Learning LaTeX by Doing

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1 Introduction

LaTeX is a document preparation system developed from Donald Knuth's TeX program. The most recent version, LaTeX 2$_\varepsilon$, is a sophisticated program designed to produce high-quality typesetting especially for mathematical text. This course is only meant as a short, hands-on introduction to LaTeX for newcomers who want to prepare rather simple documents. The main objective is to get students started with LaTeX 2$_\varepsilon$ on a UNIX or Windows platform. A more thorough, but also much longer Dutch introduction is *Handleiding LaTeX* of Piet van Oostrum [Oos97]. For complete descriptions we refer to the *LaTeX-Manual* of Leslie Lamport [Lam94] and *the LaTeX Companion* of Frank Mittelbach and MichelGoossens [MG04]. The included tables make this course document also useful as a reference manual.

We have followed a few didactical guidelines in writing the course. Learning is best done from examples, learning is done from practice. The examples are often formatted in two columns, as follows:[1]

$\frac{1}{2}$ is a fraction	`\frac{1}{2} is a fraction.`

The exercises give you the opportunity to practice LaTeX, instead of only reading about the program. You can compare your answers with the ones in Appendix A.

2 A Simple Example

LaTeX is neither a desktop publishing package nor a word processor. It is a document preparation system. First, you write a plain text containing formatting commands into a file by means of your favorite editor. Next, the LaTeX-program converts this text into formatted matter that you can preview and print. Below we shall describe the basics of this process on a Unix platform. When you use a LaTeX editor like WinEDT or WinShell on a PC platform most of the commands to typeset and preview documents are carried out by pressing the corresponding button in a toolbar.

2.1 Running LaTeX and Related Programs

EXERCISE 1 Do the following steps:

1. Create a text file, say `example.tex`, that contains the following text and LaTeX commands:

```
\documentclass{article}
\begin{document}
This is a simple example to start with \LaTeX.
\end{document}
The first task.
```

Figure 1: A Simple LaTeX document.

For example, you can use the editor XEmacs:

[1] On the left is printed the result of formatting the input on the right.

```
xemacs example.tex
```

The above UNIX command starts the editor and creates the source file `example.tex`.

Good advice: always give a source file a name with extension `.tex`.

This will make it easier for you to distinguish the source document from files with other extensions, which LaTeX will create during the formatting.

2. Convert this file into formatted, printable code. Here the LaTeX-program does the job:

   ```
   latex example
   ```

   It is not necessary to give the filename extension here. LaTeX now creates some additional files:

   `example.dvi` that can be printed and previewed;
   `example.aux` that is needed for cross-referencing;
   `example.log` that is a transcript of the formatting.

3. Preview the **d**e**v**ice **i**ndependent document (with extension `.dvi`) on your computer screen by typing:

   ```
   xdvi example
   ```

4. Convert the dvi-file into a printable PostScript document by typing:

   ```
   dvips example
   ```

   It creates the file `example.ps` that you can print in the usual way. For example, when you want print it on the student laserprinter `sl1`, just enter:

   ```
   lpr -Psl1 example.ps
   ```

5. Alternatively, convert the dvi-file into a printable pdf-document (Portable Display Format) by typing:

   ```
   dvipdf example
   ```

   It creates the file `example.pdf`, which you can view on the computer screen with the Adobe Acrobat Reader by entering the command:

   ```
   acroread example.pdf
   ```

   You can print this file in the usual way.

Two shortcuts:

- You can immediately print a dvi-file, without creating a PostScript file. For example, to print the file `example.dvi` on the printer `sl1`, you can enter the command:

```
dvips -f example.dvi | lpr -Psl1
```

- You can immediately format the source file into a pdf-file. Use the `pdflatex` command instead of `latex` for formatting.

Figure 2 summarizes the standard processing of a LaTeX document.

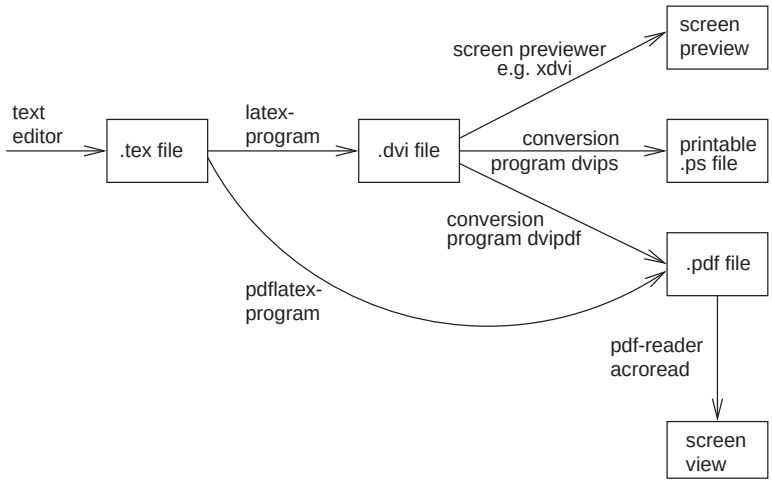


Figure 2: Standard Processing of a LaTeX document.

2.2 The Structure of a LaTeX Document

We shall use the above example to explain the basic structure of a LaTeX document. As stated before, the source file `example.tex` contains both text and LaTeX commands. You can easily recognize the formatting commands: they always start with a backslash (\). For example, the first line

```
\documentclass{article}
```

is the command that informs LaTeX what kind of document will be compiled. The five standard document classes are:

class	*purpose*
`article`	papers in scientific journals, short tutorials, etc.
`report`	rather long texts, master theses, etc.
`book`	actual books
`letter`	letters
`slides`	transparencies

Table 1: Standard Document Classes.

EXERCISE 2 Change the document class of `example.tex` from `article` into `slides`, format the document again, and see the effect on the dvi-file.

In addition to choosing the document class, you can select from among certain document-class options and additional packages. The options for the `article` and `report` classes include the following:

class option	*purpose*
`11pt`	specifies an eleven-point type size, which is 10% larger than the default ten-point type size.
`12pt`	specifies an twelve-point type size.
`twocolumn`	produces two-column output.
`twoside`	formats output for printing on both sides of a page, taking care of headers and footers.
`a4paper`	generates an A4 page layout.
`landscape`	uses the landscape orientation, where the longer side of the paper is horizontally oriented.

Table 2: Some Class Options.

You specify options between square brackets. For example, the line

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

specifies that the document should be formatted in the article style, using a twelve-point character size and an A4 page layout.

Additional packages must be declared via the `\usepackage` command in the *preamble*, i.e., they must be declared between the `\documentclass` command and `\begin{document}`. Much used packages are listed below:

packages	*purpose*
`a4wide`	produces an A4 page layout with longer lines.
`amssymb`	allows the use of mathematical symbols developed by the American Mathematical Society (AMS).
`babel`	facilitates the use of several languages.
`graphicx`	allows the use of the imported graphics via the extended graphics package.
`color`	allows the use of colors.

Table 3: Some Useful LaTeX 2_ε Packages.

For example, the two lines

```
\usepackage[dutch]{babel}
\usepackage{a4wide}
```

specify that

- document elements like chapter headings, section headings, and so on, are in Dutch;
- Dutch hyphenation rules are applied;
- the document is formatted in an A4 page layout with long lines.

In case you want to deviate from the standard settings, you can place further instructions in the preamble. For example, the two lines[2]

```
\addtolength{\textheight}{2cm}
\setlength{\parindent}{0pt}
```

will make the text height two centimeters longer than the default size and causes paragraphs to be displayed without indentation.

Finally, the text is placed between the `\begin{document}` command and `\end{document}`. All lines after the `\end{document}` command are considered by LaTeX as commentary, as you may have noticed in the example. By the way, everything that occurs after a percent sign (%) until the end of the line in the source file is considered by LaTeX as commentary, too.

EXERCISE 3 In the introduction we stated that LaTeX is *the* program to create mathematical texts. To get you motivated, change the contents of the `example.tex` file into the following:

```
\documentclass{article}
\usepackage{amssymb}
\setlength{\parindent}{0pt}

\begin{document}
This is a simple example to start with \LaTeX.
A mathematical formula can appear in the running text and
on a separate line, as the following example shows:
\bigskip

Define the function $f:(0,\infty)\to\mathbb{R}$ by
$$ f(x) = \frac{\ln x}{x^2} $$
then
$$ \lim_{x\to\infty} f(x)=0 $$
\end{document}
```

Format the file again and preview the result. Note that a mathematical formula in a running text is put between single dollar symbols `$`. A formula is centered on a separate line if it is between double dollar symbols `$$`. Alternative delimeters are tabulated below:

inline formula	***displayed formula***
`$` *formula* `$`	`$$` *formula* `$$`
`\(` *formula* `\)`	`\[` *formula* `\]`
`\begin{math}` *formula* `\end{math}`	`\begin{displaymath}` *formula* `\end{displaymath}`

Table 4: Math Mode Environments.

We end this subsection with a more elaborate document structure. A screen shot of the two pages is shown in Figure 3.

[2]Please note that in the second line `0pt` starts with the digit 0 and not with a capital O.

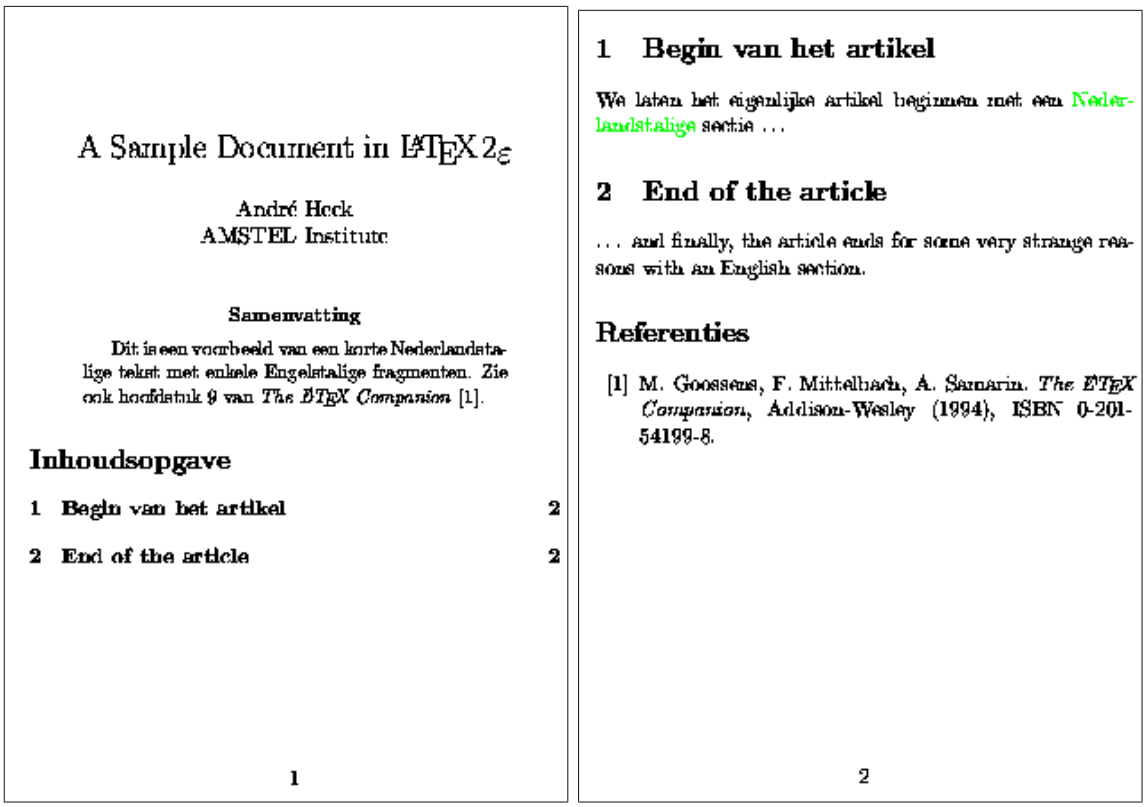


Figure 3: The Formatted Sample Document.

The program listing is in Figure 4. It shows, among other things, how to

- add a title and the name of the author;
- use accents;
- omit a date;
- add a table of contents;
- add a bibliography;
- introduce sections;
- switch between language choices.

