GSNS Intro LaTeX-course
The basics of LaTeX

TEXniCie

A–Eskwadraat

September 1, 2020

Table of contents

Basics

- The *author* writes a manuscript for his book;
- The *graphic designer* creates the lay-out (columnwidth, font, spacings of headers etc.);
- The *typesetter* sets the manuscript according to the instructions.

In LaTeX:

- LaTeX is the graphic designer and the typesetter.
- You are only the author!
- You direct LaTeX using commands in the editor.

Example
Paper

github.com/scheinerman/SampleMathPaper

A Sample Mathematics Paper

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May 13, 2005

Abstract

This is a sample LaTeX paper; its purpose is to show the basics of setting up a paper and important features of LaTeX. It can also be used for assignments or other short notes.

1 Introduction

This is a simple LaTeX document designed to illustrate the basics of typesetting a paper. The ideas shown here can be adapted for a more informal document, such as a homework assignment.

This document is created from various source files, the most important of which is named `paper.tex`. By reading `paper.tex` along side the typeset output, the diligent reader should be able to deduce how various parts of LaTeX work. Indeed, you cannot understand everything that we did in this paper without looking at the source file. For example, how did we type LaTeX?

Remember that LaTeX is a markup language and not a what-you-see-is-what-you-get word processor.

Good luck.

Example
Summary (page 2)

1 Mizera – Status of Intersection Theory and Feynman Integrals

A short overview referring to multiple different papers and giving a general idea of 'intersection theory'.

1 We want to calculate an S-matrix, $S = \mathbb{1} + iT$; T gives matrix between incoming and outgoing momenta.

- Consider two-to-two scattering:

$$T_{12\to34} = \delta^4(p_1 + p_2 - p_3 - p_4)\, \mathcal{T}_{12\to34}(s, t, p_i^2, m^2, \dots),$$

where $s = (p_1 + p_2)^2$, $t = (p_1 - p_3)^2$ are Mandelstam variables.

- What are the (analytical) properties of $\mathcal{T}_{12\to34}$ as function of the (generally complex) variables $s, t, p_i^2, m, \dots$? (The space spanned by these variables is the *Kinematic space*.)
- We want to calculate loops γ in said Kinematic space, to learn about branch cuts etc.
- Need simplifications: only perturbation theory, $4 - 2\varepsilon$ dimensional regularisation, scalar Feynman diagrams (generic Feynman can be reduced to sum of scalar Feynman).
- Example: 4-point 1-loop diagrams with no masses:

$$I_{n_1 n_2 n_3 n_4}(s, t) = \int_\Gamma \frac{d^{4-2\varepsilon}\ell}{[\ell^2]^{n_1}[(\ell + p_1)^2]^{n_2}[(\ell + p_1 + p_2)^2]^{n_3}[(\ell + p_4)^2]^{n_4}},$$

where Γ is an integration contour with the right causality conditions and n_i are integers to distinguish box, triangle and bubble diagrams by which propagators appear.

- There is a topological invariant integer χ, such that for χ different Feynman integrals (e.g. $\chi = 3$, $I_{1111}, I_{1110}, I_{1010}$) and for (s_*, t_*) fixed, we can find a $\chi \times \chi$-matrix φ such that for any path γ from (s_*, t_*) to (s, t) we have

$$(I_{1111}, I_{1110}, I_{1010})^\top(s, t) = \mathcal{P}e^{\int_\gamma \varphi}(I_{1111}, I_{1110}, I_{1010})^\top(s_*, t_*) =: \mathcal{P}e^{\int_\gamma \varphi}|\Phi\rangle.$$

Here $\mathcal{P}$ denotes the path-ordered exponential.

When would you use LaTeX?

Advantages

- Professional layout.
- Easy mathematical formula editing.
- Simple commands for complex structures like footnotes, references, table of contents and bibliographies.
- LaTeX enforces authors to write well structured documents.
- LaTeX is free.

When would you use LaTeX?

Disadvantages

- Not really suited for graphic design.
- It is not WYSIWYG (what you see is what you get), like e.g. Word.
- Less intuitive than Word.

Everything is possible in LaTeX; the bigger the deviation from normal, the harder it is.

