Learning $\ensuremath{\mathbb{A}}\ensuremath{\mathbb{T}}_E\!X$ by Doing

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1 Introduction

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. Here we shall describe the basics of this process.

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 IAT_EX document.

For example, you can use the editor XEMACS:

xemacs example.tex

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

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. LAT_EX 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 device independent 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 printer 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 LAT_FX document.

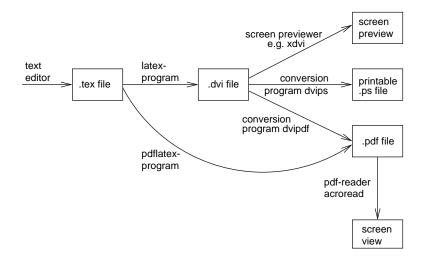


Figure 2: Standard Processing of a LATEX document.

2.2 The Structure of a LATEX Document

We shall use the above example to explain the basic structure of a LAT_EX document. As stated before, the source file example.tex contains both text and LAT_EX 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 $\mathbb{L}_{E}X$ 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 documentclass 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.
a4paper	generates an A4 page layout.
landscape	uses the landscape orientation, where the longer side
	of the paper is horizontally oriented.

Table 2: 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 $\operatorname{IAT}_{E} X 2_{\varepsilon}$ 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

```
\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, \inf y) \to \mathbb{R} by
 [f(x) = \frac{x}{x^2} ]
then
 [\lim_{x\to\infty} f(x)=0 ]
 \left( \lim_{x\to\infty} f(x)=0 ] \right)
```

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 [and], or between double dollar symbols .

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

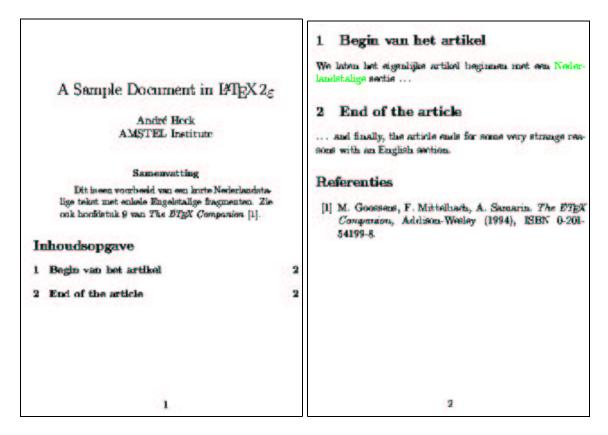


Figure 3: The Formatted Sample Document.

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 IAT_EX 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 IAT_EX 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:²

```
% 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.
```

²We omit some output for clarity.

1.21 \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 IAT_EX 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 IAT_EX spotted the error. Correct the source file³ 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.

³If you have not specified in your UNIX shell the T_EX 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 IAT_EX 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; IAT_EX joins them. Similarly, extra spaces are ignored, as the example below illustrates:

extra spaces and single line breaks	extra spaces and
in the source file are ignored.	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. IATEX uses the convention that pressing the ENTER key twice starts a new paragraph. The following example generates the lines 'one' and 'two':

one	one
two	
	two

It goes without saying that \mathbb{IAT}_{EX} contains many constructions to influence spacing, line breaking and page breaking. We list a few of them in Table 4.

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 $\mathbb{A}T_{\mathbf{E}}X$ to hyphenate a word at that point.
λ_{\Box}	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 4: Page Breaking, Line Breaking, and Spacing

A shortcut for the **\newline** command is the double backslash $\setminus \setminus$.

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: LAT_EX 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.

 IAT_EX 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:
                                  A short \emph{Mathematica} session:
                                  \begin{verbatim}
In[1] := 1/(x^3+1)
                                  In[1]:= 1/(x^3+1)
1
Out[1]= -----
                                           1
                                  Out[1] = -----
            3
                                              3
        1 + x
                                         1 + x
In[2] := D[\%, \{x, 2\}]
                                  In[2] := D[\%, \{x, 2\}]
             4
                                               4
         18 x
                    6 x
                                 18 x 6 x
Out[2]= ------
Out[2]= -----
             33
                         3 2
                                              33
                                                           32
        (1 + x) (1 + x)
                                          (1 + x) (1 + x)
In[3]:= Quit
                                  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 IAT_EX . For example, the dollar symbol, the percent sign, curly brackets, and so on. In Table 5 we list the special commands to get the characters in your document.

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

Table 5: Ten Forbidden Characters.

EXERCISE 6

Create a IAT_EX 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 Document in Question between Rules.

3 Basic Tools for Formatting Text

Although our main objective is to learn how to create with LAT_{EX} 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 6.