Do not worry too much if not every detail of the program is clear to you. We shall explain many of the issues later on in this tutorial.

```
\documentclass[a5paper,11pt]{article}
\usepackage[english, dutch]{babel}
% Note: the last language is the default at the beginning.
\usepackage{color}

\author{Andr\'e Heck\\
        AMSTEL Institute}
\title{A Sample Document in \LaTeXe}
\date{}

\begin{document}
\maketitle
\begin{abstract}
Dit is een voorbeeld van een korte Nederlandstalige tekst met
enkele Engelstalige fragmenten. Zie ook hoofdstuk 9 van
\emph{The \LaTeX\ Companion} \cite{GMS94}.
\end{abstract}
\tableofcontents

\section{Begin van het artikel}
We laten het eigenlijke artikel beginnen met een
\textcolor{green}{Nederlandstalige} sectie \ldots

\selectlanguage{english}  % we choose the English language
\section{End of the article}
\ldots\ and finally, the article ends for some very
strange reasons with an English section.

\selectlanguage{dutch}  % terug naar Nederlandstalige tekst
\begin{thebibliography}{99}
\bibitem{GMS94}
M.~Goossens, F.~Mittelbach, A.~Samarin. \emph{The \LaTeX\ Companion},
Addison-Wesley (1994), ISBN~0-201-54199-8.
\end{thebibliography}

\end{document}
```

Figure 4: A Sample LaTeX document.

EXERCISE 4

The sample text in Figure 4 is available in the source file `sample.tex`.

1. Format the document once with the `latex` command. Verify with the `ls sample.*` command that four new documents have been created. Ignore the formatting warnings for the moment.

2. Preview the dvi-file `sample.dvi` and verify that the table of contents and the bibliographic

citation in the abstract are not correct, yet. Note that LaTeX uses hyphenation rules according to the choice of language.

3. Format the document once more and verify that the table of contents and the citation are correct now.

4. The previewer `xdvi` does not display the text `Nederlandstalige` in section 1 in the green color. Convert the dvi-file into a printable pdf-document and use the Acrobat reader to verify the proper use of colors.

2.3 If Formatting Goes Wrong

If you make a mistake in the source file and LaTeX cannot format your document, the formatting process is interrupted. In the following exercise, you will practice the identification and correction of errors.

EXERCISE 5 Deliberately make the following typographical error in the source file `sample.tex`: Change the line

```
\section{Begin van het artikel}
```

into

```
\sectino{Begin van het artikel}
```

1. Try to format the document. LaTeX will be unable to do this and the processing would be interrupted. The terminal window where you entered the `latex` command looks like:[3]

```
% latex sample.tex
This is TeX, Version 3.14159 (Web2C 7.3.1)
(sample.tex
LaTeX2e <1998/12/01> patch level 1
Babel <v3.6x> and hyphenation patterns for american, french, german,
ngerman, dutch, spanish, nohyphenation, loaded.
(/opt/teTeX/share/texmf/tex/latex/base/article.cls
Document Class: article 1999/01/07 v1.4a Standard LaTeX document class
(/opt/teTeX/share/texmf/tex/latex/base/size11.clo))
(/opt/teTeX/share/texmf/tex/generic/babel/babel.sty
......
(/opt/teTeX/share/texmf/tex/latex/graphics/dvipsnam.def))
No file sample.aux.

LaTeX Warning: Citation 'GMS94' on page 1 undefined on input line 16.

No file sample.toc.
[1]
! Undefined control sequence.
```

[3] We omit some output for clarity.

```
l.21 \sectino
             {Begin van het artikel}
?
```

The first warning is innocent. You will be reminded later on that you have to format the document once more to get the cross-references correct. The second error message is serious. The LaTeX program notifies the location where it signalled that something goes wrong, viz., line number 21. However, this does not mean that the error is necessarily there.

2. There are several ways to proceed after the interupt. Enter a question mark and you see your options:

```
? ?
Type <return> to proceed, S to scroll future error messages,
R to run without stopping, Q to run quietly,
I to insert something, E to edit your file,
1 or ... or 9 to ignore the next 1 to 9 tokens of input,
H for help, X to quit.
```

3. Press RETURN. LaTeX will continue formatting and tries to make the best of it. Logging continues:

```
[2] (sample.aux)

LaTeX Warning: There were undefined references.


LaTeX Warning: Label(s) may have changed.
Rerun to get cross-references right.

 )
Output written on sample.dvi (2 pages, 2040 bytes).
Transcript written on sample.log.
```

4. Preview the dvi-file and identify the error.

5. Format again, but this time enter the character `e`. Your default editor will be opened and the cursor will be at the location where LaTeX spotted the error. Correct the source file[4] and give the formatting another try.

2.4 Basic Conventions

We end this chapter with some basic conventions of LaTeX that are essential for your understanding of the program.

[4] If you have not specified in your UNIX shell the TeX editor that you prefer, then the `vi`-editor will be started. You can leave this editor by entering `ZZ`. In the c-shell you can add in the file `.cshrc` the line `setenv TEXEDIT 'xemacs +%d %s'` so that XEMACS is used.

2.4.1 Spacing, Line Breaking and Page Breaking

Because LaTeX itself formats the document using certain fonts and a given page layout, the source file and the actual printout are different. In other words, it does not matter where the lines in the source file end (where the carriage returns are) in the source file; LaTeX joins them. Similarly, extra spaces are ignored, as the example below illustrates:

extra spaces and single line breaks in the source file are ignored.	`extra spaces and single line breaks in the source file are ignored.`

If you really want to start a new line, pressing the ENTER key once is not enough. LaTeX uses the convention that pressing the ENTER key twice starts a new paragraph, which will often start indented. Alternatively, type the command `\newline` to start a new line. The following example generates the lines '`one`' and '`two`':

one
two
	`one`
	`\newline`
	`two`

It goes without saying that LaTeX contains many constructions to influence spacing, line breaking and page breaking. We list a few of them in Table 5.

command	*effect*
`\newpage`	starts a new page at that point.
`\pagebreak`	starts a new page after the current line.
`\newline`	ends a line without justifying it.
`\linebreak`	ends a line and justifies it, i.e., stretches the spacing between words so the line extends to the right margin.
`\-`	allows LaTeX to hyphenate a word at that point.
`\␣`	a blackslash followed by a blank space causes a single space to be printed.
`\hspace`	produces a horizontal space of given size.
`\vspace`	produces vertical space of given size.
`\smallskip`	creates a little extra vertical space between paragraphs.
`\medskip`	creates medium extra vertical space between paragraphs.
`\bigskip`	creates large extra vertical space between paragraphs.

Table 5: Page Breaking, Line Breaking, and Spacing

A shortcut for the `\newline` command is the double backslash `\\` .

2.4.2 Modes and Environments

Important are the concepts 'mode' and 'environment' as they determine the way LaTeX is formatting the document. LaTeX distinguishes:

paragraph mode: LaTeX regards your input as a sequence of words and sentences to be broken into lines, paragraphs, and pages.

math mode: this mode is for generating mathematical formulas. With the dollar symbol $ you mark the start and the end of an in-line mathematical formula, i.e., a formula in a running text. A formula put between `\[` and `\]` appears on a separate line and centered.

left-to-right mode: LaTeX produces output that keeps going from left to right.

LaTeX has a clear syntax for using the brackets [], ( ), and { }. For example, in paragraph mode:

parentheses (rounded brackets) are ordinary parentheses.

braces (curly brackets) are used for the parameters of a command, like `\begin{document}`, and for grouping parts of the document into a single unit, like `2^{n+1}`.

square brackets are ordinary brackets, and are also used for optional arguments to a command, like `\documentstyle[12pt]{article}`.

A useful environment is `verbatim`: it is the one place where LaTeX pays attention to how input is formatted. The example below illustrates that the `verbatim` environment allows you to type the text exactly the way you want it to appear in the formatted version.

A short *Mathematica* session:

```
In[1]:= 1/(x^3+1)

           1
Out[1]= ------
              3
        1 + x

In[2]:= D[%, {x,2}]

                4
          18 x          6 x
Out[2]= --------- - ---------
                3 3          3 2
        (1 + x )     (1 + x )

In[3]:= Quit
```

```
A short \emph{Mathematica} session:
\begin{verbatim}
In[1]:= 1/(x^3+1)

           1
Out[1]= ------
              3
        1 + x

In[2]:= D[%, {x,2}]

                4
          18 x          6 x
Out[2]= --------- - ---------
                3 3          3 2
        (1 + x )     (1 + x )

In[3]:= Quit

\end{verbatim}
```

A LaTeX environment determines a scope in which commands have a special meaning or a special formatting. You will encounter in this tutorial many environments: `itemize`, `enumerate`, `center`, `displaymath`, and others.

2.4.3 Forbidden Characters

As you have seen before, some characters have a special meaning for LaTeX. For example, the dollar symbol, the percent sign, curly brackets, and so on. In Table 6 we list the special commands to get the characters in your document.

forbidden:	\	{	}	$	&	#	^	_	~	%
use:	`$\backslash$`	`\{`	`\}`	`\$`	`\&`	`\#`	`\^{}`	`\_{}`	`\~{}`	`\%`
result:	\	{	}	$	&	#	^	_	~	%

Table 6: Ten Forbidden Characters.

EXERCISE 6 Create a LaTeX document that formats like the text shown in Figure 5 (the first two sentences are intentionally separated).

Mathematica uses the percent sign (%) to refer to the previous result and curly brackets ({}) for grouping.
See the two instructions below:

```
Sin[x]/x
Plot[%, {x,-3,3}];
```

Figure 5: The Formatted Text in Question between Rules.

3 Basic Tools for Formatting Text

Although our main objective is to learn how to create with LaTeX well-formatted mathematical texts, we shall first discuss the organizational elements of ordinary texts that contains little or no mathematics. Large portions of the text are reference tables that help you to do the exercises. At first reading you may omit the last two subsections about tables and pictures.

3.1 Structuring

In this subsection you will learn how to structure your documents: creating sections, adding a title and table of contents, etc. It will explain parts of the program listing in Figure 4.

3.1.1 Sectioning Commands

In the document classes `article`, `report`, and `book` you can easily structure the document into chapters, sections, subsections, and so on. The commands are listed in Table 7.

LaTeX takes care of numbering chapters and sections, i.e., it automatically generates the numbers. If you want a section heading without a number, just add an asterisk to the command.

Example	`\subsubsection*{Example}`
This is an unnumbered section.	`This is an unnumbered section.`

command	*purpose*
`\part`	divides long documents into separate parts.
`\chapter`	starts a new chapter. Only in `report` and `book`, *not* in `article`.
`\section`	starts a new section.
`\subsection`	starts a new subsection.
`\subsubsection`	starts a nested subsection.

Table 7: Sectioning Commands.

3.1.2 Title and Table of Contents

Use the `\maketitle` command to create a titlepage. This command must come after the `\begin{document}` command. The actual date may be specified in the preamble with the commands `\title`, `\author`, etc. Depending on the class of the document, LaTeX may automatically generate the date when the document was formatted. In case you do not like this, you can specify an empty date with `\date{}`. See the example in Figure 4 on page 9.

The use of the sectioning commands makes generating the table of contents an easy task: just enter the `\tableofcontents` command at the point where you want to place the listing and run the formatting program twice: the first time for getting the numbering done, and the second time for creating the table of contents.

3.1.3 Cross-Referencing

With the commands `\label` and `\ref` it is possible to refer to section numbers that have been automatically generated by LaTeX. For example, the current nested subsection has been defined by the line

```
\subsubsection{Cross-Referencing} \label{crossref}
```

LaTeX replaces every occurrence of `\ref{crossref}` by the actual section number. The following example illustrates this and gives the trick of how to avoid unpleasant line breaks:

It is not difficult to refer to Section 3.1.3.
But use the tilde to ensure that no line break occurs between the word and the number:
It is not difficult to refer to Section 3.1.3.
	`It is not difficult to refer to`
	`Section \ref{crossref}.\\`
	`But use the tilde to ensure that no`
	`line break occurs between the word`
	`and the number:\\`
	`It is not difficult to refer to`
	`Section~\ref{crossref}.`

In the same way you can label and refer to pictures, tables, mathematical formulas, etc. Page references use `\label` in the same way, but are referred to using `\pageref` instead of `\ref`.

3.1.4 Footnotes

With the command `\footnote{`*footnote text*`}` an automatically labeled footnote is printed at the foot of the current page. By default, it typesets an Arabic number in text and a lowercase letter inside a `minipage` environment. To get a nice layout, place the footnote immediately after the word or sentence they refer to. Footnotes in a `minipage` environment are illustrated in the example below.

Footnote symbols[a] are sometimes lowercase letters.[b]

[a] A sample footnote.
[b] This happens e.g. in a minipage.

```
Footnote symbols\footnote{A sample footnote}
are sometimes lowercase letters.\footnote{
This happens e.g.~in a minipage}
```

3.1.5 Indexing

Making an index consists of two phases: gathering the information and writing LaTeX input to produce it. Although compiling the index is usually the first step, we explain first how an index is produced in LaTeX.