Processing
Procedure

It is not *WYSIWYG* software, so:

- You write (flat) text with commands for layout in a LaTeX editor.
- LaTeX places the text and produces a PDF as output.

Example
LaTeX code

Example

```
\documentclass[a5paper]{article}
\title{\LaTeX cursus A–Eskwadraat}
\author{\TeX nicie}
\date{November 14, 2016}
\begin{document}
\maketitle
\section{Important title}
Lorem ipsum ...
\end{document}
```

Example
LaTeX code

Example

```
\documentclass[a5paper]{article}
\title{\LaTeX cursus A–Eskwadraat
\author{\TeX nicie}
\date{November 14, 2016}
\begin{document}
\maketitle
\section{Important title}
Lorem ipsum ...
\end{document}
```

PDF output

LaTeX cursus A–Eskwadraat

TeXniCie

November 14, 2016

1 Important Title

Lorem ipsum ...

1

Structure of a LaTeX-file

A LaTeX-file always has the following structure:

LaTeX	Meaning
`\documentclass{article}`	class-definition
	preamble, commands which are valid through the whole document.
`\begin{document}`	start of the actual document
`This is a really tiny document.`	the document
`\end{document}`	end of the document

LaTeX will generate the following: This is a really tiny document.

Title and date

In order to automatically generate a title on the front page you need to place two commands in the preamble:

```
\title{Report on Recent Advancements in X}
\author{Students Y and Z}
```

Optionally, one can specify a date:

```
\date{July 5th, 2020}
```

Finally, place the following command direct after the beginning of your document.

```
\maketitle
```

If you do not include a date, LaTeX will use the date at which you generated the PDF-file.

Headings

`Headings` mark the start of a section or chapter.

The usual commands are:

- `\section{`⟨*name*⟩`}`
- `\subsection{`⟨*name*⟩`}`
- `\subsubsection{`⟨*name*⟩`}`

You might also encounter:

- `\chapter{`⟨*name*⟩`}`
- `\paragraph{`⟨*name*⟩`}`

Table of contents

Using the mentioned (sub)*sections, you can generate a table of contents with one command:

```
\tableofcontents
```

Near the end of the document, you might find:

```
\appendix
```

The \appendix command marks the start of the appendices. All sections after this command are indicated in another style.

Paragraphs

Paragraphs

Of course you want to structure your text in paragraphs:

- for **flat text** just write everything successively;
- **paragraphs** are made by including white-space.

If you really want something else

- `\\` forces a **line cut**;
- `\bigbreak` gives vertical white-space;
- `\newpage` enforces a new page;
- `\clearpage` enforces a new page, but first places all tables and figures.

You should minimise the use of above commands in your text!

Accents

Standard pdf-LaTeX can only handle flat text and certain symbols. In order to use accents, the accent has to be written in front of the letter:

Signs

ó	ò	ö	ô	õ
\'o	\`o	\"o	\^o	\~o

You will most likely need the above for names or words borrowed from another language.

"A naïve man was eating a crème brûlée during the El Niño."

Symbols

The following symbols all have a special meaning in LaTeX. In order to print them as text you will need a special command:

symbol	**command**	**symbol**	**command**
$	\$	#	\#
%	\%	&	\&
{	\{	}	\}
_	_	\	\textbackslash
‘	`	’	'

Exercise 1

Look at the following code.

```
\documentclass{article}

\title{Algebraic Geometry and Feynman Diagrams}
\author{Pepijn de Maat}

\begin{document}

\maketitle
% Maybe I should add a Table of Contents
\clearpage

\section{Introduction} %TODO
This subject is very important for TO DO reasons.

\paragraph{Physical Relevance}
TO DO, something with Cern.
\paragraph{Historical Interest}
TO DO, was there any?
\end{document}
```

1. Who is the author?
2. What date will be used in the PDF?
3. Which entries would be in the table of contents?
4. Can you guess what the % sign does?

Listings

LaTeX has three different listings:

- A plain list.
1. A numbered list.

Description A list with no predefined ‘bulletpoints’

These listings are produced by the environments `itemize`, `enumerate` and `description`.

