The Not So Short Introduction to LaTeX 2ε

Or LaTeX 2ε in 139 minutes

by Tobias Oetiker

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Thank you!

Much of the material used in this introduction comes from an Austrian introduction to LaTeX 2.09 written in German by:

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If you are interested in the German document, you can find a version updated for LaTeX 2$_\varepsilon$ by Jörg Knappen at CTAN://info/lshort/german

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If you want to contribute to this booklet, you can find all the source code on https://github.com/oetiker/lshort. Your pull requests will be appreciated.

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Preface

LaTeX [1] is a typesetting system that is very suitable for producing scientific and mathematical documents of high typographical quality. It is also suitable for producing all sorts of other documents, from simple letters to complete books. LaTeX uses TeX [2] as its formatting engine.

This short introduction describes LaTeX 2_ε and should be sufficient for most applications of LaTeX. Refer to [1, 3] for a complete description of the LaTeX system.

This introduction is split into 6 chapters:

Chapter 1 tells you about the basic structure of LaTeX 2_ε documents. You will also learn a bit about the history of LaTeX. After reading this chapter, you should have a rough understanding how LaTeX works.

Chapter 2 goes into the details of typesetting your documents. It explains most of the essential LaTeX commands and environments. After reading this chapter, you will be able to write your first documents, with itemized lists, tables, graphics and floating bodies.

Chapter 3 explains how to typeset formulae with LaTeX. Many examples demonstrate how to use one of LaTeX's main strengths. At the end of the chapter are tables listing all mathematical symbols available in LaTeX.

Chapter 4 explains indexes, bibliography generation and some finer points about creating PDFs.

Chapter 5 shows how to use LaTeX for creating graphics. Instead of drawing a picture with some graphics program, saving it to a file and then including it into LaTeX, you describe the picture and have LaTeX draw it for you.

Chapter 6 contains some potentially dangerous information about how to alter the standard document layout produced by LaTeX. It will tell you how to change things such that the beautiful output of LaTeX turns ugly or stunning, depending on your abilities.

It is important to read the chapters in order—the book is not that big, after all. Be sure to carefully read the examples, because a lot of the information is in the examples placed throughout the book.

LaTeX is available for most computers, from the PC and Mac to large UNIX and VMS systems. On many university computer clusters you will find that a LaTeX installation is available, ready to use. Information on how to access the local LaTeX installation should be provided in the *Local Guide* [5]. If you have problems getting started, ask the person who gave you this booklet. The scope of this document is *not* to tell you how to install and set up a LaTeX system, but to teach you how to write your documents so that they can be processed by LaTeX.

If you need to get hold of any LaTeX related material, have a look at one of the Comprehensive TeX Archive Network (CTAN) sites. The homepage is at http://www.ctan.org.

You will find other references to CTAN throughout the book, especially pointers to software and documents you might want to download. Instead of writing down complete URLs, I just wrote `CTAN:` followed by whatever location within the CTAN tree you should go to.

If you want to run LaTeX on your own computer, take a look at what is available from CTAN://systems.

If you have ideas for something to be added, removed or altered in this document, please let me know. I am especially interested in feedback from LaTeX novices about which bits of this intro are easy to understand and which could be explained better.

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The current version of this document is available on
CTAN://info/lshort

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Chapter 1

Things You Need to Know

The first part of this chapter presents a short overview of the philosophy and history of LaTeX 2ε. The second part focuses on the basic structures of a LaTeX document. After reading this chapter, you should have a rough knowledge of how LaTeX works, which you will need to understand the rest of this book.

1.1 A Bit of History

1.1.1 TeX

TeX is a computer program created by Donald E. Knuth [2]. It is aimed at typesetting text and mathematical formulae. Knuth started writing the TeX typesetting engine in 1977 to explore the potential of the digital printing equipment that was beginning to infiltrate the publishing industry at that time, especially in the hope that he could reverse the trend of deteriorating typographical quality that he saw affecting his own books and articles. TeX as we use it today was released in 1982, with some slight enhancements added in 1989 to better support 8-bit characters and multiple languages. TeX is renowned for being extremely stable, for running on many different kinds of computers, and for being virtually bug free. The version number of TeX is converging to π and is now at 3.141592653.

TeX is pronounced "Tech," with a "ch" as in the German word "Ach"[1] or in the Scottish "Loch." The "ch" originates from the Greek alphabet where X is the letter "ch" or "chi". TeX is also the first syllable of the Greek word technique. In an ASCII environment, TeX becomes `TeX`.

[1] In german there are actually two pronunciations for "ch" and one might assume that the soft "ch" sound from "Pech" would be a more appropriate. Asked about this, Knuth wrote in the German Wikipedia: *I do not get angry when people pronounce TeX in their favorite way ... and in Germany many use a soft ch because the X follows the vowel e, not the harder ch that follows the vowel a. In Russia, 'tex' is a very common word, pronounced 'tyekh'. But I believe the most proper pronunciation is heard in Greece, where you have the harsher ch of ach and Loch.*

1.1.2 LaTeX

LaTeX enables authors to typeset and print their work at the highest typographical quality, using a predefined, professional layout. LaTeX was originally written by Leslie Lamport [1]. It uses the TeX formatter as its typesetting engine. These days LaTeX is maintained by the LaTeX Project.

LaTeX is pronounced "Lay-tech" or "Lah-tech." If you refer to LaTeX in an ASCII environment, you type `LaTeX`. LaTeX 2$_\varepsilon$ is pronounced "Lay-tech two e" and typed `LaTeX2e`.

1.2 Basics

1.2.1 Author, Book Designer, and Typesetter

To publish something, authors give their typed manuscript to a publishing company. One of their book designers then decides the layout of the document (column width, fonts, space before and after headings, ...). The book designer writes his instructions into the manuscript and then gives it to a typesetter, who typesets the book according to these instructions.

A human book designer tries to find out what the author had in mind while writing the manuscript. He decides on chapter headings, citations, examples, formulae, etc. based on his professional knowledge and from the contents of the manuscript.

In a LaTeX environment, LaTeX takes the role of the book designer and uses TeX as its typesetter. But LaTeX is "only" a program and therefore needs more guidance. The author has to provide additional information to describe the logical structure of his work. This information is written into the text as "LaTeX commands."

This is quite different from the WYSIWYG[2] approach that most modern word processors, such as *MS Word* or *LibreOffice*, take. With these applications, authors specify the document layout interactively while typing text into the computer. They can see on the screen how the final work will look when it is printed.

When using LaTeX it is not normally possible to see the final output while typing the text, but the final output can be previewed on the screen after processing the file with LaTeX. Then corrections can be made before actually sending the document to the printer.

1.2.2 Layout Design

Typographical design is a craft. Unskilled authors often commit serious formatting errors by assuming that book design is mostly a question of aesthetics—"If a document looks good artistically, it is well designed." But

[2] What you see is what you get.

as a document has to be read and not hung up in a picture gallery, the readability and understandability is much more important than the beautiful look of it. Examples:

- The font size and the numbering of headings have to be chosen to make the structure of chapters and sections clear to the reader.
- The line length has to be short enough not to strain the eyes of the reader, while long enough to fill the page beautifully.

With WYSIWYG systems, authors often generate aesthetically pleasing documents with very little or inconsistent structure. LaTeX prevents such formatting errors by forcing the author to declare the *logical* structure of his document. LaTeX then chooses the most suitable layout.

1.2.3 Advantages and Disadvantages

When people from the WYSIWYG world meet people who use LaTeX, they often discuss "the advantages of LaTeX over a normal word processor" or the opposite. The best thing to do when such a discussion starts is to keep a low profile, since such discussions often get out of hand. But sometimes there is no escaping ...

So here is some ammunition. The main advantages of LaTeX over normal word processors are the following:

- Professionally crafted layouts are available, which make a document really look as if "printed."
- The typesetting of mathematical formulae is supported in a convenient way.
- Users only need to learn a few easy-to-understand commands that specify the logical structure of a document. They almost never need to tinker with the actual layout of the document.
- Even complex structures such as footnotes, references, table of contents, and bibliographies can be generated easily.
- Free add-on packages exist for many typographical tasks not directly supported by basic LaTeX. For example, packages are available to include PostScript graphics or to typeset bibliographies conforming to exact standards. Many of these add-on packages are described in *The LaTeX Companion* [3].
- LaTeX encourages authors to write well-structured texts, because this is how LaTeX works—by specifying structure.