Producing an Index

The `theindex` environment produces an index in two-column format. Each main index entry is begun by an `\item` command. A subentry is begun with `\subitem`, and a subsubentry is begun with `\subsubitem`. Blank lines between entries are ignored. If you want some extra vertical space, use the `\indexspace` command. The following small example illustrates the production of an index.[5]


```
\begin{theindex}
\item arithmetic operations, 2--5
  \subitem addition, $+$, 2
  \subitem division, $\slash$, 2
  \subitem double factorial, !!, 3
  \subitem factorial, !, 4
  \subitem multiplication, $\ast$, 2
  \subitem precedence of, 5
\item arranging terms,
  \see{\textbf{sort}}{11}
\indexspace
\item \textbf{sort}, \textit{23--24},
   45--47, 53
\item sorting
  \subitem lists, 45--47
  \subitem polynomials
     \subsubitem univariate, 23
     \subsubitem multivariate, 24
\end{theindex}
```

[5] We assume that the `makeidx` package has been included in the document preamble via the `\usepackage{makeidx}` so that the `\see` command can be used.

Compiling an Index

Compiling an index is not easy and takes time, but LaTeX and the support program `makeindex` can help to generate one. Here, we only discuss the basics of index generation. For in-depth information, we refer to Chapter 11 of *The LaTeX Companion* [MG04]

To enable the indexing features, the `makeidx` package must be included in the document preamble with the `\usepackage{makeidx}` statement. The special indexing commands must be enabled by putting the `\makeindex` statement into the document preamble. The content of the index is specified with `\index{`*key*`}` commands, where *key* is the index entry. You enter the index commands at the points in the text where you want the final index entries to point to. When you typeset the document, LaTeX will write an appropriate index entry together with the current page number to a special file. This file has the same name as the LaTeX input file, but a different extension, viz. `.idx` instead of `.tex`. The next table explains the syntax of the *key* argument with several examples.[6]

Example	*Index entry*	*Comment*
`\index{Airy equation}`	Airy equation, 73	plain entry on page 73
`\index{antiderivative|textbf}`	antiderivative, 55	entry at page 55, with formatted page number
`\index{argument@\textbf{argument}}`	**argument**, 13	formatted entry on page 13
`\index{arranging|see{\textbf{sort}}}`	arranging, *see* **sort**	forwarding
`\index{sort@\textbf{sort}}`	**sort**, 5–7	formatted entry on pages 5, 6, and 7
`\index{sorting!lists}`	sorting lists, 45–47	subentry on pages 45, 46, and 47
`\index{sorting!polynomials!univariate}`	polynomials univariate, 23	subsubentry on page 23

Table 8: Index Key Syntax Examples.

The generated `.idx` file contains a raw index. With the (external) program `makeindex` you can process its contents and generate a sorted index file with the extension `.ind`. If now the LaTeX input file is processed again, the sorted index gets included into the document at the point where LaTeX finds the `\printindex` statement — usually at the end, right before the `\end{document}` command.

The `showidx` package can be used to print out all index entries in the left margin of the text. This is usefull for proofreading a document and verifying the index.

3.2 Creating Lists

LaTeX has several environments for creating lists, which can also be nested. A few examples will do.

[6] Not listed in the Table 8 is the fact that the commands `\index{key|(xxx}` and `\index{key|)xxx}` on page n and m, respectively, will generate a page range of the form `\key{`n`-`m.

An enumerated (numbered) list:

1. This is the 1st item.
2. This is the 2nd item.
	`\begin{enumerate}`
	`\item This is the 1st item.`
	`\item This is the 2nd item.`
	`\end{enumerate}`

A simple unnumbered list:

• This is the 1st item.
• This is the 2d item.
	`\begin{itemize}`
	`\item This is the 1st item.`
	`\item This is the 2nd item.`
	`\end{itemize}`

A customizable list:

One This is the 1st item.
Two This is the 2nd item.
	`\begin{description}`
	`\item[One] This is the 1st item.`
	`\item[Two] This is the 2nd item.`
	`\end{description}`

[First] This is the 1st item.
[Second] This is the 2nd item.
	`\begin{description}`
	`\item{[First]} This is the 1st item`
	`\item{[Second]} This is the 2nd item`
	`\end{description}`

EXERCISE 7

Create a LaTeX document that formats like the text shown in Figure 6.

List of mathematical functions:

- Trigonometric functions
  - sine
  - cosine
  - tangent
- Special functions
  - Beta function
  - Gamma function
  - Riemann zeta function

Figure 6: Nested Lists

3.3 Changing Fonts

Occasionally you will want to change from one font to another, for example if you wish to be **bold**, to *emphasize* something, or to make it look huge. There are many ways of dealing with font changes in LaTeX.

3.3.1 Changing the Typeface

You can change the font family, font series (width and weight), and the font shape by the commands and declarations listed in Table 9.

command	*declaration*	*meaning*
`\textrm{...}`	`{\rmfamily ...}`	formatted in **roman** family
`\textsf{...}`	`{\sffamily ...}`	formatted in sans serif family
`\texttt{...}`	`{\ttfamily ...}`	formatted in `typewriter` family
`\textmd{...}`	`{\mdseries ...}`	formatted in medium series
`\textbf{...}`	`{\bfseries ...}`	formatted in **bold** series
`\textup{...}`	`{\upshape ...}`	formatted in upright shape
`\textit{...}`	`{\itshape ...}`	formatted in *italic* shape
`\textsl{...}`	`{\slshape ...}`	formatted in *slanted* shape
`\textsc{...}`	`{\scshape ...}`	formatted in SMALL CAPS shape
`\emph{...}`	`{\em ...}`	formatted in *emphasized*
`\textnormal{...}`	`{\normalfont ...}`	formatted in the document font

Table 9: Changing the Typeface.

The following example also shows how the commands and declarations can be combined:

You can strongly ***emphasize*** the possibility of formatting text **in a sans serif bold typeface**	`You can strongly \emph{\textbf{emphasize}} the possibility of formatting text {\sffamily\bfseries in a sans serif bold typeface}`

Each of the declarations in Table 9 has a corresponding environment whose name is obtained by dropping the backslash from the command name.[7] For example, text placed between `\begin{bfseries}` and `\end{bfseries}` will be formatted in bold.

You may wonder why LaTeX provides three manners of changing the typeface and when to use which method. Our advice is the following:

- A command like `\textbf` is intended for formatting words or short pieces of text in a specific family, series, or shape. Two advantages are: (1) it is consistent with other LaTeX structures. (2) LaTeX takes care of correct spacing like automatic italic correction.
- A declaration is appropriate when you define your own commands or environments as in the example below.

[7] Any declaration has a corresponding environment in this manner.

- For longer passages in your document it is clearer to use an environment.

- **Now boldface items.**
- **Note the subtle difference *if* lines are typeset with correction of spacing and *if* lines are typeset without italic correction.**

```
\newenvironment{bolditemize}{\begin{itemize}
\normalfont\bfseries}{\end{itemize}}
\begin{bolditemize}
\item Now boldface items.
\item Note the subtle difference\\
\textit{if} lines are typeset with\\
correction of spacing and\\
{\itshape if} lines are typeset\\
without italic correction.
\end{bolditemize}
```

3.3.2 Changing the Font Size

LaTeX has ten size-changing declarations. There are no corresponding size-changing command forms with one argument because such changes are normally only used in the definition of commands or in a limited scope. Table 10 lists the size-changing commands.

declaration	*size*	*declaration*	*size*	*declaration*	*size*
`{\tiny ...}`	size	`{\normalsize ...}`	size		
`{\scriptsize ...}`	size	`{\large ...}`	size		
`{\footnotesize ...}`	size	`{\Large ...}`	size	`{\huge ...}`	size
`{\small ...}`	size	`{\LARGE ...}`	size	`{\Huge ...}`	size

Table 10: Changing the Font Size.

EXERCISE 8 Create a LaTeX document that formats like the installation script shown in Figure 7.

To install Mathcad:

1. Start Windows.
2. Insert the disk marked `Disk 1` in the floppy disk drive.
3. From the File menu in the Windows Program Manager, choose Run (ALT+F,R).
4. Type ***drive*:\setup.exe**, where ***drive*** is the letter of the disk drive containing the disk.
5. Press ENTER.
6. Follow the instructions on the screen.

Figure 7: Installation Script with Various Fonts.

3.4 Paragraph Justification

There are two ways to change the alignment of lines in a paragraph: via an environment and via a declaration. The difference is that an environment starts a new paragraph, and a command does not do this. An example of centering lines of text in a paragraph, using \\ to break lines:

This
is
centered.

This
is
also
centered.

```
\begin{center}
This \\ is \\ centered.
\end{center}
\begin{quote}
\centering
This \\ is \\ also \\ centered.
\end{quote}
```

The environments and commands for left and right justification work similarly. An example:

This
is
right flushed.

This
is
also
right flushed.

```
\begin{flushright}
This \\ is \\ right flushed.
\end{flushright}
\begin{quote}
\raggedleft
This \\ is \\ also \\ right flushed.
\end{quote}
```

3.5 Using Accents

The following Portuguese text illustrates the use of accents:

A equação do pêndulo matemática com período próprio $\frac{2\pi}{\omega}$ é

$$u'' + \omega^2 u = 0$$

```
A equa\c{c}\~{a}o do p\^{e}ndulo
matem\'{a}tica com per\'{\i}odo
pr\'{o}prio $\frac{2\pi}{\omega}$ \'{e}
$$u''+\omega^2u=0$$
```

Note that the letter *i* in *período* needs special treatment: the command \i produces a dotless *i* that can be accented. The commands in Table 11 show how to produce various accented symbols in paragraph mode.

ò \‘{o}	õ \~{o}	ǒ \v{o}	o̧ \c{o}
ó \’{o}	ō \={o}	ő \H{o}	ọ \d{o}
ô \^{o}	ȯ \.{o}	o͡o \t{oo}	o̲ \b{o}
ö \"{o}	ŏ \u{o}		

Table 11: Paragraph Mode Accents.

Accents in math mode are produced with other commands. For example, use `$\tilde{g}$` for $\tilde{g}$. We list the math mode accents in Table 12.

$\hat{a}$ \hat{a}	$\acute{a}$ \acute{a}	$\bar{a}$ \bar{a}	$\dot{a}$ \dot{a}
$\check{a}$ \check{a}	$\grave{a}$ \grave{a}	$\vec{a}$ \vec{a}	$\ddot{a}$ \ddot{a}
$\breve{a}$ \breve{a}	$\tilde{a}$ \tilde{a}		

Table 12: Math Mode Accents.

EXERCISE 9 Explain how to format the following four words: Hühner-händler, débâcle, situações, naïef.

3.6 Creating Tables

Formatting tabular material is a branch of sports of its own, learned best by mimicking many good examples. The next example illustrates how to create a simple table of the first four Legendre polynomials.

n	$P_n(x)$
0	1
1	x
2	$(3x^2-1)/2$
3	$(5x^3-3x)/2$

```
\begin{tabular}{||l|l||} \hline
$n$ &  $P_n(x)$ \\ \hline
0 & $1$ \\
1 & $x$ \\
2 & $(3x^2-1)/2$ \\
3 & $(5x^3-3x)/2$ \\ \hline
\end{tabular}
```

In the first line, the options {||l|l||} stand for two left adjusted (l) columns, separated by a vertical line (|), with double vertical lines on the vertical sides of the table. In the source file, row entries are separated by an ampersand (&) and every row is closed with the \\ command. The \hline command creates a horizontal line right across the width of the table.

Column separators can differ from a vertical bar. In the next example we use the @{...} construct for this purpose. This specifier kills the inter-column space and replaces it with whatever is between the curly brackets. Below we apply it to suppress leading and trailing space in the table (with @{}) and to allow the of decimal point as separator between integral and decimal part of a floating-point number (with @{.}). A column label is placed above our numeric "column" by using the \multicolumn command. With this command one can make a single item that spans multiple columns.

e expression	value
e	2.7183
e^e	15.155
$(e^e)^e$	1618.5

```
\begin{tabular}{@{} c r @{.} l @{}} \hline
$e$ expression & \multicolumn{2}{c}{Value}
\\ \hline
$e$       &    2 & 7183 \\
$e^e$     &   15 & 155 \\
$(e^e)^e$ & 1618 & 5 \\ \hline
\end{tabular}
```

EXERCISE 10 Explain how to format the following table.[8]

errorbreak	
Value	**Purpose**
0	report error and continue reading
1	stop reading after syntax error
2	stop reading after any error

The next example[9] illustrates the power of LaTeX in creating high-quality tables in almost any shape and color that you desire. For many prototypical examples we refer to chapter 5 ('Tabular Material') of *The LaTeX Companion* [MG04].