Example
Itemize

Example

```
...
\begin{itemize}
\item Mathematics
\item Theoretical Physics
\item Experimental Physics
\item Climate Physics
\item Chemistry
\end{itemize}
...
```

PDF output

- Mathematics
- Theoretical Physics
- Experimental Physics
- Climate Physics
- Chemistry

The `enumerate` environment has the same syntax.

Example
Description

Example

```
...
\begin{description}
\item[a] Introduction
\item[aa] Remarks on Previous Version
\item[ab] Historical Relevance
\item[b] Preliminaries
\item[Cats] Felis catus
\item[Dogs] Canis familiaris
\end{description}
...
```

PDF output

a Introduction

aa Remarks on Previous Version

ab Historical Relevance

b Preliminaries

Cats Felis catus

Dogs Canis familiaris

Packages

LaTeX itself is only a basic framework, and for many things you need packages. We recommend the following:

babel The Babel package manages typographical rules such as line breaks for many different languages. The default language is 'US English'. (LuaLaTeX: use `Polyglossia` instead.)

graphicx The Graphicx package vastly simplifies including images in your output.

geometry The Geometry package allows you to change the margins and size of your document.

You can import a package with `\usepackage[optional]{package}`. E.g.: `\usepackage[English]{babel}`, `\usepackage[margin=24mm]{geometry}`, `\usepackage{graphicx}`.

Exercise 2 and a short break

Make exercise 2 on the exercise sheet:
Try to recreate the given page in LaTeX. It is an article document using the things you have learned above.

This is also a short break. It is no problem if you don't finish the exercise, but try to at least have a compiling document with a title.

Mathmode

So far we have worked in *text mode*.

Mathematical formulas and signs are made in *math mode*.

Text mode and math mode use separate commands, which will not work in the other.

Two types: inline and display math

Inline math mode:

Example

This sentence uses inline math like $a^2 + b^2 = c^2$ or $\oint_C B \cdot d\ell = \mu_0 \sum_{i=\text{encl}} I_i$. This works well for small formulas.

Display math mode:

Example

Here we see display math, which is more fitting for large or important formulas.

$$a^2 + b^2 = c^2, \qquad \oint_C B \cdot d\ell = \mu_0 \sum_{i=\text{encl}} I_i$$

Opening math mode

In order to open math mode, you need one of the following commands:

Inline math

- `\( ... \)`
- `$ ... $`

Display math

- `\[ ... \]`
- `$$ ... $$`

The basis

The basic operations works as you might expect, e.g.
`$4 + 5 - 3 * 6 / 9 = 7$` gives $4 + 5 - 3 * 6/9 = 7$.

For multiplication: use `$2 \times 3$` or `$2\cdot 3$` for 2×3 respectively $2 \cdot 3$.

Subscript and superscript

Relative placing (sub- and superscript):
The hat (^) and the dash (_).

- One argument, surrounded by brackets {...}.
- Or no brackets, then only the next character is taken into account.

Example

x_n	x_n
e^{tA}	e^{tA}
$3^r d$	3^rd

Common commands

Most mathematical symbols which are not on the keyboard are given by an abbreviation of their name (as it is pronounced).

Example (Vertical combinations)

`\frac{`⟨*num*⟩`}{`⟨*denom*⟩`}`	$\frac{1}{137}$	`$\frac{1}{137}$`
`\binom{`⟨*high*⟩`}{`⟨*low*⟩`}`	$\binom{n}{p}$	`$\binom{n}{p}$`
`\sqrt[power]{`⟨*number*⟩`}`	$\sqrt[3]{512}$	`$\sqrt[3]{512}$`

Example (Sine, cosine, etc.)

`\sin`⟨*number*⟩	$\sin 60^\circ$	`$\sin 60^\circ$`
`\cos(`⟨*number*⟩`)`	$\cos(\pi/3)$	`$\cos(\pi/3)$`
`\log`⟨*number*⟩	$\log 2i$	`$\log 2i$`

Summations, integrals and products

Integrals, sums and product absorb the sub- and superscript when in display math:

Example

$$\sum_{n=0}^{\infty} \int_0^1 \frac{1}{n!} A^n t^n dt$$

```
$$\sum_{n=0}^\infty \int_0^1 \frac{1}{n!} A^nt^n dt $$
```

Greek

Example

$$\frac{\hbar^2\nabla^2}{2m}\psi(r) + \frac{1}{4\pi\epsilon_0 r}\psi(r) = E\psi(r)$$

```
$$\frac{\hbar^2 \nabla^2}{2m} \psi(r) +
\frac{1}{4 \pi \epsilon_0 r} \psi(r) = E \psi(r) $$
```

Greek characters: `\theta` (θ).