- TEX, the formatting engine of LATEX 2ε, is highly portable and free. Therefore the system runs on almost any hardware platform available.

LATEX also has some disadvantages, and I guess it's a bit difficult for me to find any sensible ones, though I am sure other people can tell you hundreds ;-)

- LATEX does not work well for people who have sold their souls ...
- Although some parameters can be adjusted within a predefined document layout, the design of a whole new layout is difficult and takes a lot of time.[3]
- It is very hard to write unstructured and disorganized documents.
- Your hamster might, despite some encouraging first steps, never be able to fully grasp the concept of Logical Markup.

1.3 LATEX Input Files

The input for LATEX is a plain text file. On Unix/Linux text files are pretty common. On windows, one would use Notepad to create a text file. It contains the text of the document, as well as the commands that tell LATEX how to typeset the text. If you are working with a LATEX IDE, it will contain a program for creating LATEX input files in text format.

1.3.1 Spaces

"Whitespace" characters, such as blank or tab, are treated uniformly as "space" by LATEX. *Several consecutive* whitespace characters are treated as *one* "space." Whitespace at the start of a line is generally ignored, and a single line break is treated as "whitespace."

An empty line between two lines of text defines the end of a paragraph. *Several* empty lines are treated the same as *one* empty line. The text below is an example. On the left hand side is the text from the input file, and on the right hand side is the formatted output.

```
It does not matter whether you
enter one or several     spaces
after a word.

An empty line starts a new
paragraph.
```

It does not matter whether you enter one or several spaces after a word.

An empty line starts a new paragraph.

[3] Rumour says that this is one of the key elements that will be addressed in the upcoming LATEX3 system.

1.3.2 Special Characters

The following symbols are reserved characters that either have a special meaning under LaTeX or are not available in all the fonts. If you enter them directly in your text, they will normally not print, but rather coerce LaTeX to do things you did not intend.

```
# $ % ^ & _ { } ~ \
```

As you will see, these characters can be used in your documents all the same by using a prefix backslash:

```
\# \$ \% \^{} \& \_ \{ \} \~{}
\textbackslash
```

$ % ^ & _ { } ~ \

The other symbols and many more can be printed with special commands in mathematical formulae or as accents. The backslash character \ can *not* be entered by adding another backslash in front of it (\\); this sequence is used for line breaking. Use the `\textbackslash` command instead.

1.3.3 LaTeX Commands

LaTeX commands are case sensitive, and take one of the following two formats:

- They start with a backslash \ and then have a name consisting of letters only. Command names are terminated by a space, a number or any other 'non-letter.'
- They consist of a backslash and exactly one non-letter.
- Many commands exist in a 'starred variant' where a star is appended to the command name.

LaTeX ignores whitespace after commands. If you want to get a space after a command, you have to put either an empty parameter `{}` and a blank or a special spacing command after the command name. The empty parameter `{}` stops LaTeX from eating up all the white space after the command name.

```
New \TeX users may miss whitespaces
after a command. % renders wrong
Experienced \TeX{} users are
\TeX perts, and know how to use
whitespaces. % renders correct
```

New TEXusers may miss whitespaces after a command. Experienced TEX users are TEXperts, and know how to use whitespaces.

Some commands require a parameter, which has to be given between curly braces { } after the command name. Some commands take optional

parameters, which are inserted after the command name in square brackets [ ].

command[*optional parameter*]{*parameter*}

The next examples use some LaTeX commands. Don't worry about them; they will be explained later.

```
You can \textsl{lean} on me!
```

You can *lean* on me!

```
Please, start a new line
right here!\newline
Thank you!
```

Please, start a new line right here!
Thank you!

1.3.4 Comments

When LaTeX encounters a % character while processing an input file, it ignores the rest of the present line, the line break, and all whitespace at the beginning of the next line.

This can be used to write notes into the input file, which will not show up in the printed version.

```
This is an % stupid
% Better: instructive <----
example: Supercal%
              ifragilist%
    icexpialidocious
```

This is an example: Supercalifragilisticexpialidocious

The % character can also be used to split long input lines where no whitespace or line breaks are allowed.

For longer comments you could use the `comment` environment provided by the verbatim package. Add the line `\usepackage{verbatim}` to the preamble of your document as explained below to use this command.

```
This is another
\begin{comment}
rather stupid,
but helpful
\end{comment}
example for embedding
comments in your document.
```

This is another example for embedding comments in your document.

Note that this won't work inside complex environments, like math for example.

1.4 Input File Structure

When LaTeX 2ε processes an input file, it expects it to follow a certain structure. Thus every input file must start with the command

```
\documentclass{...}
```

This specifies what sort of document you intend to write. After that, add commands to influence the style of the whole document, or load packages that add new features to the LaTeX system. To load such a package you use the command

```
\usepackage{...}
```

When all the setup work is done,[4] you start the body of the text with the command

```
\begin{document}
```

Now you enter the text mixed with some useful LaTeX commands. At the end of the document you add the

```
\end{document}
```

command, which tells LaTeX to call it a day. Anything that follows this command will be ignored by LaTeX.

Figure 1.1 shows the contents of a minimal LaTeX 2ε file. A slightly more complicated input file is given in Figure 1.2.

1.5 A Typical Command Line Session

I bet you must be dying to try out the neat small LaTeX input file shown on page 7. Here is some help: LaTeX itself comes without a GUI or fancy buttons to press. It is just a program that crunches away at your input file. Some LaTeX installations feature a graphical front-end where there is a LaTeX button to start compiling your input file. On other systems there

[4] The area between `\documentclass` and `\begin{document}` is called the *preamble*.

```
\documentclass{article}
\begin{document}
Small is beautiful.
\end{document}
```

Figure 1.1: A Minimal LaTeX File.

might be some typing involved, so here is how to coax LaTeX into compiling your input file on a text based system. Please note: this description assumes that a working LaTeX installation already sits on your computer.[5]

1. Edit/Create your LaTeX input file. This file must be plain ASCII text. On Unix all the editors will create just that. On Windows you might want to make sure that you save the file in ASCII or *Plain Text* format. When picking a name for your file, make sure it bears the extension `.tex`.

2. Open a shell or cmd window, `cd` to the directory where your input file is located and run LaTeX on your input file. If successful you will end up with a `.pdf` file. It may be necessary to run LaTeX several times to get the table of contents and all internal references right. When your input file has a bug LaTeX will tell you about it and stop processing your input file. Type `ctrl-D` to get back to the command line.

   ```
   xelatex foo.tex
   ```

[5] This is the case with most well groomed Unix Systems, and ... Real Men use Unix, so ... ;-)

```
\documentclass[a4paper,11pt]{article}
% define the title
\author{H.~Partl}
\title{Minimalism}
\begin{document}
% generates the title
\maketitle
% insert the table of contents
\tableofcontents
\section{Some Interesting Words}
Well, and here begins my lovely article.
\section{Good Bye World}
\ldots{} and here it ends.
\end{document}
```

Figure 1.2: Example of a Realistic Journal Article. Note that all the commands you see in this example will be explained later in the introduction.

1.6 The Layout of the Document

1.6.1 Document Classes

The first information LaTeX needs to know when processing an input file is the type of document the author wants to create. This is specified with the `\documentclass` command.

`\documentclass[`*options*`]{`*class*`}`

Here *class* specifies the type of document to be created. Table 1.1 lists the document classes explained in this introduction. The LaTeX 2_ε distribution provides additional classes for other documents, including letters and slides. The *options* parameter customizes the behavior of the document class. The options have to be separated by commas. The most common options for the standard document classes are listed in Table 1.2.

Example: An input file for a LaTeX document could start with the line

```
\documentclass[11pt,twoside,a4paper]{article}
```

which instructs LaTeX to typeset the document as an *article* with a base font size of *eleven points*, and to produce a layout suitable for *double sided* printing on *A4 paper*.

Table 1.1: Document Classes.

`article`	for articles in scientific journals, presentations, short reports, program documentation, invitations, ...
`proc`	a class for proceedings based on the article class.
`minimal`	is as small as it can get. It only sets a page size and a base font. It is mainly used for debugging purposes.
`report`	for longer reports containing several chapters, small books, PhD theses, ...
`book`	for real books
`slides`	for slides. The class uses big sans serif letters. You might want to consider using the Beamer class instead.

Table 1.2: Document Class Options.