	Probabilities		
Blood Type	**Males**	**Females**	**Total**
O	0.21	0.21	0.42
A	0.215	0.215	0.43
B	0.055	0.055	0.11
AB	0.02	0.02	0.04
Total	0.5	0.5	1.00

The LaTeX code is as follows and it requires the use of the packages `array` and `colortbl` (e.g. through the statement `\usepackage{array, colortbl}`):

```
\begin{tabular}{l|l|l|l} \hline
\rowcolor[gray]{0.9} & \multicolumn{3}{>{\columncolor[gray]{0.9}}c}
 {\color{blue}\bfseries Probabilities} \\ \hline
\rowcolor[gray]{0.9} \color{black}\textbf{Blood Type\hspace{2.5cm}}
 & \textbf{Males} & \textbf{Females} & \textbf{Total} \\ \hline
\quad O & 0.21 & 0.21 & 0.42 \\
\quad A & 0.215 & 0.215 & 0.43 \\
\quad B & 0.055 & 0.055 & 0.11 \\
\quad AB & 0.02 & 0.02 & 0.04 \\ \hline
\textbf{Total} & 0.5 & 0.5 & 1.00 \\
\hline
\end{tabular}
```

3.7 Importing Graphics

While LaTeX can import virtually any graphics format, Encapsulated PostScript (EPS) is the easiest graphics format to import into LaTeX because it contains `BoundingBox` information about the size of the picture. For example, the EPS file `file.eps` is inserted by specifying

```
\usepackage{graphicx}
```

[8] Table 4.10 taken from André Heck, *Introduction to Maple – 3rd ed.* Springer Verlag (2003), ISBN 0-387-00230-8.

[9] Table 4-2 taken from Beth Dawson and Robert G. Trapp, *Basic & Clinical Biostatistics – 4th ed.* McGraw-Hill (2004), ISBN 0-07-141017-1.

in the document preamble and then using the command

```
\includegraphics{file.eps}
```

Optionally, the picture can be scaled to a specific height and/or width

```
\includegraphics[height=10cm]{file.eps}
\includegraphics[width=5cm]{file.eps}
```

Additionally, the `angle` option rotates the included picture

```
\includegraphics[angle=45]{file.eps}
```

More options are available for manipulating the included picture. The interested reader is referred to the tutorial *Using Imported Graphics in LaTeX 2ε* [Rec97]. The example below shows the UvA logo twice, but the second one is rotated 45 degrees.

```
\begin{center}
\includegraphics[width=1.5cm]{uvalogo.eps}
\hspace{1cm}
\includegraphics[width=1.5cm,
                 angle=45]{uvalogo.eps}
\end{center}
```

EXERCISE 11 Find out what is the effect of changing the order of options in the `\includegraphics` command in the following example;

```
\begin{center}
\includegraphics[angle=30, totalheight=2cm]{uvalogo.eps}
\includegraphics[totalheight=2cmin, angle=30]{uvalogo.eps}
\end{center}
```

A paper, report, or book often contains a lot of figures and tables. In order to get these objects nicely spread across typeset pages, LaTeX provides environments to 'float' figures or tables. Any material enclosed in a `figure` or `table` environment will be treated as floating matter. Another advantage of a floating object is that you can easily define a caption for it: just use the `\caption` command. Below, we give an example of a floating picture.

The UvA logo is shown in Figure 8.

Figure 8: UvA logo

```
The UvA logo is shown in
Figure~\ref{fig:uvalogo}.
\begin{figure}
\begin{center}
\includegraphics[width=1.5cm]{uvalogo.eps}
\caption{UvA logo}\label{fig:uvalogo}
\end{center}
\end{figure}
```

Float environments support an optional parameters called the *placement specifier*. Use this parameter to tell LaTeX about the locations the floating matter is allowed to be moved to. A *placement specifier* is constructed by building a string of *float placing permissions*. See Table 13. A figure could be started with the following statement e.g. `\begin{figure}[!htb]`. The placement specifier `[!htb]` allows LaTeX to place the figure right here (`h`), at the top of some page (`t`), or at the bottom of some page (`b`), and all this even if it does not look that good (`!`). If no placement specifier is given, the standard classes assume `[tbp]`. If you want the picture to be placed exactly at the position that you prefer, you can use capital `H` as placement specifier that is included in the `float` package.[10] It will produce a non-floating figure. To use the `[H]` option, include the `\usepackage{float}` command in the document preamble and issue the `\restylefloat{figure}` command before the `\begin{figure}[H]` command is used.

Spec	*Permission to place the float*
`h`	*here* if possible (useful mainly for small floats)
`t`	at the *top* of the page
`b`	at the *bottom* of the page
`p`	on a special *page* of floats only
`!`	ignore esthetic rules

Table 13: Float Placing Permissions.

The two statements `\listoffigures` and `\listoftables` operate analogously to the `\tableofcontents` command, printing a list of figures and tables, respectively.

It is often useful to place text next to graphics. The `minipage` environment can help in such cases (also for placing more than one graphics object next to each other). The following example[11] illustrates the basics.

The typeset material:

Compute the area of the region bounded by the x-axis and the graph of the function $f(x) = (\sin x)\, e^{\cos x}$ between the points $(0, 0)$ and $(\pi, 0)$.

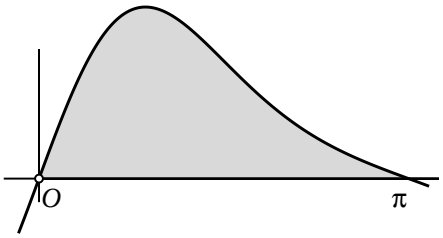


Figure 9: Sketch of the situation.

The LaTeX code:

```
\begin{center}
\begin{minipage}[t]{0.6\textwidth}
Compute the area of the region bounded by the $x$-axis and the graph
```

[10] A single-location option such as `[h]` is problematic. Recent versions of LaTeX automatically change it into `[ht]`

[11] Exercise taken from Jan van de Craats and Rob Bosch, *Basiswiskunde* (2005).

```
of the function $f(x) = (\sin x)\, e^{\cos x}$ between the points
$(0,0)$ and $(\pi,0)$.
\end{minipage}
\hfill
\begin{minipage}[t]{.3\textwidth}
\vspace{0pt}
\includegraphics[width=\textwidth]{F-bw21-opg05.eps}
\end{minipage}
\end{center}
```

What rests is to tell what LaTeX can do with other type of graphics objects such as bitmap, JPEG and GIF pictures, PDF pictures, and pictures created by METAPOST [Hec03]. The good news is that the `graphicx` package allows inclusion of pictures of this type if you use the `pdflatex` program. Drawback is that this program does not allow the inclusion of Encapsulated PostScript files. So you will have to convert such graphics files from EPS into BMP, JPG, GIF or PDF. The GNU software `GSview4.4` is one of the program that you can use for this purpose. Figure 10 shows the possible routes to typeset material that imports graphics objects from files.

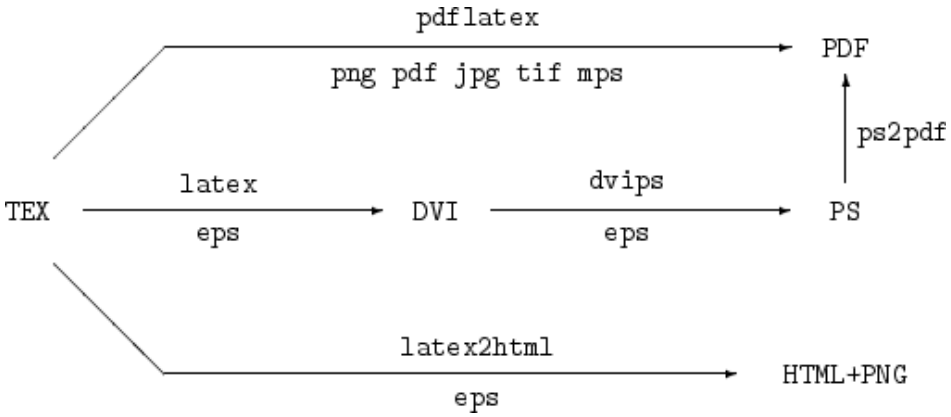


Figure 10: Import of pictures with `graphicx`.

4 Mathematical Formulas

Basic LaTeX offers a high level of mathematical typesetting capabilities. Nevertheless many packages are available for complex equations or mathematical constructs that are repeatedly required. In this tutorial we only describe the basic facilities.

4.1 Math Environments

Mathematical formulas are put in an environment. The main ones are:

- `\begin{math} ... \end{math}`:
  This places a formula in the running text. Usually, one does not start and end the `math`

environment in this way, but instead one uses a shortcut: one only puts a dollar symbol before and after the formula.

- `\begin{displaymath} ... \end{displaymath}`:
  The mathematical formula is displayed centered on a separate line. Instead of these commands you can also use $$ before and after the formula, or put the formula between `\[` and `\]`.
- `\begin{equation} ... \end{equation}`:
  The same as `displaymath` except that `equation` numbers the formula.

The following two examples give you a better idea:

If we take $-1 < a < 1$, then

$$\int_0^\infty \frac{u^a}{(1+u)^2}\,du = a!(-a)! \qquad (1)$$

By contour integration the left-hand side of (1) may by shown to be equal to $\pi a/\sin \pi a$, thus obtaining the identity

$$z!(-z)! = \frac{\pi z}{\sin \pi z}\,.$$

```
If we take $-1<a<1$, then
\begin{equation}
\int_{0}^{\infty} \frac{u^a}{(1+u)^2}\,du
= a!(-a)!
\label{eqno}
\end{equation}

By contour integration the left-hand side
of (\ref{eqno}) may by shown to be equal
to $\pi a / \sin \pi a$, thus obtaining
the identity
\[
z!(-z)!= \frac{\pi z}{\sin \pi z}\,.
\]
```

The in-line formula $\sum_{k=0}^{\infty} a_n$ differs from the displayed formula

$$\sum_{k=0}^{\infty} a_n$$

```
The in-line formula
$\sum_{k=0}^{\infty}a_n$
differs from the displayed formula
\[ \sum_{k=0}^{\infty}a_n \]
```

The above examples illustrate that LaTeX knows in math mode many special characters that cannot be used in paragraph mode, e.g., mathematical symbols like ∞, $\int$, $\sum$, and Greek characters like α, β, γ.

4.2 Basic Conventions in Math Mode

4.2.1 Spacing

In math mode, LaTeX automatically italicizes letters and it hardly uses spaces. Also, `$a b$` and `$ab$` format the same. Normally, you can best rely on LaTeX's internal spacing rules, but if desired, you can change it with one of the commands listed in Table 14.

command	*explanation*	*example*	*result*
	normal spacing between symbols	`||`	$\|\|$
`\!` or `\negthinspace`	negative thin space	`|\!|`	$\|\!\|$
`\,` or `\thinspace`	thin space	`|\,|`	$\|\,\|$
`\:` or `\medspace`	medium space	`|\:|`	$\|\:\|$
`\;` or `\thickspace`	thick space	`|\;|`	$\|\;\|$
`\quad`	extra space	`|\quad|`	$\|\quad\|$
`\qquad`	doubled extra space	`|\qquad|`	$\|\qquad\|$

Table 14: Horizontal Spacing in Math Mode.

4.2.2 Mathematical Symbols and Greek Letters

Mathematical symbols are entered

- directly from the keyboard, e.g., =, <, and > or
- by a command, e.g., `\leq` stands for the less-than-or-equal symbol $\leq$, and `\infty` stands for the infinity symbol ∞.

In Appendix B we list many mathematical symbols.

Greek letters are produced by commands that consist of the name of the letter preceded by a backslash `\`. The following example shows it all:

Examples of Greek characters are δ, Δ, θ, and Θ.
Note the difference between Π and $\prod$ (as in $\prod_{i=1}^{n}$), and between ϵ and ε.

```
Examples of Greek characters are $\delta$,
$\Delta$, $\theta$, and $\Theta$.\\
Note the difference between\\ $\Pi$ and
$\prod$ (as in $\prod_{i=1}^n$), and\\
between $\epsilon$ and $\varepsilon$.
```

4.2.3 Brackets and Ordinary Text in Formulas

In math mode, parentheses and square brackets have their ordinary meaning. Braces (curly brackets) are used for grouping parts of a formula, like in `2^{n+1}`. If you want to use real curly brackets, for example to denote a set, then specify them as `\{` and `\}`, respectively.

$2^x y \neq 2^{xy}$

```
$2^xy \not= 2^{xy}$
```

This example also shows that you can put a slash through a LaTeX symbol by preceding it with the `\not` command.