 LAT_EX 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 6: 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, IATEX 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.

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

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

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

In the same way you can label and refer to pictures, tables, mathematical formulas, etc.

3.2 Creating Lists

 ${\rm LAT}_{\rm E}\!X$ has several environments for creating lists, which can also be nested. A few examples will do.

An enumerated (numbered) list:

1. This is the 1st item.	\begin{enumerate}
	\item This is the 1st item.
2. This is the 2nd item.	\item This is the 2nd item.
	\end{enumerate}
A simple unnumbered list:	
• This is the 1st item.	\begin{itemize}
	\item This is the 1st item.
• This is the 2d item.	\item This is the 2nd item.
	\end{itemize}
A customizable list:	
One This is the 1st item.	\begin{description}
	\item[One] This is the 1st item.
Two This is the 2nd item.	\item[Two] This is the 2nd item.
	\end{description}
[First] This is the 1st item.	\begin{description}
	\item{[First]} This is the 1st item
[Second] This is the 2nd item.	\item{[Second]} This is the 2nd item
	\end{description}

EXERCISE 7

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 7.

command	declaration	meaning
$textrm{}$	{\rmfamily}	formatted in roman family
$textsf{}$	{\sffamily}	formatted in sans serif family
$texttt{}$	{\ttfamily}	formatted in typewriter family
	{\mdseries}	formatted in medium series
$textbf{}$	{\bfseries}	formatted in bold series
	{\upshape}	formatted in upright shape
	{\itshape}	formatted in <i>italic</i> shape
$textsl{}$	{\slshape}	formatted in <i>slanted</i> shape
	{\scshape}	formatted in SMALL CAPS shape
≥ 1	{\em}	formatted in <i>emphasized</i>
	{\normalfont}	formatted in the document font

Table 7: Changing the Typeface.

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

You can strongly <i>emphasize</i> the	You can strongly \emph{\textbf{emphasize}}
possibility of formatting text in a	the possibility of formatting text
sans serif bold typeface	{\sffamily\bfseries in a sans serif bold
	typeface}

Each of the declarations in Table 7 has a corresponding environment whose name is obtained by dropping the backslash from the command name.⁴ 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.

⁴Any declaration has a corresponding environment in this manner.

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

• Now boldface items.	\newenvironment{bolditemize}{\begin{itemize}
• Note the difference be- tween <i>italic</i> with italic correction of spacing and <i>italic</i> without.	<pre>\normalfont\bfseries}{\end{itemize}} \begin{bolditemize} \item Now boldface items. \item Note the difference between \textit{italic} with italic correction of spacing and {\itshape italic} without. \end{bolditemize}</pre>

3.3.2 Changing the Font Size

IATEX 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 8 lists the size-changing commands.

declaration	size	declaration	size	declaration	size
{\tiny}	size	{\normalsize}	size		
{\scriptsize}	size	{\large}	size		
{\footnotesize}	size	{\Large}	size	$\{ \ \ldots \}$	size
{\small}	size	{\LARGE}	size	{\Huge}	size

Table 8: Changing the Font Size.

EXERCISE 8

Create a ${\rm I\!A\!T}_{\rm E\!X}$ 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	\begin{center}		
is	This \setminus is \setminus centered.		
centered.	\end{center}		
	\begin{quote}		
This	\centering		
is	This \setminus is \setminus also \setminus centered.		
also	\end{quote}		
centered.	-		

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

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

3.5 Using Accents

The following Portuguese text illustrates the use of accents:

A equação do pêndulo matemática	A equa\c{c}\~{a}o do p\^{e}ndulo
com período próprio $\frac{2\pi}{\omega}$ é	<pre>matem\'{a}tica com per\'{\i}odo</pre>
-	pr\'{o}prio \$\frac{2\pi}{\omega}\$ \'{e}
$u'' + \omega^2 u = 0$	$\left[u''+\cos^2u=0\right]$

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 9 show how to produce various accented symbols in paragraph mode.

		ŏ \v{o}	
ó \'{o}	ō \={o}	ő \H{o}	o \d{o}
		00 \t{00}	
	ŏ \u{o}		

Table 9: Paragraph Mode Accents.

Accents in math mode are produced with other commands. For example, use $\pm \g g$ for \tilde{g} . We list the math mode accents in Table 10.

Ī	â	\hat{a}	á	\acute{a}	ā	\bar{a}	à	$dot{a}$
	ă	\check{a}	à	$grave{a}$	\vec{a}	$\ensuremath{vec}\$	ä	$ddot{a}$
	ă	\breve{a}	\tilde{a}	\tilde{a}				

Table 10: 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 only example in this tutorial illustrates how to create a simple table of the first four Legendre polynomials.

