across the whole document.
- **Excellent mathematical rendering**, for example $a^2 + b^2 = c^2$ and complex formulas.
- **Automatic numbering and references** for equations, figures, sections, and bibliographies.
- **Scales well** to long reports, theses, and books: structure stays manageable.

When LaTeX Is a Good Fit

- Math-heavy documents (homework, lecture notes, papers).
- Reports with many figures/tables and cross-references.
- Theses and books with chapters and bibliographies.

When It Might Not Be Necessary

- Very short, simple documents where structure and references do not matter.
- Layout-heavy marketing designs (unless you already know advanced packages).

1.1.1 Compiling a Document

A LaTeX file is typically saved with the extension `.tex`. To produce a PDF, you run a compiler (engine) that reads the source and outputs the final document.

The Basic Compile Command A common engine is `pdflatex`. The typical workflow is:

```
pdflatex file.tex
pdflatex file.tex % run twice to update references
```

Running twice matters because references (like section numbers, equation numbers, and the table of contents) are resolved across compilation passes.

What Happens During Compilation When you compile, LaTeX:

- reads your structure (chapters, sections, lists),
- calculates layout (line breaks, page breaks),
- assigns numbers (figures, tables, equations),
- writes auxiliary files (used to resolve references),
- produces a PDF output.

Recommended Tools We can write and compile LaTeX using:

- **Overleaf**: online editor; no installation required.
- **TeX Live**: a full TeX distribution commonly used on Linux/macOS.
- **MiKTeX**: a popular distribution on Windows.

1.2 Document Structure and Classes

A LaTeX source file is a plain text file, usually saved with the extension `.tex`. When you compile it, LaTeX produces a beautifully typeset output (most commonly a PDF).

1.2.1 Setup and Content

A LaTeX document is built from two main parts:

- **Preamble** (before `\begin{document}`): chooses the document class and loads packages.
- **Document body** (between `\begin{document}` and `\end{document}`): contains the content you want printed (text, math, figures, tables, etc.).

This "preamble + body" split is the standard structure shown in the reference material.

Example 1.1 (Minimal Structure)**.**

```
\documentclass{article}

\begin{document}
   This is a LaTeX document.
\end{document}
```

1.2.2 Document Classes

The first line of a LaTeX file is often the most important:

`\documentclass[options]{class}`

It sets the foundation for the entire document.

`article`	best for **shorter documents** such as papers, essays, homework, and reports.
`report`	used for **longer documents** that need chapters (e.g., theses).
`book`	designed for **books**; supports chapters and is set up for two-sided printing.
`beamer`	used for **presentations**; the output becomes slide-based rather than page-based.

Class options customize the class behavior.

`10pt`, `11pt`, `12pt`	base font size (default is commonly `10pt`).
`a4paper`, `letterpaper`	paper size
`twocolumn`	two-column layout.
`oneside`, `twoside`	single-sided or double-sided layout.

Example 1.2. `\documentclass[12pt, a4paper, twoside]{article}`

Remark. A beginner-friendly recommendation:

- Use `11pt` or `12pt` for readable notes.
- Use the correct paper size for your country/institution.
- Avoid `twocolumn` until you are comfortable with layout.

1.2.3 Packages

Packages are extensions that add new features and commands. We load them in the preamble using `\usepackage{...}`.

```
\usepackage{amsmath, amssymb}
\usepackage{graphicx}
\usepackage{hyperref}
```

`amsmath`, `amssymb`	improved math environments and symbols.
`graphicx`	enables `\includegraphics` for inserting images.
`hyperref`	clickable links and clickable cross-references in the PDF.

Example 1.3 (Margins with `geometry`)**.**

```
\usepackage[left=1.5in, right=1.5in, top=1in, bottom=1in]{geometry}
```

1.2.4 Skeleton Template

A typical skeleton combines class selection, packages, metadata (title/author/date), and document body commands. The reference provides a standard example.

Example 1.4 (Typical Structure)**.**

```
\documentclass[11pt]{article}
\usepackage[utf8]{inputenc}
\usepackage{amsmath, amssymb}
\usepackage{graphicx}
\usepackage{hyperref}

\title{My First Document}
\author{Student Name}
\date{\today}

\begin{document}
   \maketitle

   Hello, LaTeX World!

\end{document}
```

1.3 Text Formatting and Layout

1.3.1 Basic Text Commands

LATEX offers two main approaches to text styling:

- **Direct styling commands** such as `\textbf` and `\textit`.
- **Logical emphasis** using `\emph`, which adapts to context.