Note the difference between

$$x|x>1 \quad \text{and} \quad \{x|x>1\}\,.$$

However, the best set notation is

$$\{\,x \mid x>1\,\}\,.$$

```
Note the difference between
\[ {x|x>1}\quad \textrm{and} \quad
  \{x|x>1\} \,.\]
However, the best set notation is
\[ \{\,x\mid x>1\,\} \,.\]
```

The above example also illustrates how to enter ordinary text inside a mathematical expression. Other font-changing commands have been listed before in Table 9. Although we say 'font-changing', a command like `\textrm` also applies the spacing rules for ordinary text instead of mathematical text. If you only want to change the typeface, but keep the spacing rules of mathematics, then use one of the commands listed in Table 15.

command	*explanation*	*example*	*result*
`\mathrm`	roman typeface	`$\mathrm{maximum_i}$`	$\mathrm{maximum_i}$
`\mathbf`	bold	`$\mathbf{v}=(v_1,v_2,v_3)$`	$\mathbf{v} = (v_1, v_2, v_3)$
`\mathsf`	sans serif	`$\mathsf{M}_1^2$`	M_1^2
`\mathit`	italics	`$ff\neq\mathit{ff}$`	$ff \neq ff$
`\mathtt`	typewriter type	`$\mathtt{N}(g)$`	$\mathtt{N}(g)$
`\mathnormal`	normal typeface	`$ff=\mathnormal{ff}$`	$ff = ff$
`\mathcal`	calligraphic	`$\mathcal{N}$`	$\mathcal{N}$

Table 15: Changing the Mathematical Typeface

The packages `amssymb` and `amsmath` developed by the American Mathematical Society (AMS) provide more mathematical symbols and typeface-changing commands. In appendix B we shall list many of them. For example, we use the symbols for the standard notation of natural numbers, integers, fractions, and so on:

`$\mathbb{NZQRC}$` gives $\mathbb{NZQRC}$.

```
\verb|$\mathbb{NZQRC}$| gives
$\mathbb{NZQRC}$.
```

Henceforth, we shall assume that the packages ***amsmath*** *and* ***amssymb*** *have been specified in the preamble.*

4.2.4 Changing the Mathematical Style

Table 16 lists the four mathematical styles that LaTeX uses when formatting formulas and the commands to specify them:

style	*command*	*explanation*
display	`\displaystyle`	formulae displayed on lines by themselves
text	`\textstyle`	formulae embedded in the running text
script	`\scriptstyle`	formulae used as sub- or superscripts
script	`\scriptscriptstyle`	higher-order subscript or superscripts

Table 16: Changing the Mathematical Style

An example:

Compare

$$w+\frac{1}{x+\frac{1}{y+\frac{1}{z}}}$$

and

$$w+\frac{1}{x+\frac{1}{y+\frac{1}{z}}}$$

```
Compare
\[ w+\frac{1}{x+\frac{1}{y+\frac{1}{z}}} \]
and
\[ w+\frac{1}{\displaystyle x +
\frac{1}{\displaystyle y+\frac{1}{z}}} \]
```

4.3 Simple Mathematical Formulas

It is high time that you get started with mathematical typesetting in practice. In Table 17 we list commonly used constructions for mathematical formulas. We assume that we are already in math mode.

command	*example*	*result and explanation*
`^{}`	`x^{2}`	x^2, a superscript.
`_{}`	`x_{2}`	x_2, a subscript.
`\frac{}{}`	`\frac{1}{2}`	$\frac{1}{2}$, a fraction.
`\sqrt{}`	`\sqrt{2}`	$\sqrt{2}$, a square root.
`\sum_{}^{}`	`\sum_{k=1}^{n}k`	$\sum_{k=1}^{n} k$, here a definite sum.
`\int_{}^{}`	`\int_{0}^{1}x\,dx`	$\int_{x=0}^{1} x\,dx$, here a definite integral.
`\lim_{}`	`\lim_{x\to0}e^x`	$\lim_{x\to 0} e^x$, a limit.
`\ln`	`\ln x`	$\ln x$, a differently formatted function
`\cos` and `\pi`	`\cos\pi`	$\cos \pi$, a trigonometric function and a mathematical symbol.
`\infty`	`+\infty`	$+\infty$, the infinity symbol function

Table 17: Common Constructions in Math Mode.

EXERCISE 12 Explain how to format the following formulas.

1. $\cos^2\theta + \sin^2\theta = 1$
2. $\sqrt{2} \approx 1.414 \qquad \sqrt[3]{2} \approx 1.260$
3. $e^{\pi i} = 1$
4. $\frac{\partial^2 f}{\partial x \partial y}$
5. $F_n = F_{n-1} + F_{n-2}, \qquad n \geq 0.$
6. $A = B \qquad$ if and only if $\qquad A \subseteq B \quad$ and $\quad A \supseteq B\,.$

EXERCISE 13 Compare the following commands.

1. `$F_{2}^{2}$` and `$F{}_{2}^{2}$`.
2. `$x_{1}^{y}$`, `$x^{y}_{1}$`, and `$x^{y_{1}}$`.

EXERCISE 14 Explain how to format the following unit conversion.

$$\text{henry} = 1.113 \times 10^{-12}\,\text{sec}^2/\text{cm}$$

EXERCISE 15 Create a LaTeX document that formats the text shown in Figure 11.

The equation

$$ax^2 + bx + c$$

has as solution

$$x_{12} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Figure 11: A Mathematical Text.

EXERCISE 16 Create a LaTeX document that formats the text shown in Figure 12.[12]

$$\epsilon > 0 \qquad (2)$$

From condition (2) follows...

Figure 12: A Mathematical Fragment.

4.4 Alignments

An example that shows how you can align equations in LaTeX:

$$\begin{aligned} x^2 + y^2 &= 1 && (3)\\ y &= \sqrt{1 - x^2} && (4) \end{aligned}$$

```
\begin{eqnarray}
x^2+y^2 &=& 1 \\ y &=& \sqrt{1-x^2}
\end{eqnarray}
```

Vertical alignment is with respect to the mathematical symbol that has been placed between ampersands. Lines are separated by the usual `\\`. All lines are numbered separately, except lines that have a `\nonumber` command. The `eqnarray*` environment is the same as `eqnarray` except that it does not generate equation numbers.

[12] The label is automatically created and will probably differ form yours.

EXERCISE 17

Explain how to format the following system of equations.

$$\begin{aligned} x + 2y - 3z &= -11 \\ y + z &= 11 \\ 3z &= 21 \end{aligned}$$

The `amsmath` package defines several convenient environments for creating multiline display equations, some of which allowing you to align parts of a formula. They also provide better spacing around the alignment points compared to the `eqnarray` environment. The following example illustrates this.

Compare

$$x^2 + y^2 < 1$$
$$y = \sqrt{1 - x^2}$$

with

$$\begin{aligned} x^2 + y^2 &< 1 \\ y &= \sqrt{1 - x^2} \end{aligned}$$

```
Compare
\begin{align*}
x^2+y^2 &< 1 \\ y &= \sqrt{1-x^2}
\end{align*}
with
\begin{eqnarray*}
x^2+y^2 &<& 1 \\ y &=& \sqrt{1-x^2}
\end{eqnarray*}
```

Note the difference between the `eqnarray` and `align` environment in their method for marking the alignment points. `eqnarray` uses two ampersand characters surrounding the part that should be aligned. The `align` environment uses a single ampersand to mark the alignment point: the ampersand is placed in front of the character that should be aligned vertically with other lines.

The packages `align` and `align*`, which is the same but without automatic numbering of the formula, align at a single place. For alignment at several places you must use the `alignat` environment or `alignat*`. An example:

$$\begin{aligned} F_0 &= 0 & F_1 &= 1 \\ F_2 &= 1 & F_3 &= 2 \\ F_4 &= 3 & F_5 &= 5 \end{aligned}$$

```
\begin{alignat*}{2}
F_0 &= 0 & \qquad F_1 &= 1 \\
F_2 &= 1 & \qquad F_3 &= 2 \\
F_4 &= 3 & \qquad F_5 &= 5
\end{alignat*}
```

The `split` environment allows you to split a large formula into multiple lines.

$$\begin{aligned} (x+y)^n &= \sum_{k=0}^{n} \binom{n}{k} x^k y^{n-k} \\ &= x^n + nx^{n-1}y + \frac{n(n-1)}{2}x^{n-2}y^2 \\ &\quad + \cdots + nxy^{n-1} + y^n \end{aligned}$$

```
\[ \begin{split}
(x+y)^n &= \sum_{k=0}^{n}\binom{n}{k}
x^{k}y^{n-k} \\ &= x^n + nx^{n-1}y +
\frac{n(n-1)}{2}x^{n-2}y^2\\ &\quad +
\cdots + nxy^{n-1} + y^n\\
\end{split} \]
```

This example also shows you how to format a binomial coefficent in the `amsmath` package.

EXERCISE 18

Explain how to format the following formula.

$$\begin{aligned} x &= r\cos\phi\sin\theta \\ y &= r\sin\phi\sin\theta \\ z &= r\cos\theta \end{aligned}$$

EXERCISE 19

Explain how you can format the following formula.

$$\begin{aligned} x + 2y - 3z &= -11 \\ y + \ z &= \ \ 11 \\ z &= \ \ 21 \end{aligned}$$

4.5 Matrices

In Table 18 we list the matrix environments that LaTeX provides. In these environments you cannot specify the format of the columns. If you do want to control this, then you must use the `array` environment. A simple example will do.

Compare

$$\mathbf{M} = \begin{pmatrix} x & x^2 \\ 1+x & 1+x+x^2 \end{pmatrix}$$

and

$$\mathbf{M} = \left(\begin{array}{ll} x & x^2 \\ 1+x & 1+x+x^2 \end{array} \right)$$

```
Compare
\[
\mathbf{M} = \begin{pmatrix}
x & x^2 \\ 1+x & 1+x+x^2 \end{pmatrix}
\]
and
\[
\mathbf{M} = \left( \begin{array}{ll}
x & x^2 \\ 1+x & 1+x+x^2
\end{array}\right)
\]
```

environment	*example*	*result*
`\matrix`	`$\begin{matrix} 1 & 2 \\ 3 & 4\end{matrix}$`	$\begin{matrix} 1 & 2 \\ 3 & 4 \end{matrix}$
`\pmatrix`	`$\begin{pmatrix} 1 & 2 \\ 3 & 4\end{pmatrix}$`	$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$
`\bmatrix`	`$\begin{bmatrix} 1 & 2 \\ 3 & 4\end{bmatrix}$`	$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$
`\vmatrix`	`$\begin{vmatrix} 1 & 2 \\ 3 & 4\end{vmatrix}$`	$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix}$
`\Vmatrix`	`$\begin{Vmatrix} 1 & 2 \\ 3 & 4\end{bmatrix}$`	$\begin{Vmatrix} 1 & 2 \\ 3 & 4 \end{Vmatrix}$

Table 18: Matrix Environments.

EXERCISE 20

Explain how to format the following matrix.

$$\mathbf{A} = \begin{pmatrix} 1 & a & b \\ . & 1 & c \\ . & . & 1 \end{pmatrix}$$

4.6 Dots in Formulas

The commands `\ldots` and `\cdots` produce two kinds of ellipsis (...).

A low ellipsis: $x_1, \ldots, x_n$.	`A low ellipsis: $x_1, \ldots, x_n$.\\`
A centered ellipsis: $x_1 + \cdots + x_n$	`A centered ellipsis: $x_1 + \cdots + x_n$`

Other commands to produce dots are shown in the following example:

$$A = \begin{pmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{pmatrix}$$

```
\[ A = \begin{pmatrix}
a_{11} & a_{12} & \ldots & a_{1n} \\
a_{21} & a_{22} & \ldots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{m1} & a_{m2} & \ldots & a_{mn} \\
\end{pmatrix} \]
```

EXERCISE 21

Explain how to format the following statement.

$$\text{if} \quad \mathbf{v} = (v_1, \ldots, v_n) \quad \text{then} \quad \mathbf{v}^t = \begin{pmatrix} v_1 \\ \vdots \\ v_n \end{pmatrix}$$

4.7 Delimiters

In Table 19 are listed the basic brackets and delimiters.

input	*meaning*	*display*
`(`	left parenthesis	(
`)`	right parenthesis	)
`[` or `\lbrack`	left bracket	[
`]` or `\rbrack`	right bracket	]
`\{` or `\lbrace`	left curly bracket	{
`\}` or `\rbrace`	right curly bracket	}
`\lfloor`	left floor bracket	⌊
`\rfloor`	right floor bracket	⌋
`\lceil`	left ceil bracket	⌈
`\rceil`	right ceil bracket	⌉
`\langle`	left angle bracket	⟨
`\rangle`	right angle bracket	⟩
`/`	slash	/
`\backslash`	reverse slash	\
`|` or `\vert`	vertical bar	|
`\\|` or `\Vert`	double vertical bar	‖
`\uparrow`	upward arrow	↑
`\Uparrow`	double upward arrow	⇑
`\downarrow`	downward arrow	↓
`\Downarrow`	double downward arrow	⇓
`\updownarrow`	up-and-down arrow	↕
`\Updownarrow`	double up-and-down arrow	⇕

Table 19: Delimiters.