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

In the first line, the options $\{||1||1||\}$ stand for two left adjusted (1) columns, separated by a vertical line (1), 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.

3.7 Importing Graphics

While IATEX can import virtually any graphics format, Encapsulated PostScript (EPS) is the easiest graphics format to import into IATEX. For example, the EPS file file.eps is inserted by specifying

```
\usepackag{graphicx}
```

in the 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}
```

The example below shows the UvA logo twice, but the second one is rotated 90 degrees.



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	If we take \$-1 <a<1\$, th="" then<=""></a<1\$,>
$\int_0^\infty \frac{u^a}{(1+u)^2} du = a!(-a)! (1)$ By contour integration the left-hand side of (1) may by shown to be	<pre>\begin{equation} \int_{0}^{\infty} \frac{u^a}{(1+u)^2}du = a!(-a)! \label{eqno} \end{equation}</pre>
equal to $\pi a / \sin \pi a$, thus obtaining the identity $z!(-z)! = \frac{\pi z}{\sin \pi z}$.	<pre>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 \[z!(-z)!= \frac{\pi z}{\sin \pi z}. \]</pre>

The in-line formula $\sum_{k=0}^{\infty} a_n$ differs	The in-line formula
from the displayed formula	\$\sum_{k=0}^{\infty}a_n\$
$\sum_{k=0}^{\infty} a_n$	differs from the displayed formula $[\sum_{k=0}^{\min_{n} \sum_{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 11.

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

Table 11: 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 sumbol ≤, and \infty stands for the infinity symbol ∞.

In Appendex 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 ,	Examples of Greek characters are \$\delta\$,
$\Delta, \theta, \text{ and } \Theta.$	<pre>\$\Delta\$, \$\theta\$, and \$\Theta\$.\\</pre>
Note the difference between	Note the difference between\\ \$\Pi\$ and
Π and \prod (as in $\prod_{i=1}^{n}$), and	<pre>\$\prod\$ (as in \$\prod_{i=1}^n\$), and\\</pre>
between ϵ and ε .	<pre>between \$\epsilon\$ and \$\varepsilon\$.</pre>

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.

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

Note the difference between	Note the difference between
$x x>1$ and $\{x x>1\}$.	<pre>\[{x x>1} \textrm{and} </pre>
However, the best set notation is	However, the best set notation is $[,x x x x x, x x x, x x, x x, x x, x $
$\{ x \mid x > 1 \}.$	

The above example also illustrates how to enter ordinary text inside a mathematical expression. Other font-changing commands have been listed before in Table 7. 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 12.

command	explanation	example	result
\mathrm	roman typeface	<pre>\$\mathrm{maximum_i}\$</pre>	\max_{i}
\mathbf	bold	\$\mathbf{v}=(v_1,v_2,v_3)\$	$\mathbf{v} = (v_1, v_2, v_3)$
\mathsf	sans serif	$\Lambda _1^2\$	M_1^2
\mathit	italics	<pre>\$ff\neq\mathit{ff}\$</pre>	$ff \neq ff$
\mathtt	typewriter type	$\lambda \in \mathbb{N}(g)$	$\mathtt{N}(g)$
\mathnormal	normal typeface	<pre>\$ff=\mathnormal{ff}\$</pre>	ff = ff
\mathcal	calligraphic	<pre>\$\mathcal{N}\$</pre>	\mathcal{N}

Table 12: 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:

$\operatorname{Mathbb{NZQRC}} gives \mathbb{NZQRC}.$	\verb \$\mathbb{NZQRC}\$	gives
	$\scriptstyle \$	

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

4.2.4 Changing the Mathematical Style

Table 13 lists the four mathematical styles that ${\rm IAT}_{\rm E} X$ 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 13:	Changing	the	Mathematical	Style
-----------	----------	-----	--------------	-------

An example:

Compare		Compare
and	$w + \frac{1}{x + \frac{1}{y + \frac{1}{z}}}$	<pre>\[w+\frac{1}{x+\frac{1}{y+\frac{1}{z}}} \] and \[w+\frac{1}{\displaystyle x+ \frac{1}{\displaystyle y+\frac{1}{z}}} \]</pre>
	$w\frac{1}{x+\frac{1}{y+\frac{1}{z}}}$	