`10pt`, `11pt`, `12pt` Sets the size of the main font in the document. If no option is specified, `10pt` is assumed.

`a4paper`, `letterpaper`, ... Defines the paper size. The default size is `letterpaper`. Besides that, `a5paper`, `b5paper`, `executivepaper`, and `legalpaper` can be specified.

`fleqn` Typesets displayed formulae left-aligned instead of centred.

`leqno` Places the numbering of formulae on the left hand side instead of the right.

`titlepage`, `notitlepage` Specifies whether a new page should be started after the document title or not. The `article` class does not start a new page by default, while `report` and `book` do.

`onecolumn`, `twocolumn` Instructs LaTeX to typeset the document in one column or two columns.

`twoside, oneside` Specifies whether double or single sided output should be generated. The classes `article` and `report` are single sided and the `book` class is double sided by default. Note that this option concerns the style of the document only. The option `twoside` does *not* tell the printer you use that it should actually make a two-sided printout.

`landscape` Changes the layout of the document to print in landscape mode.

`openright, openany` Makes chapters begin either only on right hand pages or on the next page available. This does not work with the `article` class, as it does not know about chapters. The `report` class by default starts chapters on the next page available and the `book` class starts them on right hand pages.

1.6.2 Packages

While writing your document, you will probably find that there are some areas where basic LaTeX cannot solve your problem. If you want to include graphics, coloured text or source code from a file into your document, you need to enhance the capabilities of LaTeX. Such enhancements are called packages. Packages are activated with the

`\usepackage[`*options*`]{`*package*`}`

command, where *package* is the name of the package and *options* is a list of keywords that trigger special features in the package. The `\usepackage` command goes into the preamble of the document. See section 1.4 for details.

Some packages come with the LaTeX 2_ε base distribution (See Table 1.3). Others are provided separately. You may find more information on the packages installed at your site in your *Local Guide* [5]. The prime source for information about LaTeX packages is *The LaTeX Companion* [3]. It contains descriptions on hundreds of packages, along with information of how to write your own extensions to LaTeX 2_ε.

Modern TeX distributions come with a large number of packages preinstalled. If you are working on a Unix system, use the command `texdoc` for accessing package documentation.

1.6.3 Page Styles

LaTeX supports three predefined header/footer combinations—so-called page styles. The *style* parameter of the

`\pagestyle{`*style*`}`

command defines which one to use. Table 1.4 lists the predefined page styles.

It is possible to change the page style of the current page with the command

`\thispagestyle{`*style*`}`

A description how to create your own headers and footers can be found in *The LaTeX Companion* [3] and in section 4.3 on page 76.

1.7 Files You Might Encounter

When you work with LaTeX you will soon find yourself in a maze of files with various extensions and probably no clue. The following list explains the various file types you might encounter when working with TeX. Please

Table 1.3: Some of the Packages Distributed with LaTeX.

doc Allows the documentation of LaTeX programs.
Described in `doc.dtx`[a] and in *The LaTeX Companion* [3].

exscale Provides scaled versions of the math extension font.
Described in `ltexscale.dtx`.

fontenc Specifies which font encoding LaTeX should use.
Described in `ltoutenc.dtx`.

ifthen Provides commands of the form
'if...then do...otherwise do....'
Described in `ifthen.dtx` and *The LaTeX Companion* [3].

latexsym To access the LaTeX symbol font, you should use the `latexsym` package. Described in `latexsym.dtx` and in *The LaTeX Companion* [3].

makeidx Provides commands for producing indexes. Described in section 4.2 and in *The LaTeX Companion* [3].

syntonly Processes a document without typesetting it.

inputenc Allows the specification of an input encoding such as ASCII, ISO Latin-1, ISO Latin-2, 437/850 IBM code pages, Apple Macintosh, Next, ANSI-Windows or user-defined one. Described in `inputenc.dtx`.

[a] This file should be installed on your system, and you should be able to get a `dvi` file by typing `latex doc.dtx` in any directory where you have write permission. The same is true for all the other files mentioned in this table.

Table 1.4: The Predefined Page Styles of LaTeX.

`plain` prints the page numbers on the bottom of the page, in the middle of the footer. This is the default page style.

`headings` prints the current chapter heading and the page number in the header on each page, while the footer remains empty. (This is the style used in this document)

`empty` sets both the header and the footer to be empty.

note that this table does not claim to be a complete list of extensions, but if you find one missing that you think is important, please drop me a line.

.tex LaTeX or TeX input file. Can be compiled with `latex`.

.sty LaTeX Macro package. Load this into your LaTeX document using the `\usepackage` command.

.dtx Documented TeX. This is the main distribution format for LaTeX style files. If you process a .dtx file you get documented macro code of the LaTeX package contained in the .dtx file.

.ins The installer for the files contained in the matching .dtx file. If you download a LaTeX package from the net, you will normally get a .dtx and a .ins file. Run LaTeX on the .ins file to unpack the .dtx file.

.cls Class files define what your document looks like. They are selected with the `\documentclass` command.

.fd Font description file telling LaTeX about new fonts.

The following files are generated when you run LaTeX on your input file:

.dvi Device Independent File. This is the main result of a classical LaTeX compile run. Look at its content with a DVI previewer program or send it to a printer with `dvips` or a similar application. If you are using pdfLaTeX then you should not see any of these files.

.log Gives a detailed account of what happened during the last compiler run.

.toc Stores all your section headers. It gets read in for the next compiler run and is used to produce the table of contents.

.lof This is like .toc but for the list of figures.

.lot And again the same for the list of tables.

.aux Another file that transports information from one compiler run to the next. Among other things, the .aux file is used to store information associated with cross-references.

.idx If your document contains an index. LaTeX stores all the words that go into the index in this file. Process this file with `makeindex`. Refer to section 4.2 on page 74 for more information on indexing.

.ind The processed .idx file, ready for inclusion into your document on the next compile cycle.

.ilg Logfile telling what `makeindex` did.

1.8 Big Projects

When working on big documents, you might want to split the input file into several parts. LaTeX has two commands that help you to do that.

`\include{`*filename*`}`

Use this command in the document body to insert the contents of another file named *filename.tex*. Note that LaTeX will start a new page before processing the material input from *filename.tex*.

The second command can be used in the preamble. It allows you to instruct LaTeX to only input some of the `\included` files.

`\includeonly{`*filename*`,`*filename*`,...}`

After this command is executed in the preamble of the document, only `\include` commands for the filenames that are listed in the argument of the `\includeonly` command will be executed.

The `\include` command starts typesetting the included text on a new page. This is helpful when you use `\includeonly`, because the page breaks will not move, even when some include files are omitted. Sometimes this might not be desirable. In this case, use the

`\input{`*filename*`}`

command. It simply includes the file specified. No flashy suits, no strings attached.

To make LaTeX quickly check your document use the syntonly package. This makes LaTeX skim through your document only checking for proper syntax and usage of the commands, but doesn't produce any (pdf) output. As LaTeX runs faster in this mode you may save yourself valuable time. Usage is very simple:

```
\usepackage{syntonly}
\syntaxonly
```

When you want to produce pages, just comment out the second line (by adding a percent sign).

Chapter 2

Typesetting Text

After reading the previous chapter, you should know about the basic stuff of which a LaTeX 2ε document is made. In this chapter I will fill in the remaining structure you will need to know in order to produce real world material.

2.1 The Structure of Text and Language

By Hanspeter Schmid <hanspi@schmid-werren.ch>

The main point of writing a text, is to convey ideas, information, or knowledge to the reader. The reader will understand the text better if these ideas are well-structured, and will see and feel this structure much better if the typographical form reflects the logical and semantic structure of the content.

LaTeX is different from other typesetting systems in that you just have to tell it the logical and semantic structure of a text. It then derives the typographical form of the text according to the "rules" given in the document class file and in various style files.

The most important text unit in LaTeX (and in typography) is the paragraph. We call it "text unit" because a paragraph is the typographical form that should reflect one coherent thought, or one idea. You will learn in the following sections how to force line breaks with e.g. \\, and paragraph breaks with e.g. leaving an empty line in the source code. Therefore, if a new thought begins, a new paragraph should begin, and if not, only line breaks should be used. If in doubt about paragraph breaks, think about your text as a conveyor of ideas and thoughts. If you have a paragraph break, but the old thought continues, it should be removed. If some totally new line of thought occurs in the same paragraph, then it should be broken.