Greek capitals: `\Phi` (Φ).

Nicer Greek characters: `\varepsilon` (ε).

N.B. Not all characters can be made nicer.

Different variants of a character: `\hbar` ($\hbar$), `\ell` (ℓ).

Symbols

LaTeX has many, many mathematical symbols. You can find them here:

- Complete list at CTAN: `http://www.ctan.org/tex-archive/info/symbols/comprehensive/`.
- Drawing a symbol yourself: `https://detexify.kirelabs.org/`
- Other problems:
  - `http://duckduckgo.com/`
  - `http://www.google.com/`
  - `http://www.bing.com/`
  - `http://www.yahoo.com/`
  - `http://yandex.com/`
  - `https://search.creativecommons.org/`
  - `https://swisscows.com/`

Brackets (left and right)

Pairs of vertical symbols can be enlarged automatically using `\left` en `\right` right in front of the symbol.

Example

Ugly:

$(\frac{1}{2})$ `(\frac{1}{2})`

Beautiful:

$\left(\frac{1}{2}\right)$ `\left( \frac{1}{2} \right)`

Only a left bracket? Place a dot/period after `\right`.

`\left\{ ... \right.` → $\left\{ \frac{1}{\omega} \right.$

White space

White spacings are neglected in math mode. You can force white spacings using:

`\!`	‖	`\pi\!\varphi`	$\pi\varphi$
	||	`\pi \varphi`	$\pi\varphi$
`\,`	||	`\pi\,\varphi`	$\pi\,\varphi$
`\quad`	| |	`\pi\quad\varphi`	$\pi\quad\varphi$
`\qquad`	| |	`\pi\qquad\varphi`	$\pi\qquad\varphi$

AMS-LaTeX

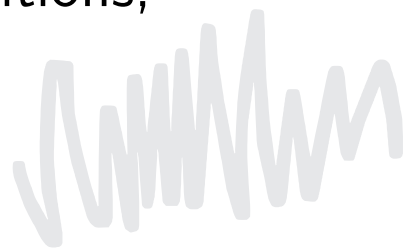
The American Mathematical Society provides a number of packages for working with mathematical formulae. This project includes the following packages:

amsmath The basis of most mathematical editing, used many times in these slides.

amssymb Additional symbols like $\therefore$, $\beth$ and $\mho$, as well as the most important math fonts.

amsfonts Provides more additional font types. (Try also the packages eufrak and eucal).

amsthm Support for defining environments for definitions, theorems, exercises and so on.



Advanced *math mode*-environments

align Displays multiple vertically aligned numbered equations.

equation A 'better' version of

`$$ ... $$` which also adds a number at the end of the line.

No numbering: place a star (*) after the environment.
Example: `\begin{equation*} ... \end{equation*}`.

You can add a row of text within the align environment using `\intertext`.

Advanced *math mode*-environments *(example)*

Example

$$a = b + c \quad (1)$$

$$a + 2b = c \quad (2)$$

```
\begin{align}
a      &=  b+c\\
a+2b &=  c
\end{align}
```

$$2x + 3 = 0$$

Hence:

$$x = -\frac{3}{2}$$

```
\begin{align*}
2x + 3 &= 0    \\
\intertext{Hence:}
x      &= -\frac{3}{2}
\end{align*}
```

Exercise 3

For the final exercise, reconstruct the following formulas in the document of Exercise 2.

$$\int_{-\infty}^{\infty} e^{ax^2} = \sqrt{\frac{\pi}{a}}$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}$$

(This formula uses the Lambda and the mu, nu and kappa from Greek.)
Your formulas might look slightly different since this presentation uses a non-standard math font.

Closing remarks

The solutions for the exercises as well as a cheat-sheet and further challenging exercises can be found on the site or in this Team.

Good luck working with LaTeX in the future!