4.3 Simple Mathematical Formulas

It is high time that you get started with mathematical typesetting in practice. In Table 14 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.
$^{}$	$\sum_{k=1}^{n}k$	$\sum_{k=1}^{n} k$, 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 14: Common Constructions in Math Mode.

EXERCISE 10

Explain how to format the following formulas.

- 1. $\cos^2 \theta + \sin^2 \theta = 1$ 2. $\sqrt{2} \approx 1.414$ $\sqrt[3]{2} \approx 1.260$ 3. $e^{\pi i} = 1$ 4. $\frac{\partial^2 f}{\partial x \partial y}$ 5. $F_n = F_{n-1} + F_{n-2}, \quad n \ge 0.$ 6. A = B if and only if $A \subseteq B$ and $A \supseteq B$. EXERCISE 11 Compare the following commands.
 - 1. \$F_{2}^{2}\$ and \$F{}_{2}^{2}\$.
 - 2. x_{1}^{y} , x^{y}_{1} , and x^{y}_{1} .

EXERCISE 12

Explain how to format the following unit conversion.

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

EXERCISE 13

Create a LATEX document that formats the text shown in Figure 8.

The equation

 $ax^2 + bx + c$

has as solution

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

Figure 8: A Mathematical Text.

EXERCISE 14

Create a $\square T_E X$ document that formats the text shown in Figure 9.⁵

 $\epsilon > 0$

(2)

From condition (2) follows ...

Figure 9: A Mathematical Fragment.

⁵The label is automatically created and will probably differ form yours.

4.4 Alignments

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

		\begin{eqnarray}
0 0 .	(-)	x^2+y^2 &=& 1 \\ y &=& \sqrt{1-x^2}
$x^2 + y^2 = 1$	(3)	\end{eqnarray}
$y = \sqrt{1 - x^2}$	(4)	

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.

EXERCISE 15

Explain how to format the following system of equations.

$$x + 2y - 3z = -11$$
$$y + z = 11$$
$$3z = 21$$

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 equarray environment. The following example illustrates this.

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

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:

	Ň	\begin{alignat*}{2}
	I	F_0 &= 0 & \qquad F_1 &= 1 \\
$F_0 = 0 \qquad F_1$	I = 1 I	F_2 &= 1 & \qquad F_3 &= 2 \\
$F_2 = 1$ F_3	s = 2 I	F_4 &= 3 & \qquad F_5 &= 5
$F_4 = 3$ F_5	j = 5	\end{alignat*}

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

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

EXERCISE 16

Explain how to format the following formula.

$$x = r \cos \phi \sin \theta$$
$$y = r \sin \phi \sin \theta$$
$$z = r \cos \theta$$

EXERCISE 17

Explain how you can format the following formula.

$$x + 2y - 3z = -11$$
$$y + z = 11$$
$$z = 21$$

4.5 Matrices

In Table 15 we list the matrix environments that IAT_EX 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

and

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

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

Compare
\[
\mathbf{M} = \begin{pmatrix}
x & x^2 \\ 1+x & 1+x+x^2 \end{pmatrix}
\]
and
\[
\mathbf{M} = \left(\begin{array}{11}
x & x^2 \\ 1+x & 1+x+x^2
\end{array}\right)
\]

command	example	result
	\$\begin{matrix} 1 & 2 \\	$\begin{array}{ccc} 1 & 2 \\ 3 & 4 \end{array}$
	3 & 4\end{matrix}\$	
	<pre>\$\begin{pmatrix} 1 & 2 \\</pre>	$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$
	3 & 4\end{pmatrix}\$	
	<pre>\$\begin{bmatrix} 1 & 2 \\</pre>	$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$
	3 & 4\end{bmatrix}\$	
	<pre>\$\begin{vmatrix} 1 & 2 \\</pre>	$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix}$
	3 & 4\end{vmatrix}\$	
	\$\begin{Vmatrix} 1 & 2 \\	$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix}$
	3 & 4\end{bmatrix}\$	

Table 15: Matrix Environments.

EXERCISE 18

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:

					<pre>\[A = \begin{pmatrix}</pre>
	/			``	a_{11} & a_{12} & \ldots & a_{1n} \\
	$\int a_{11}$	a_{12}	•••	a_{1n}	a_{21} & a_{22} & \ldots & a_{2n} \\