Most people completely underestimate the importance of well-placed paragraph breaks. Many people do not even know what the meaning of a paragraph break is, or, especially in LaTeX, introduce paragraph breaks without knowing it. The latter mistake is especially easy to make if equations are used in the text. Look at the following examples, and figure out

why sometimes empty lines (paragraph breaks) are used before and after the equation, and sometimes not. (If you don't yet understand all commands well enough to understand these examples, please read this and the following chapter, and then read this section again.)

```
% Example 1
\ldots when Einstein introduced his formula
\begin{equation}
  e = m \cdot c^2 \; ,
\end{equation}
which is at the same time the most widely known
and the least well understood physical formula.


% Example 2
\ldots from which follows Kirchhoff's current law:
\begin{equation}
  \sum_{k=1}^{n} I_k = 0 \; .
\end{equation}

Kirchhoff's voltage law can be derived \ldots


% Example 3
\ldots which has several advantages.

\begin{equation}
  I_D = I_F - I_R
\end{equation}
is the core of a very different transistor model. \ldots
```

The next smaller text unit is a sentence. In English texts, there is a larger space after a period that ends a sentence than after one that ends an abbreviation. LaTeX tries to figure out which one you wanted to have. If LaTeX gets it wrong, you must tell it what you want. This is explained later in this chapter.

The structuring of text even extends to parts of sentences. Most languages have very complicated punctuation rules, but in many languages (including German and English), you will get almost every comma right if you remember what it represents: a short stop in the flow of language. If you are not sure about where to put a comma, read the sentence aloud and take a short breath at every comma. If this feels awkward at some place, delete that comma; if you feel the urge to breathe (or make a short stop) at some other place, insert a comma.

Finally, the paragraphs of a text should also be structured logically at a higher level, by putting them into chapters, sections, subsections, and so on. However, the typographical effect of writing e.g. `\section{The Structure of Text and Language}` is so obvious that it is almost self-evident how these high-level structures should be used.

2.2 Line Breaking and Page Breaking

2.2.1 Justified Paragraphs

Books are often typeset with each line having the same length. LaTeX inserts the necessary line breaks and spaces between words by optimizing the contents of a whole paragraph. If necessary, it also hyphenates words that would not fit comfortably on a line. How the paragraphs are typeset depends on the document class. Normally the first line of a paragraph is indented, and there is no additional space between two paragraphs. Refer to section 6.3.2 for more information.

In special cases it might be necessary to order LaTeX to break a line:

`\\ or \newline`

starts a new line without starting a new paragraph.

`\\*`

additionally prohibits a page break after the forced line break.

`\newpage`

starts a new page.

`\linebreak[`*n*`]`, `\nolinebreak[`*n*`]`, `\pagebreak[`*n*`]`, `\nopagebreak[`*n*`]`

suggest places where a break may (or may not) happen. They enable the author to influence their actions with the optional argument *n*, which can be set to a number between zero and four. By setting *n* to a value below 4, you leave LaTeX the option of ignoring your command if the result would look very bad. Do not confuse these "break" commands with the "new" commands. Even when you give a "break" command, LaTeX still tries to even out the right border of the line and the total length of the page, as described in the next section; this can lead to unpleasant gaps in your text. If you really want to start a "new line" or a "new page", then use the corresponding command. Guess their names!

LaTeX always tries to produce the best line breaks possible. If it cannot find a way to break the lines in a manner that meets its high standards, it lets one line stick out on the right of the paragraph. LaTeX then complains ("overfull hbox") while processing the input file. This happens most often when LaTeX cannot find a suitable place to hyphenate a word.[1] Instruct LaTeX to lower its standards a little by giving the `\sloppy` command. It prevents such over-long lines by increasing the inter-word spacing—even if the final output is not optimal. In this case a warning ("underfull hbox") is given to the user. In most such cases the result doesn't look very good. The command `\fussy` brings LaTeX back to its default behaviour.

2.2.2 Hyphenation

LaTeX hyphenates words whenever necessary. If the hyphenation algorithm does not find the correct hyphenation points, remedy the situation by using the following commands to tell TeX about the exception.

The command

`\hyphenation{`*word list*`}`

causes the words listed in the argument to be hyphenated only at the points marked by "-". The argument of the command should only contain words built from normal letters, or rather signs that are considered to be normal letters by LaTeX. The hyphenation hints are stored for the language that is active when the hyphenation command occurs. This means that if you place a hyphenation command into the preamble of your document it will influence the English language hyphenation. If you place the command after the `\begin{document}` and you are using some package for national language support like polyglossia, then the hyphenation hints will be active in the language activated through polyglossia.

The example below will allow "hyphenation" to be hyphenated as well as "Hyphenation", and it prevents "FORTRAN", "Fortran" and "fortran" from being hyphenated at all. No special characters or symbols are allowed in the argument.

Example:

```
\hyphenation{FORTRAN Hy-phen-a-tion}
```

The command `\-` inserts a discretionary hyphen into a word. This also becomes the only point hyphenation is allowed in this word. This command is especially useful for words containing special characters (e.g. accented

[1] Although LaTeX gives you a warning when that happens (`Overfull \hbox`) and displays the offending line, such lines are not always easy to find. If you use the option `draft` in the `\documentclass` command, these lines will be marked with a thick black line on the right margin.

characters), because LaTeX does not automatically hyphenate words containing special characters.

```
I think this is: su\-per\-cal\-%
i\-frag\-i\-lis\-tic\-ex\-pi\-%
al\-i\-do\-cious
```

I think this is: supercalifragilisticexpialidocious

Several words can be kept together on one line with the command

`\mbox{`*text*`}`

It causes its argument to be kept together under all circumstances.

```
My phone number will change soon.
It will be \mbox{0116 291 2319}.

The parameter
\mbox{\emph{filename}} should
contain the name of the file.
```

My phone number will change soon. It will be 0116 291 2319.

The parameter *filename* should contain the name of the file.

`\fbox` is similar to `\mbox`, but in addition there will be a visible box drawn around the content.

2.3 Ready-Made Strings

In some of the examples on the previous pages, you have seen some very simple LaTeX commands for typesetting special text strings:

Command	Example	Description
`\today`	February 28, 2018	Current date
`\TeX`	TeX	Your favorite typesetter
`\LaTeX`	LaTeX	The Name of the Game
`\LaTeXe`	LaTeX 2$_\varepsilon$	The current incarnation

2.4 Special Characters and Symbols

2.4.1 Quotation Marks

You should *not* use the " for quotation marks as you would on a typewriter. In publishing there are special opening and closing quotation marks. In LaTeX, use two ‘ (grave accent) for opening quotation marks and two ’ (vertical quote) for closing quotation marks. For single quotes you use just one of each.

```
``Please press the `x' key.''
```

“Please press the ‘x’ key.”

Yes I know the rendering is not ideal, it's really a back-tick or grave accent (‘) for opening quotes and vertical quote (’) for closing, despite what the font chosen might suggest.

2.4.2 Dashes and Hyphens

LaTeX knows four kinds of dashes. Access three of them with different number of consecutive dashes. The fourth sign is actually not a dash at all—it is the mathematical minus sign:

```
daughter-in-law, X-rated\\
pages 13--67\\
yes---or no? \\
$0$, $1$ and $-1$
```

daughter-in-law, X-rated
pages 13–67
yes—or no?
0, 1 and −1

The names for these dashes are: ‘-’ hyphen, ‘–’ en-dash, ‘—’ em-dash and ‘−’ minus sign.

2.4.3 Tilde (∼)

A character often seen in web addresses is the tilde. To generate this in LaTeX use `\~{}` but the result (˜) is not really what you want. Try this instead:

```
http://www.rich.edu/\~{}bush \\
http://www.clever.edu/$\sim$demo
```

http://www.rich.edu/˜bush
http://www.clever.edu/∼demo

2.4.4 Slash (/)

In order to typeset a slash between two words, one can simply type e.g. `read/write`, but this makes LaTeX treat the two words as one. Hyphenation is disabled for these two words, so there may be ‘overfull’ errors. To overcome this, use `\slash`. For example type ‘`read\slash write`’ which allows hyphenation. But normal ‘`/`’ character may be still used for ratios or units, e.g. `5 MB/s`.

2.4.5 Degree Symbol (◦)

Printing the degree symbol in pure LaTeX.

```
It's $-30\,^{\circ}\mathrm{C}$.
I will soon start to
super-conduct.
```

It's −30 °C. I will soon start to superconduct.