The most common beginner commands are:

- `\textbf{bold}` → **bold**
- `\textit{italic}` → *italic*
- `\underline{underline}` → <u>underline</u>
- `\emph{emphasized}` → *emphasized*

A useful rule:

- Use `\emph` when you mean “emphasize this concept.”
- Use `\textit` or `\textbf` when you want a specific visual style.

1.3.2 Paragraphs and Line Breaks

In LATEX, a new paragraph is created by leaving a blank line in your source. A manual line break can be forced using `\\`.

Example 1.5.

```
This is the first line.\\
This is the second line.
```

1.3.3 Quotes and Quotations

- `quote`: short quotations (indented, typically one paragraph).
- `quotation`: longer quotations (indented, with paragraph formatting).

Example 1.6.

```
\begin{quote}
   A well-structured document is easier to write and easier to read.
\end{quote}
```

1.3.4 Text Alignment

Alignment environments are helpful for small blocks of text:

- `\begin{center}...\end{center}` → centered text
- `\begin{flushleft}...\end{flushleft}` → left-aligned text
- `\begin{flushright}...\end{flushright}` → right-aligned text

1.3.5 Font Sizes

LaTeX provides relative font size switches that affect the enclosed group:

- `\tiny`, `\scriptsize`, `\footnotesize`
- `\small`, `\normalsize`, `\large`, `\Large`
- `\LARGE`, `\huge`, `\Huge`

Example 1.7.

This is tiny text.
This is scriptsize text.
This is footnotesize text.
This is small text.
This is normalsize text.
This is large text.
This is Large text.
This is Large text.
This is huge text.
This is Huge text.

1.3.6 Special Characters

Some characters are reserved because LaTeX uses them for commands or syntax.

`\%`	% (percent)
`\$`	$ (dollar)
`\#`	# (hash)
`\_`	_ (underscore)
`\&`	& (ampersand)
`\{ \}`	{ } (braces)

Use `%` to write comments that will not appear in the output PDF:

```
% This is a comment and will not appear in the output
```

1.4 Lists and Tables

1.4.1 Unordered Lists (Bulleted)

Use the `itemize` environment to create bulleted lists. Each list item begins with `\item`.

Example 1.8.

```
\begin{itemize}
    \item Apples
    \item Bananas
    \item Cherries
\end{itemize}
```

- Apples
- Bananas
- Cherries

Example 1.9. We can nest `itemize` to create sub-bullets.

```
\begin{itemize}
    \item Fruit
    \begin{itemize}
        \item Apples
        \item Bananas
    \end{itemize}
    \item Vegetables
\end{itemize}
```

- Fruit
  - Apples
  - Bananas
- Vegetables

1.4.2 Ordered Lists (Numbered)

Use the `enumerate` environment for numbered lists. LaTeX automatically handles numbering, which is exactly the beginner-friendly point emphasized in the reference notes.

Example 1.10.

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

1. First
2. Second
3. Third

Example 1.11. We can nest `enumerate` just like `itemize`:

```
\begin{enumerate}
   \item Main step
   \begin{enumerate}
      \item Sub-step
      \item Sub-step
   \end{enumerate}
   \item Next main step
\end{enumerate}
```

1. Main step
    (a) Sub-step
    (b) Sub-step
2. Next main step

1.4.3 Description Lists

Use the `description` environment when each item needs a label.

Example 1.12.

```
\begin{description}
   \item[Dog] A friendly animal.
   \item[Cat] A curious animal.
\end{description}
```

Dog A friendly animal.

Cat A curious animal.

1.4.4 Tables

Tables in LaTeX are typically built in two layers:

- `tabular`: the grid itself (rows/columns).
- `table`: an optional floating wrapper for captions and labels.

Example 1.13.

```
\begin{tabular}{|l|c|r|}
   \hline
   Name & Age & Score \\
   \hline
   Alice & 24 & 95 \\
   Bob & 22 & 88 \\
   \hline
\end{tabular}
```

Name	Age	Score
Alice	24	95
Bob	22	88

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

Alignment Options in Tables The column specification controls alignment:

- `l` – left aligned
- `c` – centered
- `r` – right aligned
- `|` – vertical line between columns

Beyond `l`, `c`, `r`, we will often need fixed-width columns:

- `p{3cm}`: a paragraph column of width 3cm (text wraps automatically).

Example 1.14 (Fixed-width column)**.**

```
\begin{tabular}{|l|p{6cm}|}
   \hline
   Term & Explanation \\
   \hline
   LaTeX & A document preparation system for professional typesetting. \\
   \hline
\end{tabular}
```

Term	Explanation
LaTeX	A document preparation system for professional typesetting.