A -	a_{21}	a_{22}	•••	a_{2n}	\vdots & \vdots & \ddots & \vdots \\
A =		÷	·	÷	a_{m1} & a_{m2} & \ldots & a_{mn} \\
	a_{m1}	a_{m2}		a_{mn}	\end{pmatrix} \]

EXERCISE 19

Explain how to format the following statement.

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

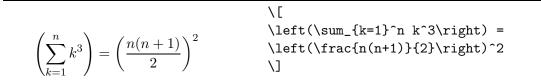
4.7 Delimiters

In Table 16 are listed the basic brackets and delimiters.

input	meaning	display
(left parenthesis	(
)	right parenthesis)
[or \lbrack	left bracket	[
] or \rbrack	right bracket]
$\ \ \ \ \ \ \ \ \ \ \ \ \ $	left curly bracket	{
$\}$ or $rbrace$	right curly bracket	}
\lfloor	left floor bracket	L
\rfloor	right floor bracket	
\lceil	left ceil bracket	
\rceil	right ceil bracket]
\langle	left angle bracket	\langle
\rangle	right angle bracket	\rangle
1	slash	/
\backslash	reverse slash	\setminus
or \vert	vertical bar	
\ or \Vert	double vertical bar	
\uparrow	upward arrow	\uparrow
\Uparrow	double upward arrow	↑
\downarrow	downward arrow	\downarrow
\Downarrow	double downward arrow	\Downarrow
\updownarrow	up-and-down arrow	\uparrow
\Updownarrow	double up-and-down arrow	\uparrow

Table 16: 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.



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 17 we show the various sizes.

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

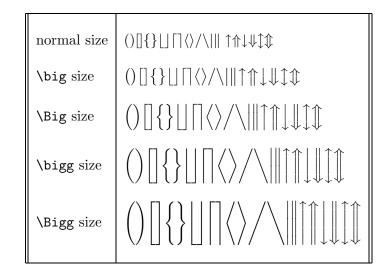


Table 17: Resizing Delimiters.

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 = \begin{cases} -x & \text{if } x < 0, \\ x & \text{otherwise} \end{cases}$	<pre>\[x = \left\{ \begin{array}{ll} -x & \textnormal{if \$x<0\$}, \\</pre>
	x & \textnormal{otherwise}
	\end{array} \right. \]

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

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

EXERCISE 20

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 21

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 22

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.

	\[1 + \frac{1}{2} +
1 1 1 1 1 1 1	$\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $
$1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} + \frac{1}{6} + \frac{1}{7} + \frac{1}{8} + \cdots$	$\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $
$2 \underbrace{3 4}_{2} \underbrace{5 0}_{2} \underbrace{7 8}_{2}$	\frac{1}{7} + \frac{1}{8}} + \cdots \]

The \stackrel command stacks one symbol above another.

 $\vec{v} \stackrel{\text{def}}{=} (v_1, \dots, v_n) \qquad \begin{array}{l} & & \\ & & \\ vec\{v\} \ \text{stackrel}\{\text{mathrm}\{\text{def}\}\{=\} \\ & & (v_1, \ \text{ldots, } v_n) \\ & & \\ & \\ & \\ & \\ \end{array}$

4.9 Theorem, Conjectures, etc.

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

Theorem 1 There exist infinitely	$\mbox{newtheorem{theorem}{Theorem}}$
many prime numbers.	\begin{theorem}
Conjecture 1 There exist infinite- ly 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 .	<pre>\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\$.</pre>
	\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 \dots
\$-\$	minus sign	-4

Table 18: Dashes and Hyphens.

- The \noindent command at the beginning of a paragraph suppresses indentation.
- You can split large LAT_EX 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 $\mathbb{P}_{T_E}X$?

There are several distributions of IAT_EX 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 T_EX — Users Group (website: www.ntg.nl) is the producer of a cd-rom with the **4AllTeX** distribution for PC-users. This version can also be downloaded anonymously from the CTAN server. The website of the worldwide TeX Users Group is

www.tug.org

This is a main source of information about IAT_EX.

References

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- [Oos97] P. Oostrum. Handleiding LATEX (in Dutch), A version adapted to the local situation is available (date: 11/4/2001) in PDF-format on the website at URL http://www.science.uva.nl/onderwijs/ict/handleiding/tex/latex.pdf.