If you put the `\left` command in front of an opening delimiter and the `\right` command at closure, then LaTeX automatically tries to resize the delimiters to an appropriate size.

$$\left(\sum_{k=1}^{n} k^3\right) = \left(\frac{n(n+1)}{2}\right)^2$$

```
\[
\left(\sum_{k=1}^n k^3\right) =
\left(\frac{n(n+1)}{2}\right)^2
\]
```

In this example, you may want to have the outmost brackets of the same size. Then you must use one of the commands `\bigl`, `\Bigl`, `\biggl`, `\Biggl`, and the analogous command with `\bigr`, and so on. In Table 20 we show the various sizes.

$$\Biggl(\sum_{k=1}^{n} k^3\Biggr) = \Biggl(\frac{n(n+1)}{2}\Biggr)^2$$

```
\[
\Biggl(\sum_{k=1}^n k^3\Biggr) =
\Biggr(\frac{n(n+1)}{2}\Biggr)^2
\]
```

normal size	$()[]\{\}\lfloor\rfloor\lceil\rceil\langle\rangle/\backslash\|\| \uparrow\Uparrow\downarrow\Downarrow\updownarrow\Updownarrow$
`\big` size	$\big()\big[\big]\big\{\big\}\big\lfloor\big\rfloor\big\lceil\big\rceil\big\langle\big\rangle\big/\big\backslash\big\|\big\|\big\uparrow\big\Uparrow\big\downarrow\big\Downarrow\big\updownarrow\big\Updownarrow$
`\Big` size	$\Big()\Big[\Big]\Big\{\Big\}\Big\lfloor\Big\rfloor\Big\lceil\Big\rceil\Big\langle\Big\rangle\Big/\Big\backslash\Big\|\Big\|\Big\uparrow\Big\Uparrow\Big\downarrow\Big\Downarrow\Big\updownarrow\Big\Updownarrow$
`\bigg` size	$\bigg()\bigg[\bigg]\bigg\{\bigg\}\bigg\lfloor\bigg\rfloor\bigg\lceil\bigg\rceil\bigg\langle\bigg\rangle\bigg/\bigg\backslash\bigg\|\bigg\|\bigg\uparrow\bigg\Uparrow\bigg\downarrow\bigg\Downarrow\bigg\updownarrow\bigg\Updownarrow$
`\Bigg` size	$\Bigg()\Bigg[\Bigg]\Bigg\{\Bigg\}\Bigg\lfloor\Bigg\rfloor\Bigg\lceil\Bigg\rceil\Bigg\langle\Bigg\rangle\Bigg/\Bigg\backslash\Bigg\|\Bigg\|\Bigg\uparrow\Bigg\Uparrow\Bigg\downarrow\Bigg\Downarrow\Bigg\updownarrow\Bigg\Updownarrow$

Table 20: Resizing Delimiters.

The `\left` and `\right` commands must come in matching pairs, but the matching delimiters need not be the same. An invisible delimiter can for instance be created by entering a dot ('.') after the `\left` and `\right` command. The following example illustrates this:

$$|x| = \left\{ \begin{array}{ll} -x & \text{if } x < 0, \\ x & \text{otherwise} \end{array} \right.$$

```
\[ |x| = \left\{ \begin{array}{ll}
-x & \textnormal{if $x<0$}, \\
x & \textnormal{otherwise}
\end{array} \right. \]
```

However, it easier to use the `cases` environment in this example.

$$|x| = \begin{cases} -x & \text{if } x < 0, \\ x & \text{otherwise} \end{cases}$$

```
\[ |x| = \begin{cases}
-x & \textnormal{if $x<0$}, \\
x & \textnormal{otherwise}
\end{cases} \]
```

EXERCISE 22

Explain how to format the following formula.

$$\lim_{x \downarrow 0} \frac{1}{x} = \infty \quad \left[\neq \lim_{x \uparrow 0} \frac{1}{x} \right]$$

EXERCISE 23

Explain how to format the following formula.

$$f(x) = \begin{cases} 1 & \text{if } x \neq 0, \\ \frac{\sin x}{x} & \text{otherwise} \end{cases}$$

EXERCISE 24

Explain how to format the following rule of partial integration.

$$\int_a^b f'(x)g(x)\,dx = f(x)g(x)\Big|_a^b - \int_a^b f(x)g'(x)\,dx$$

4.8 Decorations

You can easily put a horizontal line or horizontal brace above or below a formula.

$$1+\frac{1}{2}+\underbrace{\frac{1}{3}+\frac{1}{4}}+\underbrace{\frac{1}{5}+\frac{1}{6}+\frac{1}{7}+\frac{1}{8}}+\cdots$$

```
\[ 1 + \frac{1}{2} +
\underbrace{\frac{1}{3} + \frac{1}{4}} +
\underbrace{\frac{1}{5} + \frac{1}{6} +
\frac{1}{7} + \frac{1}{8}} + \cdots \]
```

The `\stackrel` command stacks one symbol above another.

$$\vec{v} \stackrel{\mathrm{def}}{=} (v_1, \ldots, v_n)$$

```
\[
\vec{v} \stackrel{\mathrm{def}}{=}
    (v_1,\ldots, v_n)
\]
```

4.9 Theorem, Conjectures, etc.

Statement of theorems, lemmas, corollaries, conjectures, and so on, is rather easy in LaTeX as the following examples illustrate.

Theorem 1 *There exist infinitely many prime numbers.*

Conjecture 1 *There exist infinitely many prime numbers p of the form $p = 2^n - 1$.*

Conjecture 2 (Artin, 1927)
Let $a > 1$ be an integer that is not a square. Then, a is a primitive root modulo infinitely many prime numbers p.

```
\newtheorem{theorem}{Theorem}
\begin{theorem}
There exist infinitely many prime numbers.
\end{theorem}
\newtheorem{conj}{Conjecture}
\begin{conj}
There exist infinitely many prime numbers
$p$ of the form $p=2^n-1$.
\end{conj}
\begin{conj}[Artin, 1927]
Let $a>1$ be an integer that is not a
square. Then, $a$ is a primitive root
modulo infinitely many prime numbers $p$.
\end{conj}
```

5 Odd and Ends

- LaTeX uses the single quotes ` and ' as quotation marks. Never use the double quote " from the keyboard for this purpose. To get a double quote as quotation mark, just enter two single quotes.
- Note the various uses of dashes in LaTeX:

input	*meaning*	*example*
`-`	hyphen	X-rated
`--`	en-dash	pages 1–10
`---`	em-dash	this is —nomen est omen— for ...
`$-$`	minus sign	−4

Table 21: Dashes and Hyphens.

- The `\noindent` command at the beginning of a paragraph suppresses indentation.
- You can split large LaTeX files into smaller ones and use the `\include` command to include the file for formatting. The main structure of the document may look like:

```
\begin{document}
\include{ch1}  % include chapter ch1.tex
\include{ch2}  % include chapter ch2.tex
\include{app}  % include appendix app.tex
\end{document}
```

  Formatting of an included file starts always at a new page. To avoid this, use the `input` command.

6 Where to Get LaTeX?

There are several distributions of LaTeX in the public domain. On the UNIX computer of FNWI, the **teTeX** distribution has been installed. It can be downloaded from the Comprehensive Tex Archive Network (CTAN), in the Netherlands from URL

`ftp://ftp.ntg.nl/pub/tex-archive/`

teTeX comes along with the RedHat distribution of Linux. The website of teTeX is

`www.tug.org/teTeX`

The Dutch TeX— Users Group (website: `www.ntg.nl`) is the producer of a cd-rom with the **4TeX** distribution for PC-users. For details we refer to the website

`4tex.ntg.nl`

A highly regarded setup for Windows (all current variants) is **MikTeX**. It can be obtained from its website

`www.miktex.org`

This is a rather complete configuration, which includes previewing and PDF conversion. You will only need a convenient edit. Some widely used editors are *WinShell for Windows* (downloadable at URL `www.winshell.de`) and `WinEdt` (downloadable from `www.winedt.com`).

A complete list of available systems can be found on the website of the worldwide TeX Users Group is

`www.tug.org`

This is anyway the main source of information about LaTeX.

References

[GMS94] M. Goossens, F. Mittelbach, A. Samarin. *The LaTeX Companion – 1st ed.*, Addison-Wesley (1994), ISBN 0-201-54199-8.

[Hec03] A. Heck. *Learning MetaPost by Doing* (2003), Electronically available (date: 3/3/2005) in PDF-format at URL
`www.science.uva.nl/~heck/Courses/mptut.pdf`.

[MG04] F. Mittelbach, M. Goossens. *The LaTeX Companion – 2nd ed.* Addison-Wesley (2004), ISBN 0-201-36299-6.

[Lam94] L. Lamport: *LaTeX, A Document Preparation System, User's Guide and Reference Manual – 2nd ed.*, Addison-Wesley (1994), ISBN 0-201-52983-1.

[Oos97] P. van Oostrum. *Handleiding LaTeX* (in Dutch, 1997), A version adapted to the local situation is available (date: 3/3/2005) in PDF-format on the website at URL
`www.science.uva.nl/onderwijs/lesmateriaal/latex/latex.pdf`.

[Rec97] K. Reckdahl. *Using Imported Graphics in LaTeX 2ε* (1997). Electronically available (date: 3/3/2005) in PDF-format at URL
`ftp://ftp.dante.de/tex-archive/info/epslatex.pdf`.

Appendices

A Answers to the Exercises

EXERCISE 6

```
\emph{Mathematica} uses the percent sign (\%)  to refer to the previous result and
curly brackets (\{\}) for grouping.\\ See the two instructions below:
\begin{verbatim}

Sin[x]/x
Plot[%, {x,-3,3}];

\end{verbatim}
```

EXERCISE 7

```
List of mathematical functions:
\begin{itemize}
  \item Trigonometric functions
  \begin{itemize}
    \item sine
    \item cosine
    \item tangent
  \end{itemize}
  \item Special functions
  \begin{itemize}
    \item Beta function
    \item Gamma function
    \item Riemann zeta function
  \end{itemize}
\end{itemize}
```

EXERCISE 8

```
To install Mathcad:
\begin{enumerate}
  \item Start Windows.
  \item Insert the disk marked \texttt{Disk 1} in the floppy disk drive.
  \item From the \textsf{File} menu in the Windows Program Manager,
        choose \textsf{Run} (\textsc{alt+f},\textsc{r}).
  \item Type \textbf{\emph{drive}:$\backslash$setup.exe}, where \textbf{\emph{drive}}
        is the letter of the disk drive containing the disk.
  \item Press \textsc{enter}.
  \item Follow the instructions on the screen.
\end{enumerate}
```

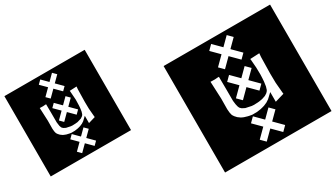
EXERCISE 9

```
H\"uhner-h\"andler, d\'eb\^acle, situa\c{c}\~oes, na\"{\i}ef.
```

EXERCISE 10

```
\begin{tabular}{|l|l|} \hline
\multicolumn{2}{|c|}{\textbf{errorbreak}} \\ \hline
\textbf{Value} & \textbf{Purpose}\\ \hline
0 & report error and continue reading \\
1 & stop reading after syntax error \\
2 & stop reading after any error \\ \hline
\end{tabular}
```

EXERCISE 11 The proof is in the eating of the pudding:



The first logo is rotated 45 degrees and then scaled such that its height is 2 centimeters. The second logo is scaled such that its height is 2 centimeters and then it is rotated 45 degrees.