The textcomp package makes the degree symbol also available as `\textdegree` or in combination with the C by using the `\textcelsius`.

```
30 \textcelsius{} is
86 \textdegree{}F.
```

30 ℃ is 86 °F.

2.4.6 The Euro Currency Symbol (€)

When writing about money these days, you need the Euro symbol. Many current fonts contain a Euro symbol. After loading the textcomp package in the preamble of your document

```
\usepackage{textcomp}
```

use the command

```
\texteuro
```

to access it.

If your font does not provide its own Euro symbol or if you do not like the font's Euro symbol, you have two more choices:

First the eurosym package. It provides the official Euro symbol:

```
\usepackage[official]{eurosym}
```

If you prefer a Euro symbol that matches your font, use the option `gen` in place of the `official` option.

Table 2.1: A bag full of Euro symbols

LM+textcomp	`\texteuro`	€	€	€
eurosym	`\euro`	€	€	€
[gen]eurosym	`\euro`	€	€	€

2.4.7 Ellipsis (...)

On a typewriter, a comma or a period takes the same amount of space as any other letter. In book printing, these characters occupy only a little space and are set very close to the preceding letter. Therefore, entering 'ellipsis'

by just typing three dots would produce the wrong result. Instead, there is a special command for these dots. It is called

`\ldots` (low dots)

```
Not like this ... but like this:\\
New York, Tokyo, Budapest, \ldots
```

Not like this ... but like this:
New York, Tokyo, Budapest, ...

2.4.8 Ligatures

Some letter combinations are typeset not just by setting the different letters one after the other, but by actually using special symbols.

ff fi fl ffi... instead of ff fi fl ffi ...

These so-called ligatures can be prohibited by inserting an `\mbox{}` between the two letters in question. This might be necessary with words built from two words.

```
\Large Not shelfful\\
but shelf\mbox{}ful
```

Not shelfful
but shelfful

2.4.9 Accents and Special Characters

LaTeX supports the use of accents and special characters from many languages. Table 2.2 shows all sorts of accents being applied to the letter o. Naturally other letters work too.

To place an accent on top of an i or a j, its dots have to be removed. This is accomplished by typing `\i` and `\j`.

```
H\^otel, na\"\i ve, \'el\`eve,\\
sm\o rrebr\o d, !`Se\~norita!,\\
Sch\"onbrunner Schlo\ss{}
Stra\ss e
```

Hôtel, naïve, élève,
smørrebrød, ¡Señorita!,
Schönbrunner Schloß Straße

2.5 International Language Support

By Axel Kielhorn <A.Kielhorn@web.de>

When you write documents in languages other than English, there are three areas where LaTeX has to be configured appropriately:

1. All automatically generated text strings[2] have to be adapted to the new language.
2. LaTeX needs to know the hyphenation rules for the current language.
3. Language specific typographic rules. In French for example, there is a mandatory space before each colon character (:).

Also entering text in your language of choice might be a bit cumbersome using all the commands from figure 2.2. To overcome this problem, until recently you had to delve deep into the abyss of language specific encodings both for input as well as fonts. These days, with modern TeX engines speaking UTF-8 natively, these problems have relaxed considerably.

The package polyglossia[18] is a replacement for venerable babel package. It takes care of the hyphenation patterns and automatically generated text strings in your documents.

The package fontspec[20] handles font loading for XeLaTeX and LuaTeX. The default font is Latin Modern Roman.

2.5.1 Polyglossia Usage

Depending on the TeX engine you use slighly different commands are necessary in the preamble of your document to properly enable multilingual processing. Figure 2.1 on page 24 shows a sample preamble that takes care of all the necessary settings.

So far there has been no advantage to using a Unicode TeX engine. This changes when we leave the Latin script and move to a more interesting language like Greek or Russian. With a Unicode based system, you can

[2] Table of Contents, List of Figures, ...

Table 2.2: Accents and Special Characters.

ò	\`o	ó	\'o	ô	\^o	õ	\~o
ō	\=o	ȯ	\.o	ö	\"o	ç	\c c
ǒ	\u o	ő	\v o	ő	\H o	ǫ	\c o
ọ	\d o	o̲	\b o	o͡o	\t oo		
œ	\oe	Œ	\OE	æ	\ae	Æ	\AE
å	\aa	Å	\AA				
ø	\o	Ø	\O	ł	\l	Ł	\L
ı	\i	ȷ	\j	¡	!`	¿	?`

simply[3] enter the native characters in your editor and TEX will understand them.

Writing in different languages is easy, just specify the languages in the preamble. This example uses the csquotes package which generates the right kind of quotes according to the language you are writing in. Note that it needs to be loaded *before* loading the language support.

```
\usepackage[autostyle=true]{csquotes}
\setdefaultlanguage{english}
\setotherlanguage{german}
```

To write a paragraph in German, you can use the German environment:

```
English text.
\begin{german}
Deutscher \enquote{Text}.
\end{german}
More English \enquote{text}.
```

English text. Deutscher „Text“. More English “text”.

If you just need a word in a foreign language you can use the `\text`*language* command:

```
Did you know that
\textgerman{Gesundheit} is
actually a German word.
```

Did you know that Gesundheit is actually a German word.

This may look unnecessary since the only advantage is a correct hyphenation, but when the second language is a little bit more exotic it will be worth the effort.

Sometimes the font used in the main document does not contain glyphs that are required in the second language. Latin Modern for example does

[3] For small values of simple.

```
\usepackage{iftex}
\ifXeTeX
   \usepackage{fontspec}
\else
   \usepackage{luatextra}
\fi
\defaultfontfeatures{Ligatures=TeX}
\usepackage{polyglossia}
```

Figure 2.1: All in one preamble that takes care of LuaLATEX and XELATEX

not contain Cyrillic letters. The solution is to define a font that will be used for that language. Whenever a new language is activated, polyglossia will first check whether a font has been defined for that language. If you are happy with the computer modern font, you may want to try the "Computer Modern Unicode" font by adding the following commands to the preamble of your document.

For LuaLaTeX it is pretty simple

```
\setmainfont{CMU Serif}
\setsansfont{CMU Sans Serif}
\setmonofont{CMU Typewriter Text}
```

For XeLaTeX you have to be a bit more explicit:

```
\setmainfont{cmun}[
   Extension=.otf,UprightFont=*rm,ItalicFont=*ti,
   BoldFont=*bx,BoldItalicFont=*bi,
 ]
 \setsansfont{cmun}[
   Extension=.otf,UprightFont=*ss,ItalicFont=*si,
   BoldFont=*sx,BoldItalicFont=*so,
 ]
 \setmonofont{cmun}[
   Extension=.otf,UprightFont=*btl,ItalicFont=*bto,
   BoldFont=*tb,BoldItalicFont=*tx,
 ]
```

With the appropriate fonts loaded, you can now write:

```
\textrussian{Правда} is
a russian newspaper.
\textgreek{ἀλήθεια} is truth
or disclosure in philosophy
```

Правда is a russian newspaper. ἀλήθεια is truth or disclosure in philosophy

The package xgreek[21] offers support for writing either ancient or modern (monotonic or polytonic) greek.

Right to Left (RTL) languages.

Some languages are written left to right, others are written right to left(RTL). polyglossia needs the bidi[22] package[4] in order to support RTL languages. The bidi package should be the last package you load, even after hyperref which is usually the last package. (Since polyglossia loads bidi this means that polyglossia should be the last package loaded.)

[4] `bidi` does not support LuaTeX.

The package xepersian[23] offers support for the Persian language. It supplies Persian LaTeX-commands that allows you to enter commands like `\section` in Persian, which makes this really attractive to native speakers. xepersian is the only package that supports kashida with XeLaTeX. A package for Syriac which uses a similar algorithm is under development.

The IranNastaliq font provided by the SCICT[5] is available at their website http://www.scict.ir/Portal/Home/Default.aspx.

The arabxetex[19] package supports several languages with an Arabic script:

- arab (Arabic)
- persian
- urdu
- sindhi
- pashto
- ottoman (turk)
- kurdish
- kashmiri
- malay (jawi)
- uighur

It offers a font mapping that enables XeLaTeX to process input using the ArabTeX ASCII transcription.

Fonts that support several Arabic laguages are offered by the IRMUG[6] at http://wiki.irmug.org/index.php/X_Series_2.