Appendices

A Answers to the Exercises

EXERCISE 6

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

EXERCISE 10

- 1. $\ \pm \frac{1}{1}$
- 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. $F_{n}=F_{n-1}+F_{n-2}, \quad 0.$
- 6. \$\displaystyle A=B \qquad\textrm{if and only if}\qquad A\subseteq B
 \quad\textrm{and}\quad A\supseteq B\,.\$

EXERCISE 12

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

EXERCISE 13

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

EXERCISE 14

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

EXERCISE 15

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

EXERCISE 16

\begin{align*}

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

EXERCISE 17

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

EXERCISE 18

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

EXERCISE 19

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

EXERCISE 20

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

EXERCISE 21

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

EXERCISE 22

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 [GSM94]

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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 $\mathcal{A}_{\mathcal{M}}S$ -IATEX project came into being in 1987 and three years later $\mathcal{A}_{\mathcal{M}}S$ -IATEX version 1.0 was released. The conversion of $\mathcal{A}_{\mathcal{M}}S$ -TEX's mathematical capabilities to IATEX, 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} -IATEX) 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} -IATEX User's Guide (amsfndoc.tex).¹

8.2 Fonts and Symbols in Formulae

8.2.1 Mathematical Symbols

 $\begin{array}{ll} (\mathcal{L} \ 42-47) & \text{Tables 8.2 on the next page to 8.11 on page 227 review the mathematical symbols} \\ & \text{available in standard IATEX. You can put a slash through a IATEX symbol by} \\ (\mathcal{L} \ 44) & \text{preceding it with the \not command, for instance.} \end{array}$

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

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

Tables 8.12 on page 227 to 8.19 on page 229 show the extra math symbols of the $\mathcal{A}_{\mathcal{M}}\mathcal{S}$ -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 $\mathcal{A}_{\mathcal{MS}}$ -IATEX. Note in particular that in versions 1.0 and 1.1 of $\mathcal{A}_{\mathcal{MS}}$ -IATEX, which predated IATEX 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 IAT_EX and $\mathcal{A}_{\mathcal{M}}S$ symbols but with different shapes compared to the Computer Modern math fonts.

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\hat{a}	$hat{a}$	\acute{a}	$\ \$	\bar{a}	\bar{a}	\dot{a}	\det{a}	\breve{a}	\breve{a}
ă	\check{a}	à	$grave{a}$	\vec{a}	$\ensuremath{vec}\$	ä	$ddot{a}$	\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	0	0	π	\pi	ϖ	\varpi	ρ	\rho
ϱ	\varrho	σ	∖sigma	ς	\varsigma	au	\tau	v	\upsilon
ϕ	\phi	φ	\varphi	χ	\chi	ψ	\psi	ω	\omega
Г	\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 LAT_EX)

\pm	\pm	\cap	\cap	\diamond	\diamond	\oplus	\oplus
Ŧ	\mp	U	∖cup	\triangle	\bigtriangleup	\ominus	∖ominus
×	\times	\boxplus	\uplus	\bigtriangledown	\bigtriangledown	\otimes	\otimes
÷	\div	Π	\sqcap	\triangleleft	\triangleleft	\oslash	oslash
*	\ast	\Box	\sqcup	\triangleright	\triangleright	\odot	\odot
*	\star	\vee	\vee	\triangleleft	\label{lhd}^a	\bigcirc	\bigcirc
0	\circ	\wedge	\wedge	\triangleright	\rhd^a	†	\dagger
•	\bullet	\setminus	\setminus	\leq	$\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	‡	\ddagger
•	\cdot	2	\wr	\geq	$\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	Ш	\amalg

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

Table 8.3: Binary operation symbols (available in LAT_EX)