1.4.5 Floating Tables

A `table` environment is a *float*: LaTeX may move it to an optimal location for page layout.

Example 1.15. Standard Pattern: `table` + `tabular` + caption/label

```
\begin{table}[h]
   \centering
   \begin{tabular}{lrr}
      \hline
      Item & Qty & Price \\
      \hline
      Apples & 3 & 1.20 \\
      Bananas & 5 & 0.80 \\
      \hline
   \end{tabular}
   \caption{Fruit Inventory}
   \label{tab:fruit}
\end{table}
```

Item	Qty	Price
Apples	3	1.20
Bananas	5	0.80

Table 1: Fruit Inventory

Placement Options The optional argument `[h]` suggests "place here". Common options:

`h`	here
`t`	top of page
`b`	bottom of page
`p`	float page

- `h`: here
- `t`: top of page
- `b`: bottom of page
- `p`: float page

A common practical choice is `[htbp]` to give LaTeX flexibility.

Captions, Labels, and Referencing A best practice:

- Put `\label` after `\caption`.
- Refer to the table using `Table~\ref{tab:fruit}`. (Table 1)

1.5 Mathematical Typesetting

Mathematics is one of the strongest reasons to use LaTeX. Compared to ordinary word processors, LaTeX typesets formulas with consistent spacing, professional symbol shapes, and stable numbering. Once we learn the patterns, we can write math quickly and keep it readable in both short notes and long theses.

A major advantage is that LaTeX treats math as a structured language: we build expressions from commands (like `\frac` or `\sum`) rather than trying to align symbols manually.

1.5.1 Inline and Display Mathematics

We distinguish two modes: inline math (inside a sentence) and display math (on its own line).

Inline Mathematics Inline math is used inside a sentence.

Example 1.16.

```
The quadratic polynomial $ax^2 + bx + c$ has degree $2$.
```

```
The quadratic polynomial \(ax^2 + bx + c\) has degree \(2\).
```

The quadratic polynomial $ax^2 + bx + c$ has degree 2.

Displayed Mathematics Displayed math is used for important equations that appear on their own line. We list display math forms such as `\[...\]` (and also mentions `$$...$$`).

Example 1.17.

```
   The quadratic polynomial $$ax^2 + bx + c$$ has degree $2$.
```

```
   The quadratic polynomial \[ax^2 + bx + c\] has degree \(2\).
```

The quadratic polynomial

$$ax^2 + bx + c$$

has degree 2.

1.5.2 Numbered vs. Unnumbered Display Math

- Use `equation` when you want a number you can reference later.
- Use an unnumbered display (commonly `\[...\]`) for one-off formulas you will not reference.

Example 1.18 (Numbered display)**.**

```
\begin{equation}
   \int_0^\infty e^{-x^2}\,dx = \frac{\sqrt{\pi}}{2}
\end{equation}
```

$$\int_0^\infty e^{-x^2}\,dx = \frac{\sqrt{\pi}}{2} \tag{1}$$

Example 1.19 (Unnumbered display)**.**

```
\[
\int_0^\infty e^{-x^2}\,dx = \frac{\sqrt{\pi}}{2}
\]
```

$$\int_0^\infty e^{-x^2}\,dx = \frac{\sqrt{\pi}}{2}$$

1.5.3 Superscripts and Subscripts

Superscripts and subscripts are fundamental.

- Superscripts use `^`: x^2, a^{n+1}.
- Subscripts use `_`: a_1, b_{ij}.

Example 1.20.

```
The sequence $a_n = n^2$ grows quadratically.
```

The sequence $a_n = n^2$ grows quadratically.

Remark.

- `a_12` means a_12 (subscript applies only to 1).
- `a_{12}` means a_{12} with subscript 12.

1.5.4 Fractions and Roots

Fractions and roots are also highlighted as essential commands.

Example 1.21.

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

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

1.6 Theorems, Definitions, and Proofs

1.6.1 Using the `amsthm` Package

Mathematical writing often needs structured statements such as definitions, theorems, lemmas, corollaries, and remarks. In LaTeX, the most standard tool for this is the `amsthm` package, which provides:

- theorem-like environments with automatic numbering,
- consistent formatting (bold theorem headings, italic theorem body, etc.),
- a built-in `proof` environment that automatically prints a QED symbol.

In our preamble, we define theorem-style environments like this:

```
\usepackage{amsthm}

\newtheorem{theorem}{Theorem}[section]
\newtheorem{lemma}[theorem]{Lemma}
\newtheorem{definition}[theorem]{Definition}
\newtheorem{corollary}[theorem]{Corollary}

\theoremstyle{remark}
\newtheorem*{remark}{Remark}
```