EXERCISE 12

1. `$\cos^2\theta+\sin^2\theta=1$`
2. `$\sqrt{2}\approx 1.414 \qquad\sqrt[3]{2}\approx 1.260$`
3. `$e^{\pi i}=1$`
4. `$\frac{\partial^2f}{\partial x\partial y}$`
5. `$F_{n}=F_{n-1}+F_{n-2}, \qquad n\geq0.$`
6. `$\displaystyle A=B \qquad\textrm{if and only if}\qquad A\subseteq B \quad\textrm{and}\quad A\supseteq B\,.$`

EXERCISE 13 Compare the following results:

1. F_2^2 and F_2^2.
2. x_1^y, x_1^y, and x^{y_1}.

EXERCISE 14

```
\[ \mathrm{henry} = 1.113\times 10^{-12}\,\mathrm{sec}^2\!/\mathrm{cm} \]
```

EXERCISE 15

```
The equation \[ a x^2 + b x + c \] has as solution
\[ x_{12} = \frac{-b \pm \sqrt{b^2 -4ac}}{2a} \]
```

EXERCISE 16

```
\begin{equation} \epsilon>0 \label{eps}\end{equation}
From condition (\ref{eps}) follows\ldots
```

EXERCISE 17

```
\begin{eqnarray*}
x+2y-3z &=& -11\\ y+z &=& 11\\ 3z &=& 21
\end{eqnarray*}
```

EXERCISE 18

```
\begin{align*}
x &= r\cos\phi\sin\theta \\ y &= r\sin\phi\sin\theta \\ z &= r\cos\theta
\end{align*}
```

EXERCISE 19

```
\begin{alignat*}{5}
x + 2& y   - 3& z & = -&11\\
     & y\; +  & z & = &11\\
     &        & z & = &21\\
\end{alignat*}
```

EXERCISE 20

```
\[ \mathbf{A} = \begin{pmatrix} 1 & a & b\\ . & 1 & c\\ . & . & 1 \end{pmatrix} \]
```

EXERCISE 21

```
\[ \textrm{if} \quad \mathbf{v} = (v_1, \ldots, v_n) \quad \textrm{then} \quad
\mathbf{v}^t = \begin{pmatrix} v_1\\ \vdots\\ v_n \end{pmatrix} \]
```

EXERCISE 22

```
\[ \lim_{x\downarrow 0}\frac{1}{x}=\infty\quad
   \left[\;\neq \lim_{x\uparrow 0}\frac{1}{x}\;\right] \]
```

EXERCISE 23

```
\[ f(x) = \begin{cases} 1 & \textnormal{if $x\neq0$},\\
   \frac{\sin x}{x} & \textnormal{otherwise} \end{cases} \]
```

EXERCISE 24

```
\[ \int_a^b f'(x)g(x)\,dx = f(x)g(x)\biggr|_{a}^{b} - \int_a^b f(x)g'(x)\,dx \]
```

B List of Mathematical Symbols

In the following tables are listed all symbols that are by default available in math mode (referred to as NFSS) and all symbols that are provided by the packages `amsmath` and `amssymb`. The pages are exact copies of the relevant pages of [GMS94]

it have the laborsaving abilities of LaTeX for preparing indexes, bibliographies, tables, or simple diagrams. These features are such a convenience for authors that the use of LaTeX spread rapidly in the mid-1980s (a reasonably mature version of LaTeX was available by the end of 1983), and the American Mathematical Society began to be asked by its authors to accept electronic submissions in LaTeX.

Thus, the $\mathcal{AMS}$-LaTeX project came into being in 1987 and three years later $\mathcal{AMS}$-LaTeX version 1.0 was released. The conversion of $\mathcal{AMS}$-TeX's mathematical capabilities to LaTeX, and the integration with the NFSS, were done by Frank Mittelbach and Rainer Schöpf, working as consultants to the AMS, with assistance from Michael Downes of the AMS technical support staff.

The most often used packages are amsmath (from $\mathcal{AMS}$-LaTeX) and amssymb (from the AMSFonts distribution). To invoke them in a document you write, e.g., `\usepackage{amsmath}` in the usual way. Installation and usage documentation is included with the packages. For amssymb the principal piece of documentation is the *AMSFonts User's Guide* (`amsfndoc.tex`); for amsmath it is the *$\mathcal{AMS}$-LaTeX User's Guide* (`amsldoc.tex`).[1]

8.2 Fonts and Symbols in Formulae

8.2.1 Mathematical Symbols

(*L* 42–47) Tables 8.2 on the next page to 8.11 on page 227 review the mathematical symbols available in standard LaTeX. You can put a slash through a LaTeX symbol by (*L* 44) preceding it with the `\not` command, for instance.

$u \not< v$ or $a \not\in \mathbf{A}$

```
$u \not< v$ or $a \not\in \mathbf{A}$
```

Tables 8.12 on page 227 to 8.19 on page 229 show the extra math symbols of the $\mathcal{AMS}$-Fonts, which are automatically available when you specify the amssymb package.[2] However, if you want to define only some of them (perhaps because your TeX installation has insufficient memory to define all the symbol names), you can use the amsfonts package and the `\DeclareMathSymbol` command, which is explained in section 7.7.6.

[1] The AMS distribution also contains a file `diff12.tex` which describes differences between version 1.1 and 1.2 of $\mathcal{AMS}$-LaTeX. Note in particular that in versions 1.0 and 1.1 of $\mathcal{AMS}$-LaTeX, which predated LaTeX 2_ε, the amsmath package was named "amstex" and included some of the font-related features that are now separated in the amssymb and amsfonts packages.

[2] Note that the Companion uses Lucida math fonts which contain the standard LaTeX and $\mathcal{AMS}$ symbols but with different shapes compared to the Computer Modern math fonts.

$\hat{a}$	\hat{a}	$\acute{a}$	\acute{a}	$\bar{a}$	\bar{a}	$\dot{a}$	\dot{a}	$\breve{a}$	\breve{a}
$\check{a}$	\check{a}	$\grave{a}$	\grave{a}	$\vec{a}$	\vec{a}	$\ddot{a}$	\ddot{a}	$\tilde{a}$	\tilde{a}

Table 8.1: Math mode accents (available in LaTeX)

α	\alpha	β	\beta	γ	\gamma	δ	\delta	ϵ	\epsilon
ε	\varepsilon	ζ	\zeta	η	\eta	θ	\theta	ϑ	\vartheta
ι	\iota	κ	\kappa	λ	\lambda	μ	\mu	ν	\nu
ξ	\xi	o	o	π	\pi	ϖ	\varpi	ρ	\rho
ϱ	\varrho	σ	\sigma	ς	\varsigma	τ	\tau	υ	\upsilon
ϕ	\phi	φ	\varphi	χ	\chi	ψ	\psi	ω	\omega
Γ	\Gamma	Δ	\Delta	Θ	\Theta	Λ	\Lambda	Ξ	\Xi
Π	\Pi	Σ	\Sigma	Υ	\Upsilon	Φ	\Phi	Ψ	\Psi
Ω	\Omega								

Table 8.2: Greek letters (available in LaTeX)

$\pm$	\pm	$\cap$	\cap	$\diamond$	\diamond	$\oplus$	\oplus
$\mp$	\mp	$\cup$	\cup	$\triangle$	\bigtriangleup	$\ominus$	\ominus
$\times$	\times	$\uplus$	\uplus	$\triangledown$	\bigtriangledown	$\otimes$	\otimes
$\div$	\div	$\sqcap$	\sqcap	$\triangleleft$	\triangleleft	$\oslash$	\oslash
$*$	\ast	$\sqcup$	\sqcup	$\triangleright$	\triangleright	$\odot$	\odot
$\star$	\star	$\vee$	\vee	$\lhd^a$	\lhd	$\bigcirc$	\bigcirc
$\circ$	\circ	$\wedge$	\wedge	$\rhd^a$	\rhd	$\dagger$	\dagger
$\bullet$	\bullet	$\setminus$	\setminus	$\unlhd^a$	\unlhd	$\ddagger$	\ddagger
$\cdot$	\cdot	$\wr$	\wr	$\unrhd^a$	\unrhd	$\amalg$	\amalg

[a] Not predefined in NFSS. Use the latexsym or amssymb package.

Table 8.3: Binary operation symbols (available in LaTeX)

$\leq$	\leq,\le	$\geq$	\geq,\ge	$\equiv$	\equiv	$\models$	\models	$\prec$	\prec
$\succ$	\succ	$\sim$	\sim	$\perp$	\perp	$\preceq$	\preceq	$\succeq$	\succeq
$\simeq$	\simeq	$\mid$	\mid	$\ll$	\ll	$\gg$	\gg	$\asymp$	\asymp
$\parallel$	\parallel	$\subset$	\subset	$\supset$	\supset	$\approx$	\approx	$\bowtie$	\bowtie
$\subseteq$	\subseteq	$\supseteq$	\supseteq	$\cong$	\cong	$\Join$	\Join	$\sqsubset$	\sqsubset
$\sqsupset$	\sqsupset	$\neq$	\neq	$\smile$	\smile	$\sqsubseteq$	\sqsubseteq	$\sqsupseteq$	\sqsupseteq
$\doteq$	\doteq	$\frown$	\frown	$\in$	\in	$\ni$	\ni	$\propto$	\propto
$=$	=	$\vdash$	\vdash	$\dashv$	\dashv	$<$	¡	$>$	¿

Table 8.4: Relation symbols (available in LaTeX)

$\leftarrow$	\leftarrow	$\longleftarrow$	\longleftarrow	$\uparrow$	\uparrow
$\Leftarrow$	\Leftarrow	$\Longleftarrow$	\Longleftarrow	$\Uparrow$	\Uparrow
$\rightarrow$	\rightarrow	$\longrightarrow$	\longrightarrow	$\downarrow$	\downarrow
$\Rightarrow$	\Rightarrow	$\Longrightarrow$	\Longrightarrow	$\Downarrow$	\Downarrow
$\leftrightarrow$	\leftrightarrow	$\longleftrightarrow$	\longleftrightarrow	$\updownarrow$	\updownarrow
$\Leftrightarrow$	\Leftrightarrow	$\Longleftrightarrow$	\Longleftrightarrow	$\Updownarrow$	\Updownarrow
$\mapsto$	\mapsto	$\longmapsto$	\longmapsto	$\nearrow$	\nearrow
$\hookleftarrow$	\hookleftarrow	$\hookrightarrow$	\hookrightarrow	$\searrow$	\searrow
$\leftharpoonup$	\leftharpoonup	$\rightharpoonup$	\rightharpoonup	$\swarrow$	\swarrow
$\leftharpoondown$	\leftharpoondown	$\rightharpoondown$	\rightharpoondown	$\nwarrow$	\nwarrow

Table 8.5: Arrow symbols (available in LaTeX)

$\ldots$	\ldots	$\cdots$	\cdots	$\vdots$	\vdots	$\ddots$	\ddots	$\aleph$	\aleph
$\prime$	\prime	$\forall$	\forall	∞	\infty	$\hbar$	\hbar	$\emptyset$	\emptyset
$\exists$	\exists	∇	\nabla	$\surd$	\surd	$\Box$	\Box[a]	$\triangle$	\triangle
$\Diamond$	\Diamond[a]	$\imath$	\imath	$\jmath$	\jmath	ℓ	\ell	$\neg$	\neg
$\top$	\top	$\flat$	\flat	$\natural$	\natural	$\sharp$	\sharp	$\wp$	\wp
$\bot$	\bot	$\clubsuit$	\clubsuit	$\diamondsuit$	\diamondsuit	$\heartsuit$	\heartsuit	$\spadesuit$	\spadesuit
$\mho$	\mho[a]	$\Re$	\Re	$\Im$	\Im	$\angle$	\angle	∂	\partial

[a] Not predefined in NFSS. Use the latexsym or amssymb package.

Table 8.6: Miscellaneous symbols (available in LaTeX)

$\sum$	\sum	$\prod$	\prod	$\coprod$	\coprod	$\int$	\int	$\oint$	\oint
$\bigcap$	\bigcap	$\bigcup$	\bigcup	$\bigsqcup$	\bigsqcup	$\bigvee$	\bigvee	$\bigwedge$	\bigwedge
$\bigodot$	\bigodot	$\bigotimes$	\bigotimes	$\bigoplus$	\bigoplus	$\biguplus$	\biguplus		

Table 8.7: Variable-sized symbols (available in LaTeX)

\arccos	\cos	\csc	\exp	\ker	\limsup	\min	\sinh
\arcsin	\cosh	\deg	\gcd	\lg	\ln	\Pr	\sup
\arctan	\cot	\det	\hom	\lim	\log	\sec	\tan
\arg	\coth	\dim	\inf	\liminf	\max	\sin	\tanh

Table 8.8: Log-like symbols (available in LaTeX)

$\uparrow$	\uparrow	$\Uparrow$	\Uparrow	$\downarrow$	\downarrow	$\Downarrow$	\Downarrow
$\{$	\{	$\}$	\}	$\updownarrow$	\updownarrow	$\Updownarrow$	\Updownarrow
$\lfloor$	\lfloor	$\rfloor$	\rfloor	$\lceil$	\lceil	$\rceil$	\rceil
$\langle$	\langle	$\rangle$	\rangle	/	/	$\backslash$	\backslash
$\vert$	—	$\Vert$	|				

Table 8.9: Delimiters (available in LaTeX)

⎰	\rmoustache	⎮	\lmoustache	⎱	\rgroup	⎛	\lgroup
|	\arrowvert	‖	\Arrowvert	⎪	\bracevert		

Table 8.10: Large delimiters (available in LaTeX)