\leq	\leq,\le	\geq	\geq,\ge	\equiv	\equiv	Þ	\models	\prec	\prec
\succ	\succ	\sim	\sim	\perp	\perp	\preceq	\preceq	\succeq	\succeq
\simeq	\simeq		\mid	\ll	\11	\gg	\gg	\asymp	\asymp
	\parallel	\subset	\subset	\supset	\supset	\approx	\approx	\bowtie	\bowtie
\subseteq	\subseteq	\supseteq	\supseteq	\cong	\cong	\bowtie	\Join		\sqsubset
\Box	\sqsupset	\neq	\neq	\smile	\smile		\sqsubseteq	\square	\sqsupseteq
÷	\doteq	\frown	\frown	\in	\in	\ni	\ni	\propto	\propto
=	=	\vdash	\vdash	\dashv	\dashv	<	i	>	i

Table 8.4: Relation symbols (available in IATEX)

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Higher Mathematics

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$\stackrel{\leftarrow}{\leftarrow}$	\leftarrow \Leftarrow	$\stackrel{\longleftarrow}{\Leftarrow}$	\longleftarrow \Longleftarrow	↑ ↑	\uparrow \Uparrow
\rightarrow	\rightarrow	\longrightarrow	\longrightarrow	Ļ	\downarrow
\Rightarrow	Rightarrow	\implies	\Longrightarrow	↓	\Downarrow
\leftrightarrow	\leftrightarrow	\longleftrightarrow	$\line longleftrightarrow$	Ĵ	\updownarrow
\Leftrightarrow	\Leftrightarrow	\iff	\Longleftrightarrow	\uparrow	\Updownarrow
\mapsto	\mapsto	\longmapsto	\longmapsto	/	\nearrow
\leftarrow	\bookleftarrow	\hookrightarrow	\hookrightarrow	\searrow	\searrow
	\leftharpoonup	\rightarrow	$\$	\checkmark	\swarrow
	\leftharpoondown	\neg	$\$	$\overline{\}$	\nwarrow

Table 8.5: Arrow symbols (available in IAT_EX)

	\ldots		\cdots	÷	\vdots	·	\ddots	х	\aleph
1	\prime	\forall	\forall	∞	\infty	\hbar	\hbar	Ø	\emptyset
Ξ	\exists	∇	\nabla		\surd		\Box^a	\triangle	\triangle
\diamond	\Diamond^a	ı	$\$	J	\jmath	ℓ	\ell		\neg
Т	\top	þ	\flat	þ	\natural	#	\sharp	\wp	\wp
\perp	\bot	÷	\clubsuit	\diamond	\diamondsuit	\heartsuit	\heartsuit	¢	\spadesuit
Ω	\mbox{mho}^a	\Re	∖Re	¥	\Im	Z	\angle	∂	\partial

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

Table 8.6: Miscellaneous symbols (available in LAT_EX)

\sum	\sum	Π	\prod	Ш	\coprod	ſ	\in	∮	\oint
\cap	\bigcap	U	\bigcup	\Box	\bigsqcup	V	\bigvee	Λ	\bigwedge
\odot	\bigodot	\otimes	\bigotimes	\oplus	\bigoplus	$\left + \right $	\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)

Î	\uparrow	↑	\Uparrow	\downarrow	\downarrow	\Downarrow	\Downarrow
{	\{	}	\}	¢	\updownarrow	\uparrow	\Updownarrow
L	\lfloor		\rfloor	Γ	\lceil]	\rceil
Ā	\langle	$\overline{\rangle}$	\rangle	/	/	Ń	\backslash
Í	_	Ì	M				

Table 8.9: Delimiters (available in LATEX)

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)	\rmoustache	$\left(\right)$	\rgroup	(\lgroup
	\arrowvert	\Arrowvert	\bracevert		

Table 8.10: Large delimiters (available in IATEX)

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

Table 8.11: LATEX math constructs

F \digamma ≈ \varkappa □ \beth □ \daleth □ \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)

\Rightarrow	\Rrightarrow	$\sim \rightarrow$	\rightsquigarrow	\rightleftharpoons	\leftleftarrows
$\stackrel{\longleftarrow}{\longrightarrow}$	\leftrightarrows	ŧ	\Lleftarrow	—≫	\twoheadleftarrow
\leftarrow	\leftarrowtail	ᡩ	\looparrowleft	$ \rightleftharpoons$	\leftrightharpoons
	\curvearrowleft	Q	\circlearrowleft	ſ	\Lsh
$\uparrow\uparrow$	\upuparrows	1	\upharpoonleft	1	\downharpoonleft
_0	\multimap	\longleftrightarrow	\leftrightsquigarrow		\rightleftarrows
\Rightarrow	\rightrightarrows	\rightarrow	\times twoheadrightarrow	\rightarrow	$\ ightarrowtail$
\rightarrow	\looparrowright	\rightleftharpoons	$\ \$	\frown	\curvearrowright
\circlearrowright	\circlearrowright	ſ	\Rsh	$\downarrow\downarrow$	\downdownarrows
L	\downharpoonright	1	\upharpoonright,\rest	ricti	on

Table 8.14: AMS arrows (available with amssymb package)

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\leq	\leqq	\leq	\leqslant	\leqslant	\eqslantless
2011	\lesssim	\approx	\lessapprox	\approx	\approxeq
\triangleleft	\lessdot	≪ ∨ ≈ ₩	$\111,\11less$	≶	\lessgtr
\leq	\lesseqgtr	·	\lesseqqgtr	÷	\doteqdot,\Doteq