There is no package available for Hebrew because none is needed. The Hebrew support in polyglossia should be sufficient. But you do need a suitable font with real Unicode Hebrew. SBL Hebrew is free for non-commercial use and available at http://www.sbl-site.org/educational/biblicalfonts.aspx. Another font available under the Open Font License is Ezra SIL, available at http://www.sil.org/computing/catalog/show_software.asp?id=76.

Remember to select the correct script:

```
\newfontfamily\hebrewfont[Script=Hebrew]{SBL Hebrew}
\newfontfamily\hebrewfont[Script=Hebrew]{Ezra SIL}
```

[5] Supreme Council of Information and Communication Technology
[6] Iranian Mac User Group

Chinese, Japanese and Korean (CJK)

The package xeCJK[24] takes care of font selection and punctuation for these languages.

2.6 The Space Between Words

To get a straight right margin in the output, LaTeX inserts varying amounts of space between the words. It inserts slightly more space at the end of a sentence, as this makes the text more readable. LaTeX assumes that sentences end with periods, question marks or exclamation marks. If a period follows an uppercase letter, this is not taken as a sentence ending, since periods after uppercase letters normally occur in abbreviations.

Any exception from these assumptions has to be specified by the author. A backslash in front of a space generates a space that will not be enlarged. A tilde '~' character generates a space that cannot be enlarged and additionally prohibits a line break. The command `\@` in front of a period specifies that this period terminates a sentence even when it follows an uppercase letter.

```
Mr.~Smith was happy to see her\\
cf.~Fig.~5\\
I like BASIC\@. What about you?
```

Mr. Smith was happy to see her
cf. Fig. 5
I like BASIC. What about you?

The additional space after periods can be disabled with the command

```
\frenchspacing
```

which tells LaTeX *not* to insert more space after a period than after an ordinary character. This is very common in non-English languages, except bibliographies. If you use `\frenchspacing`, the command `\@` is not necessary.

2.7 Titles, Chapters, and Sections

To help the reader find his or her way through your work, you should divide it into chapters, sections, and subsections. LaTeX supports this with special commands that take the section title as their argument. It is up to you to use them in the correct order.

The following sectioning commands are available for the `article` class:

```
\section{...}
\subsection{...}
\subsubsection{...}
\paragraph{...}
\subparagraph{...}
```

If you want to split your document into parts without influencing the section or chapter numbering use

```
\part{...}
```

When you work with the `report` or `book` class, an additional top-level sectioning command becomes available

```
\chapter{...}
```

As the `article` class does not know about chapters, it is quite easy to add articles as chapters to a book. The spacing between sections, the numbering and the font size of the titles will be set automatically by LaTeX.

Two of the sectioning commands are a bit special:

- The `\part` command does not influence the numbering sequence of chapters.
- The `\appendix` command does not take an argument. It just changes the chapter numbering to letters.[7]

LaTeX creates a table of contents by taking the section headings and page numbers from the last compile cycle of the document. The command

```
\tableofcontents
```

expands to a table of contents at the place it is issued. A new document has to be compiled ("LaTeXed") twice to get a correct table of contents. Sometimes it might be necessary to compile the document a third time. LaTeX will tell you when this is necessary.

All sectioning commands listed above also exist as "starred" versions. A "starred" version of a command is built by adding a star `*` after the command name. This generates section headings that do not show up in the table of contents and are not numbered. The command `\section{Help}`, for example, would become `\section*{Help}`.

[7] For the article style it changes the section numbering.

Normally the section headings show up in the table of contents exactly as they are entered in the text. Sometimes this is not possible, because the heading is too long to fit into the table of contents. The entry for the table of contents can then be specified as an optional argument in front of the actual heading.

```
\chapter[Title for the table of contents]{A long
    and especially boring title, shown in the text}
```

The title of the whole document is generated by issuing a

`\maketitle`

command. The contents of the title have to be defined by the commands

`\title{...}`, `\author{...}` and optionally `\date{...}`

before calling `\maketitle`. In the argument to `\author`, you can supply several names separated by `\and` commands.

An example of some of the commands mentioned above can be found in Figure 1.2 on page 8.

Apart from the sectioning commands explained above, LaTeX 2$_\varepsilon$ introduced three additional commands for use with the `book` class. They are useful for dividing your publication. The commands alter chapter headings and page numbering to work as you would expect in a book:

`\frontmatter` should be the very first command after the start of the document body (`\begin{document}`). It will switch page numbering to Roman numerals and sections will be non-enumerated as if you were using the starred sectioning commands (eg `\chapter*{Preface}`) but the sections will still show up in the table of contents.

`\mainmatter` comes right before the first chapter of the book. It turns on Arabic page numbering and restarts the page counter.

`\appendix` marks the start of additional material in your book. After this command chapters will be numbered with letters.

`\backmatter` should be inserted before the very last items in your book, such as the bibliography and the index. In the standard document classes, this has no visual effect.

2.8 Cross References

In books, reports and articles, there are often cross-references to figures, tables and special segments of text. LaTeX provides the following commands for cross referencing

`\label{`*marker*`}`, `\ref{`*marker*`}` and `\pageref{`*marker*`}`

where *marker* is an identifier chosen by the user. LaTeX replaces `\ref` by the number of the section, subsection, figure, table, or theorem after which the corresponding `\label` command was issued. `\pageref` prints the page number of the page where the `\label` command occurred.[8] As with section titles and page numbers for the table of contents, the numbers from the previous compile cycle are used.

```
A reference to this subsection
\label{sec:this} looks like:
``see section~\ref{sec:this} on
page~\pageref{sec:this}.''
```

A reference to this subsection looks like: "see section 2.8 on page 30."

2.9 Footnotes

With the command

`\footnote{`*footnote text*`}`

a footnote is printed at the foot of the current page. Footnotes should always be put[9] after the word or sentence they refer to. Footnotes referring to a sentence or part of it should therefore be put after the comma or period.[10]

```
Footnotes\footnote{This is
  a footnote.} are often used
by people using \LaTeX.
```

Footnotes[a] are often used by people using LaTeX.

[a] This is a footnote.

[8] Note that these commands are not aware of what they refer to. `\label` just saves the last automatically generated number.

[9] "put" is one of the most common English words.

[10] Note that footnotes distract the reader from the main body of your document. After all, everybody reads the footnotes—we are a curious species, so why not just integrate everything you want to say into the body of the document?[11]

[11] A guidepost doesn't necessarily go where it's pointing to :-).

2.10 Emphasized Words

If a text is typed using a typewriter, important words are `emphasized by underlining them`.

`\underline{`*text*`}`

In printed books, however, words are emphasized by typesetting them in an *italic* font. As an author you shouldn't care either way. The important bit is, to tell LaTeX that a particular bit of text is important and should be emphasized. Hence the command

`\emph{`*text*`}`

to emphasize text. What the command actually does with its argument depends on the context:

```
\emph{If you use
  emphasizing inside a piece
  of emphasized text, then
  \LaTeX{} uses the
  \emph{normal} font for
  emphasizing.}
```

If you use emphasizing inside a piece of emphasized text, then LaTeX uses the normal *font for emphasizing.*

If you want control over font and font size, section 6.2 on page 107 might provide some inspiration.

2.11 Environments

`\begin{`*environment*`}` *text* `\end{`*environment*`}`

Where *environment* is the name of the environment. Environments can be nested within each other as long as the correct nesting order is maintained.

```
\begin{aaa}...\begin{bbb}...\end{bbb}...\end{aaa}
```

In the following sections all important environments are explained.

2.11.1 Itemize, Enumerate, and Description

The `itemize` environment is suitable for simple lists, the `enumerate` environment for enumerated lists, and the `description` environment for descriptions.

```
\flushleft
\begin{enumerate}
\item You can nest the list
environments to your taste:
\begin{itemize}
\item But it might start to
look silly.
\item[-] With a dash.
\end{itemize}
\item Therefore remember:
\begin{description}
\item[Stupid] things will not
become smart because they are
in a list.
\item[Smart] things, though,
can be presented beautifully
in a list.
\end{description}
\end{enumerate}
```

1. You can nest the list environments to your taste:
   - But it might start to look silly.
   - With a dash.
2. Therefore remember:

   Stupid things will not become smart because they are in a list.

   Smart things, though, can be presented beautifully in a list.