$\widetilde{abc}$	\widetilde{abc}	$\widehat{abc}$	\widehat{abc}
$\overleftarrow{abc}$	\overleftarrow{abc}	$\overrightarrow{abc}$	\overrightarrow{abc}
$\overline{abc}$	\overline{abc}	$\underline{abc}$	\underline{abc}
$\overbrace{abc}$	\overbrace{abc}	$\underbrace{abc}$	\underbrace{abc}
$\sqrt{abc}$	\sqrt{abc}	$\sqrt[n]{abc}$	\sqrt[n]{abc}
f'	f'	$\frac{abc}{xyz}$	\frac{abc}{xyz}

Table 8.11: LaTeX math constructs

ϝ	\digamma	ϰ	\varkappa	ב	\beth	ד	\daleth	ג	\gimel

Table 8.12: AMS Greek and Hebrew (available with amssymb package)

⌜	\ulcorner	⌝	\urcorner	⌞	\llcorner	⌟	\lrcorner

Table 8.13: AMS delimiters (available with amssymb package)

⇛	\Rrightarrow	⇝	\rightsquigarrow	⇇	\leftleftarrows
⇆	\leftrightarrows	⇚	\Lleftarrow	↞	\twoheadleftarrow
↢	\leftarrowtail	↫	\looparrowleft	⇋	\leftrightharpoons
↶	\curvearrowleft	↺	\circlearrowleft	↰	\Lsh
⇈	\upuparrows	↿	\upharpoonleft	⇃	\downharpoonleft
⊸	\multimap	↭	\leftrightsquigarrow	⇄	\rightleftarrows
⇉	\rightrightarrows	↠	\twoheadrightarrow	↣	\rightarrowtail
↬	\looparrowright	⇌	\rightleftharpoons	↷	\curvearrowright
↻	\circlearrowright	↱	\Rsh	⇊	\downdownarrows
⇂	\downharpoonright	↾	\upharpoonright,\restriction		

Table 8.14: AMS arrows (available with amssymb package)

↚	\nleftarrow	↛	\nrightarrow	⇍	\nLeftarrow
⇏	\nRightarrow	↮	\nleftrightarrow	⇎	\nLeftrightarrow

Table 8.15: AMS negated arrows (available with amssymb package)

$\leqq$	\leqq	$\leqslant$	\leqslant	$\eqslantless$	\eqslantless
$\lesssim$	\lesssim	$\lessapprox$	\lessapprox	$\approxeq$	\approxeq
$\lessdot$	\lessdot	$\lll$,$\llless$	\lll,\llless	$\lessgtr$	\lessgtr
$\lesseqgtr$	\lesseqgtr	$\lesseqqgtr$	\lesseqqgtr	$\doteqdot$,$\Doteq$	\doteqdot,\Doteq
$\risingdotseq$	\risingdotseq	$\fallingdotseq$	\fallingdotseq	$\backsim$	\backsim
$\backsimeq$	\backsimeq	$\subseteqq$	\subseteqq	$\Subset$	\Subset
$\sqsubset$	\sqsubset	$\preccurlyeq$	\preccurlyeq	$\curlyeqprec$	\curlyeqprec
$\precsim$	\precsim	$\precapprox$	\precapprox	$\vartriangleleft$	\vartriangleleft
$\trianglelefteq$	\trianglelefteq	$\vDash$	\vDash	$\Vvdash$	\Vvdash
$\smallsmile$	\smallsmile	$\smallfrown$	\smallfrown	$\bumpeq$	\bumpeq
$\Bumpeq$	\Bumpeq	$\geqq$	\geqq	$\geqslant$	\geqslant
$\eqslantgtr$	\eqslantgtr	$\gtrsim$	\gtrsim	$\gtrapprox$	\gtrapprox
$\gtrdot$	\gtrdot	$\ggg$,$\gggtr$	\ggg,\gggtr	$\gtrless$	\gtrless
$\gtreqless$	\gtreqless	$\gtreqqless$	\gtreqqless	$\eqcirc$	\eqcirc
$\circeq$	\circeq	$\triangleq$	\triangleq	$\thicksim$	\thicksim
$\thickapprox$	\thickapprox	$\supseteqq$	\supseteqq	$\Supset$	\Supset
$\sqsupset$	\sqsupset	$\succcurlyeq$	\succcurlyeq	$\curlyeqsucc$	\curlyeqsucc
$\succsim$	\succsim	$\succapprox$	\succapprox	$\vartriangleright$	\vartriangleright
$\trianglerighteq$	\trianglerighteq	$\Vdash$	\Vdash	$\shortmid$	\shortmid
$\shortparallel$	\shortparallel	$\between$	\between	$\pitchfork$	\pitchfork
$\varpropto$	\varpropto	$\blacktriangleleft$	\blacktriangleleft	$\therefore$	\therefore
$\backepsilon$	\backepsilon	$\blacktriangleright$	\blacktriangleright	$\because$	\because

Table 8.16: AMS binary relations (available with amssymb package)

$\nless$	\nless	$\nleq$	\nleq	$\nleqslant$	\nleqslant
$\nleqq$	\nleqq	$\lneq$	\lneq	$\lneqq$	\lneqq
$\lvertneqq$	\lvertneqq	$\lnsim$	\lnsim	$\lnapprox$	\lnapprox
$\nprec$	\nprec	$\npreceq$	\npreceq	$\precnsim$	\precnsim
$\precnapprox$	\precnapprox	$\nsim$	\nsim	$\nshortmid$	\nshortmid
$\nmid$	\nmid	$\nvdash$	\nvdash	$\nvDash$	\nvDash
$\ntriangleleft$	\ntriangleleft	$\ntrianglelefteq$	\ntrianglelefteq	$\nsubseteq$	\nsubseteq
$\subsetneq$	\subsetneq	$\varsubsetneq$	\varsubsetneq	$\subsetneqq$	\subsetneqq
$\varsubsetneqq$	\varsubsetneqq	$\ngtr$	\ngtr	$\ngeq$	\ngeq
$\ngeqslant$	\ngeqslant	$\ngeqq$	\ngeqq	$\gneq$	\gneq
$\gneqq$	\gneqq	$\gvertneqq$	\gvertneqq	$\gnsim$	\gnsim
$\gnapprox$	\gnapprox	$\nsucc$	\nsucc	$\nsucceq$	\nsucceq
$\succnsim$	\succnsim	$\succnapprox$	\succnapprox	$\ncong$	\ncong
$\nshortparallel$	\nshortparallel	$\nparallel$	\nparallel	$\nvDash$	\nvDash
$\nVDash$	\nVDash	$\ntriangleright$	\ntriangleright	$\ntrianglerighteq$	\ntrianglerighteq
$\nsupseteq$	\nsupseteq	$\nsupseteqq$	\nsupseteqq	$\supsetneq$	\supsetneq
$\varsupsetneq$	\varsupsetneq	$\supsetneqq$	\supsetneqq	$\varsupsetneqq$	\varsupsetneqq

Table 8.17: AMS negated binary relations (available with amssymb package)

$\dotplus$	\dotplus	$\smallsetminus$	\smallsetminus	$\Cap$	\Cap,\doublecap
$\Cup$	\Cup,\doublecup	$\barwedge$	\barwedge	$\veebar$	\veebar
$\doublebarwedge$	\doublebarwedge	$\boxminus$	\boxminus	$\boxtimes$	\boxtimes
$\boxdot$	\boxdot	$\boxplus$	\boxplus	$\divideontimes$	\divideontimes
$\ltimes$	\ltimes	$\rtimes$	\rtimes	$\leftthreetimes$	\leftthreetimes
$\rightthreetimes$	\rightthreetimes	$\curlywedge$	\curlywedge	$\curlyvee$	\curlyvee
$\circleddash$	\circleddash	$\circledast$	\circledast	$\circledcirc$	\circledcirc
$\centerdot$	\centerdot	$\intercal$	\intercal		

Table 8.18: AMS binary operators (available with amssymb package)

$\hbar$	\hbar	$\hslash$	\hslash	$\vartriangle$	\vartriangle
$\triangledown$	\triangledown	$\square$	\square	$\lozenge$	\lozenge
$\circledS$	\circledS	$\angle$	\angle	$\measuredangle$	\measuredangle
$\nexists$	\nexists	$\mho$	\mho	$\Finv$	\Finv
$\Game$	\Game	$\Bbbk$	\Bbbk	$\backprime$	\backprime
$\varnothing$	\varnothing	$\blacktriangle$	\blacktriangle	$\blacktriangledown$	\blacktriangledown
$\blacksquare$	\blacksquare	$\blacklozenge$	\blacklozenge	$\bigstar$	\bigstar
$\sphericalangle$	\sphericalangle	$\complement$	\complement	$\eth$	\eth
$\diagup$	\diagup	$\diagdown$	\diagdown		

Table 8.19: AMS miscellaneous (available with amssymb package)

8.2.2 Names of Math Font Commands

The list of math font commands provided by the $\mathcal{AMS}$ packages is shown in table 8.20 on the next page, where for each case an example is shown. In addition, the math font commands of table 7.4 on page 183 can be used.

In the amsmath package, `\boldsymbol` is to be used for individual bold math symbols and bold Greek letters—everything in math except for letters (where one would use `\mathbf`). For example, to obtain a bold $\boldsymbol{\infty}$, or `\boldsymbol{\infty}`, `\boldsymbol{+}`, `\boldsymbol{\pi}`, or `\boldsymbol{0}`.

Since `\boldsymbol` takes a lot of typing, you can introduce new commands for bold symbols to be used frequently:

$$B_\infty + \pi B_1 \sim \mathbf{B_\infty + \pi B_1}$$

```
\newcommand{\bpi}{\boldsymbol{\pi}}
\newcommand{\binfty}{\boldsymbol{\infty}}
\[ B_\infty + \pi B_1 \sim
   \mathbf{B}_{\binfty} \boldsymbol{+}
   \bpi \mathbf{B}_{\boldsymbol{1}}
\]
```

For those math symbols where the command `\boldsymbol` has no effect because the bold version of the symbol does not exist in the currently available fonts, there exists a command "Poor man's bold" (`\pmb`), which simulates bold

`\mathbb`	Blackboard bold alphabet, e.g., `$\mathbb{NQRZ}$` gives: $\mathbb{NQRZ}$ (not available in amsmath, need to load amssymb).
`\mathfrak`	Euler Fraktur alphabet, e.g., `$\mathfrak{E}=\mathfrak{mc}^2$` gives: $\mathfrak{E} = \mathfrak{mc}^2$ (not available in amsmath, need to load amssymb).
`\boldsymbol`	Used to obtain bold numbers and other nonalphabetic symbols, as well as bold Greek letters (defined in amsbsy).
`\pmb`	"Poor man's bold," used for math symbols when bold versions don't exist in the available fonts, e.g., `$\pmb{\oint}$` gives: $\pmb{\oint}$ and `$\pmb{\triangle}$` gives: $\pmb{\triangle}$ (defined in amsbsy).
`\text`	Produce normal text with correct text-spacing in the current font used outside math, e.g., `$E=mc^2\quad\text{(Einstein)}$` gives: $E = mc^2 \quad$ (Einstein) (defined in amstext).

Table 8.20: Font commands available in mathematics with the $\mathcal{AMS}$ packages

by typesetting several copies of the symbol with slight offsets. This procedure must be used for the extension and large operator symbols from the `cmex` font, as well as the $\mathcal{AMS}$ extra math symbols from the `msam` and `msbm` fonts.

$$\frac{\partial w}{\partial u}\pmb{\Bigg\vert}\frac{\partial u}{\partial v}$$

```
\[ \frac{\partial w}{\partial u}
   \pmb{\Bigg\vert}
   \frac{\partial u}{\partial v} \]
```

With large operators and extension symbols (for example, $\sum$ and $\prod$) `\pmb` does not currently work very well because the proper spacing and treatment of limits is not preserved. Therefore, the TEX operator `\mathop` needs to be used (see table 7.13 on page 213).

$$\sum_{j<P}\prod_{\lambda}\lambda R(r_i) \qquad \sum_{x_j}\prod_{\lambda}\lambda R(x_j)$$

```
\[ \sum_{j<P}
   \prod_\lambda \lambda R(r_i) \qquad
   \mathop{\pmb{\sum}}_{x_j}
   \mathop{\pmb{\prod}}_\lambda \lambda R(x_j)
\]
```

To make an entire math formula bold (or as much of it as possible, depending on the available fonts), use `\boldmath` preceding the formula.

The sequence `\mathbf{\hat{A}}` produces a bold accent character over the **A**. However, combinations like `\mathcal{\hat{A}}` will not work in ordinary LATEX because the `\mathcal` font does not have its own accents. In the amsmath package the font change commands are defined in such a way that accent characters will be taken from the `\mathrm` font if they are not available in the current font (in addition to the `\mathcal` font, the `\mathbb` and `\mathfrak` fonts don't contain accents).