,= :	\risingdotseq	i,	\fallingdotseq	\sim	\backsim
\leq	\backsimeq	\subseteq	\subseteqq	\subseteq	\Subset
	\sqsubset	\preccurlyeq	\preccurlyeq	$\stackrel{\scriptstyle <}{\scriptstyle \prec}$	\curlyeqprec
$\stackrel{\scriptstyle }{\sim}$	\precsim	⊤ % ∕	\precapprox	\triangleleft	vartriangleleft
\triangleleft	\trianglelefteq	F	\vDash	ll⊢	\Vvdash
\smile	\smallsmile	\sim	\smallfrown	\sim	\bumpeq
≎	\Bumpeq	\geq	∖geqq	\geq	\geqslant
\geq	\eqslantgtr	2/11/	\gtrsim	\gtrsim	\gtrapprox
≫	\gtrdot	>>>>	\ggg,\gggtr	$\sim \approx \sim$	\gtrless
\geq	\gtreqless	≫ ∧IIV⊲II	\gtreqqless		\eqcirc
-	\circeq	\triangleq	\triangleq	\sim	\thicksim
\approx	\thickapprox	\supseteq	\supseteqq	∋	\Supset
	\sqsupset	≽	\succcurlyeq	$\not\succ$	\curlyeqsucc
\succeq	\succsim	×≈	\succapprox	\triangleright	vartriangleright
\geq	\trianglerighteq	I⊢	\Vdash	I	\shortmid
П	\shortparallel	Q	\between	Ψ	\pitchfork
\propto	\varpropto	◀	blacktriangleleft	<i>.</i> .	\therefore
Э	\backepsilon	►	\blacktriangleright	$\dot{\cdot}$	\because

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

¢	\nless	≰	\nleq	≰	\nleqslant
	\nleqq	, ≨	\lneq	≨	\lneqq
¥#V#⊀	\lvertneqq		\lnsim	$\stackrel{\cdot}{\approx}$	\lnapprox
\prec	\nprec	\ } *{↓	\npreceq	8Y#V	\precnsim
¥¥	\precnapprox	\sim	\nsim	ł	\nshortmid
ł	\nmid	¥	\nvdash	¥	\nvDash
\triangleleft	\ntriangleleft	⊉	\ntrianglelefteq	⊈	\nsubseteq
\subsetneq	\subsetneq	Ş	varsubsetneq	ALCHA	\subsetneqq
⊊	\varsubsetneqq	$\not\geq$	\ngtr	Ź	\ngeq
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	\ngeqslant	≱	\ngeqq	$\geq$	\gneq
$\geq$	\gneqq	≩	\gvertneqq	$\gtrsim$	\gnsim
$\geq \approx$	\gnapprox	$ \neq$	\nsucc	^%¥4	\nsucceq
, X	\succnsim	%√	\succnapprox	¥	\ncong
ł	\nshortparallel	7%≠	\nparallel	¥	\nvDash
J⊭	\nVDash	$\not\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!\!$	\ntriangleright	⊉	$\ntrianglerighteq$
⊉	\nsupseteq	⊉	\nsupseteqq	⊋	\supsetneq
₽	varsupsetneq	7¶∩#	\supsetneqq	¥	varsupsetneqq

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

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÷	\dotplus	$\sim$	\smallsetminus	${\mathbb M}$	\Cap,\doublecap
U	\Cup,\doublecup	$\overline{\wedge}$	\barwedge	$\underline{\vee}$	\veebar
$\overline{\wedge}$	\doublebarwedge	$\square$	\boxminus	$\boxtimes$	\boxtimes
·	\boxdot	$\blacksquare$	\boxplus	*	\divideontimes
$\ltimes$	\ltimes	$\rtimes$	\rtimes	$\mathbf{\lambda}$	$\leftthreetimes$
$\checkmark$	$\ ight three times$	人	\curlywedge	γ	\curlyvee
Θ	$\circleddash$	*	$\circledast$	0	\circledcirc
	\centerdot	т	\intercal		

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

$\hbar$	\hbar	ħ	\hslash	$\triangle$	\vartriangle
$\bigtriangledown$	\triangledown		\square	$\diamond$	<b>\lozenge</b>
$(\mathbb{S})$	\circledS	Z	\angle	$\checkmark$	\measuredangle
∄	\nexists	Ω	\mho	F	\Finv
G	\Game	k	\Bbbk	١	\backprime
Ø	varnothing		\blacktriangle	▼	blacktriangledown
	\blacksquare	•	\blacklozenge	$\star$	\bigstar
$\triangleleft$	\sphericalangle	С	\complement	ð	\eth
/	\diagup	$\mathbf{i}$	\diagdown		

Table 8.19: AMS miscellaneous (available with amssymb package)

# 8.2.2 Names of Math Font Commands

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The list of math font commands provided by the  $\mathcal{A}_{\mathcal{M}}\mathcal{S}$  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  $\infty$ , or \boldsymbol{\infty}, \boldsymbol{symbol{+}, \boldsymbol{\pi}, or \boldsymbol{\left}).

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

	<pre>\newcommand{\bpi}{\boldsymbol{\pi}}</pre>
	<pre>\newcommand{\binfty}{\boldsymbol{\infty}}</pre>
$B_{\infty} + \pi B_1 \sim \mathbf{B}_{\infty} + \pi \mathbf{B}_1$	$[ B_\infty + \pi B_1 \sim$
	<pre>\mathbf{B}_{\binfty} \boldsymbol{+} \bpi \mathbf{B}_{\boldsymbol{1}}</pre>
	\]

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

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