2.11.2 Flushleft, Flushright, and Center

The environments `flushleft` and `flushright` generate paragraphs that are either left- or right-aligned. The `center` environment generates centred text. If you do not issue \\ to specify line breaks, LaTeX will automatically determine line breaks.

```
\begin{flushleft}
This text is\\ left-aligned.
\LaTeX{} is not trying to make
each line the same length.
\end{flushleft}
```

This text is
left-aligned. LaTeX is not trying to make each line the same length.

```
\begin{flushright}
This text is right-\\aligned.
\LaTeX{} is not trying to make
each line the same length.
\end{flushright}
```

This text is right-
aligned. LaTeX is not trying to make each
line the same length.

```
\begin{center}
At the centre\\of the earth
\end{center}
```

At the centre
of the earth

2.11.3 Quote, Quotation, and Verse

The `quote` environment is useful for quotes, important phrases and examples.

```
A typographical rule of thumb
for the line length is:
\begin{quote}
On average, no line should
be longer than 66 characters.
\end{quote}
This is why \LaTeX{} pages have
such large borders by default
and also why multicolumn print
is used in newspapers.
```

A typographical rule of thumb for the line length is:

> On average, no line should be longer than 66 characters.

This is why LaTeX pages have such large borders by default and also why multicolumn print is used in newspapers.

There are two similar environments: the `quotation` and the `verse` environments. The `quotation` environment is useful for longer quotes going over several paragraphs, because it indents the first line of each paragraph. The `verse` environment is useful for poems where the line breaks are important. The lines are separated by issuing a `\\` at the end of a line and an empty line after each verse.

```
I know only one English poem by
heart. It is about Humpty Dumpty.
\begin{flushleft}
\begin{verse}
Humpty Dumpty sat on a wall:\\
Humpty Dumpty had a great fall.\\
All the King's horses and all
the King's men\\
Couldn't put Humpty together
again.
\end{verse}
\end{flushleft}
```

I know only one English poem by heart. It is about Humpty Dumpty.

> Humpty Dumpty sat on a wall:
> Humpty Dumpty had a great fall.
> All the King's horses and all the King's men
> Couldn't put Humpty together again.

2.11.4 Abstract

In scientific publications it is customary to start with an abstract which gives the reader a quick overview of what to expect. LaTeX provides the `abstract` environment for this purpose. Normally `abstract` is used in documents typeset with the article document class.

```
\begin{abstract}
The abstract abstract.
\end{abstract}
```

> The abstract abstract.

2.11.5 Printing Verbatim

Text that is enclosed between `\begin{verbatim}` and `\end{verbatim}` will be directly printed, as if typed on a typewriter, with all line breaks and spaces, without any LaTeX command being executed.

Within a paragraph, similar behavior can be accessed with

`\verb+`*text*`+`

The + is just an example of a delimiter character. Use any character except letters, * or space. Many LaTeX examples in this booklet are typeset with this command.

```
The \verb|\ldots| command \ldots

\begin{verbatim}
10 PRINT "HELLO WORLD ";
20 GOTO 10
\end{verbatim}
```

The \ldots command ...

```
10 PRINT "HELLO WORLD ";
20 GOTO 10
```

```
\begin{verbatim*}
the starred version of
the      verbatim
environment emphasizes
the spaces   in the text
\end{verbatim*}
```

```
the␣starred␣version␣of
the␣␣␣␣␣␣␣verbatim
environment␣emphasizes
the␣spaces␣␣␣␣in␣the␣text
```

The \verb command can be used in a similar fashion with a star:

```
\verb*|like   this :-) |
```

```
like␣␣␣␣this␣:-)␣
```

The verbatim environment and the \verb command may not be used within parameters of other commands.

2.11.6 Tabular

The tabular environment can be used to typeset beautiful tables with optional horizontal and vertical lines. LaTeX determines the width of the columns automatically.

The *table spec* argument of the

`\begin{tabular}[`*pos*`]{`*table spec*`}`

command defines the format of the table. Use an `l` for a column of left-aligned text, `r` for right-aligned text, and `c` for centred text; `p{`*width*`}`

for a column containing justified text with line breaks, and `|` for a vertical line.

If the text in a column is too wide for the page, LaTeX won't automatically wrap it. Using `p{width}` you can define a special type of column which will wrap-around the text as in a normal paragraph.

The *pos* argument specifies the vertical position of the table relative to the baseline of the surrounding text. Use one of the letters `t`, `b` and `c` to specify table alignment at the top, bottom or centre.

Within a `tabular` environment, `&` jumps to the next column, `\\` starts a new line and `\hline` inserts a horizontal line. Add partial lines by using `\cline{`*i*`-`*j*`}`, where *i* and *j* are the column numbers the line should extend over.

```
\begin{tabular}{|r|l|}
\hline
7C0 & hexadecimal \\
3700 & octal \\ \cline{2-2}
11111000000 & binary \\
\hline \hline
1984 & decimal \\
\hline
\end{tabular}
```

7C0	hexadecimal
3700	octal
11111000000	binary
1984	decimal

```
\begin{tabular}{|p{4.7cm}|}
\hline
Welcome to Boxy's paragraph.
We sincerely hope you'll
all enjoy the show.\\
\hline
\end{tabular}
```

Welcome to Boxy's paragraph. We sincerely hope you'll all enjoy the show.

The column separator can be specified with the `@{...}` construct. This command kills the inter-column space and replaces it with whatever is between the curly braces. One common use for this command is explained below in the decimal alignment problem. Another possible application is to suppress leading space in a table with `@{}`.

```
\begin{tabular}{@{} l @{}}
\hline
no leading space\\
\hline
\end{tabular}
```

no leading space

```
\begin{tabular}{l}
\hline
leading space left and right\\
\hline
\end{tabular}
```

leading space left and right

Since there is no built-in way to align numeric columns to a decimal point,[12] we can "cheat" and do it by using two columns: a right-aligned integer and a left-aligned fraction. The `@{.}` command in the `\begin{tabular}` line replaces the normal inter-column spacing with just a ".", giving the appearance of a single, decimal-point-justified column. Don't forget to replace the decimal point in your numbers with a column separator (`&`)! A column label can be placed above our numeric "column" by using the `\multicolumn` command.

```
\begin{tabular}{c r @{.} l}
Pi expression       &
\multicolumn{2}{c}{Value} \\
\hline
$\pi$               & 3&1416  \\
$\pi^{\pi}$         & 36&46   \\
$(\pi^{\pi})^{\pi}$ & 80662&7 \\
\end{tabular}
```

Pi expression	Value
π	3.1416
π^{π}	36.46
$(\pi^{\pi})^{\pi}$	80662.7

```
\begin{tabular}{|c|c|}
\hline
\multicolumn{2}{|c|}{Ene} \\
\hline
Mene & Muh! \\
\hline
\end{tabular}
```

Ene	
Mene	Muh!

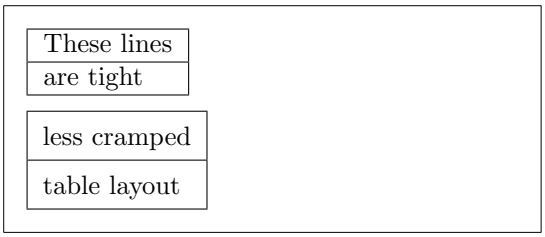
Material typeset with the tabular environment always stays together on one page. If you want to typeset long tables, you might want to use the longtable environments.

Sometimes the default LaTeX tables do feel a bit cramped. So you may want to give them a bit more breathing space by setting a higher `\arraystretch` and `\tabcolsep` value.

[12] If the 'tools' bundle is installed on your system, have a look at the dcolumn package.

```
\begin{tabular}{|l|}
\hline
These lines\\\hline
are tight\\\hline
\end{tabular}

{\renewcommand{\arraystretch}{1.5}
\renewcommand{\tabcolsep}{0.2cm}
\begin{tabular}{|l|}
\hline
less cramped\\\hline
table layout\\\hline
\end{tabular}}
```



If you just want to grow the height of a single row in your table add an invisible vertical bar[13]. Use a zero width `\rule` to implement this trick.

```
\begin{tabular}{|c|}
\hline
\rule{1pt}{4ex}Pitprop \ldots\\
\hline
\rule{0pt}{4ex}Strut\\
\hline
\end{tabular}
```

The `pt` and `ex` in the example above are TEX units. Read more on units in table 6.5 on page 114.

A number of extra commands, enhancing the tabular environment are available in the booktabs package. It makes the creation of professional looking tables with proper spacing quite a bit simpler.

2.12 Including Graphics and Images

As explained in the previous section LATEX provides the facilities to work with floating bodies, such as images or graphics, with the `figure` and `table` environments.

A good set of commands for inclusion of graphics into these floating boddies is provided in the graphicx package by D. P. Carlisle. It is part of a whole family of packages called the "graphics" bundle.[14]

Use the following step by step guide to include a picture into your document:

1. Export the picture from your graphics program in EPS, PDF, PNG or JPEG format.

[13] In professional typesetting, this is called a strut.

[14] CTAN://pkg/graphics

Table 2.3: Key Names for graphicx Package.

`width`	scale graphic to the specified width
`height`	scale graphic to the specified height
`angle`	rotate graphic counterclockwise
`scale`	scale graphic

```
\includegraphics[angle=90,width=\textwidth]{test.png}
```

Figure 2.2: Example code for including `test.png` into a document.

2. If you exported your graphics as an EPS vector graphics, you have to convert it to PDF format prior to using it. There is a `epstopdf` command line tool that helps with this task. Note that it may be sensible to export EPS eventhough your software can export PDF too, as PDFs often are full page and will this get very small when imported into a document. EPS on the other hand come with a bounding box showing the extent of the actual graphics.

3. Load the graphicx package in the preamble of the input file with

   `\usepackage{graphicx}`

4. Use the command

   `\includegraphics[`*key*=*value*, ...`]{`*file-name*`}`

   to include *file* into your document. The optional parameter accepts a comma separated list of *keys* and associated *values*. The *keys* can be used to alter the width, height and rotation of the included graphic. Table 2.3 lists the most important keys.

The example code in figure 2.2 on page 38 may help to clarify things. It includes the graphic stored in the file `test.png`. The graphic is *first* rotated by an angle of 90 degrees and *then* scaled to the final width of 0.5 times the width of a standard paragraph. The aspect ratio is 1.0, because no special height is specified. The width and height parameters can also be specified in absolute dimensions. Refer to Table 6.5 on page 114 for more information. If you want to know more about this topic, make sure to read [9].

2.13 Floating Bodies

Today most publications contain a lot of figures and tables. These elements need special treatment, because they cannot be broken across pages. One method would be to start a new page every time a figure or a table is too large to fit on the present page. This approach would leave pages partially empty, which looks very bad.

The solution to this problem is to 'float' any figure or table that does not fit on the current page to a later page, while filling the current page with body text. LaTeX offers two environments for floating bodies; one for tables and one for figures. To take full advantage of these two environments it is important to understand approximately how LaTeX handles floats internally. Otherwise floats may become a major source of frustration, because LaTeX never puts them where you want them to be.

Let's first have a look at the commands LaTeX supplies for floats:

Any material enclosed in a `figure` or `table` environment will be treated as floating matter. Both float environments support an optional parameter

`\begin{figure}[`*placement specifier*`]` or `\begin{table}[...]`

called the *placement specifier*. This parameter is used to tell LaTeX about the locations to which the float is allowed to be moved. A *placement specifier* is constructed by building a string of *float-placing permissions*. See Table 2.4.

For example, a table could be started with the following line

```
\begin{table}[!hbp]
```

The placement specifier `[!hbp]` allows LaTeX to place the table right here (`h`) or at the bottom (`b`) of some page or on a special floats page (`p`), and

Table 2.4: Float Placing Permissions.

Spec	Permission to place the float ...
`h`	*here* at the very place in the text where it occurred. This is useful mainly for small floats.
`t`	at the *top* of a page
`b`	at the *bottom* of a page
`p`	on a special *page* containing only floats.
`!`	without considering most of the internal parameters[a], which could otherwise stop this float from being placed.

[a] Such as the maximum number of floats allowed on one page.

all this even if it does not look that good (`!`). If no placement specifier is given, the standard classes assume `[tbp]`.

LaTeX will place every float it encounters according to the placement specifier supplied by the author. If a float cannot be placed on the current page it is deferred either to the *figures* queue or the *tables* queue.[15] When a new page is started, LaTeX first checks if it is possible to fill a special 'float' page with floats from the queues. If this is not possible, the first float on each queue is treated as if it had just occurred in the text: LaTeX tries again to place it according to its respective placement specifiers (except 'h,' which is no longer possible). Any new floats occurring in the text get placed into the appropriate queues. LaTeX strictly maintains the original order of appearance for each type of float. That's why a figure that cannot be placed pushes all further figures to the end of the document. Therefore:

> If LaTeX is not placing the floats as you expected, it is often only one float jamming one of the two float queues.

While it is possible to give LaTeX single-location placement specifiers, this causes problems. If the float does not fit in the location specified it becomes stuck, blocking subsequent floats. In particular, you should never, ever use the [h] option—it is so bad that in more recent versions of LaTeX, it is automatically replaced by [ht].

Having explained the difficult bit, there are some more things to mention about the `table` and `figure` environments. Use the

`\caption{`*caption text*`}`

command to define a caption for the float. A running number and the string "Figure" or "Table" will be added by LaTeX.

The two commands

`\listoffigures` and `\listoftables`

operate analogously to the `\tableofcontents` command, printing a list of figures or tables, respectively. These lists will display the whole caption, so if you tend to use long captions you must have a shorter version of the caption for the lists. This is accomplished by entering the short version in brackets after the `\caption` command.

```
\caption[Short]{LLLLLooooooonnnnnggggg}
```

[15] These are FIFO—'first in first out'—queues!

Use `\label` and `\ref` to create a reference to a float within your text. Note that the `\label` command must come *after* the `\caption` command since you want it to reference the number of the caption.

The following example draws a square and inserts it into the document. You could use this if you wanted to reserve space for images you are going to paste into the finished document.

```
Figure~\ref{white} is an example of Pop-Art.
\begin{figure}[!hbtp]
\includegraphics[angle=90,width=\textwidth]{white-box.pdf}
\caption{White Box by Peter Markus Paulian.\label{white}}
\end{figure}
```

In the example above, LaTeX will try *really hard* (`!`) to place the figure right *here* (`h`).[16] If this is not possible, it tries to place the figure at the *bottom* (`b`) of the page. Failing to place the figure on the current page, it determines whether it is possible to create a float page containing this figure and maybe some tables from the tables queue. If there is not enough material for a special float page, LaTeX starts a new page, and once more treats the figure as if it had just occurred in the text.

Under certain circumstances it might be necessary to use the

`\clearpage` or even the `\cleardoublepage`

command. It orders LaTeX to immediately place all floats remaining in the queues and then start a new page. `\cleardoublepage` even goes to a new right-hand page.

[16] assuming the figure queue is empty.

Chapter 3

Typesetting Mathematical Formulae

Now you are ready! In this chapter, we will attack the main strength of TEX: mathematical typesetting. But be warned, this chapter only scratches the surface. While the things explained here are sufficient for many people, don't despair if you can't find a solution to your mathematical typesetting needs here. It is highly likely that your problem is addressed in $\mathcal{AMS}$-LATEX.

3.1 The $\mathcal{AMS}$-LATEX bundle

If you want to typeset (advanced) mathematics, you should use $\mathcal{AMS}$-LATEX. The $\mathcal{AMS}$-LATEX bundle is a collection of packages and classes for mathematical typesetting. We will mostly deal with the amsmath package which is a part of the bundle. $\mathcal{AMS}$-LATEX is produced by The *American Mathematical Society* and it is used extensively for mathematical typesetting. LATEX itself does provide some basic features and environments for mathematics, but they are limited (or maybe it's the other way around: $\mathcal{AMS}$-LATEX is *unlimited*!) and in some cases inconsistent.

$\mathcal{AMS}$-LATEX is a part of the required distribution and is provided with all recent LATEX distributions.[1] In this chapter, we assume amsmath is loaded in the preamble; `\usepackage{amsmath}`.

3.2 Single Equations

A mathematical formula can be typeset in-line within a paragraph (*text style*), or the paragraph can be broken and the formula typeset separately (*display style*). Mathematical equations *within* a paragraph are entered between $ and $:

[1] If yours is missing it, go to CTAN://pkg/amslatex.

```
Add $a$ squared and $b$ squared
to get $c$ squared. Or, using
a more mathematical approach:
$a^2 + b^2 = c^2$
```

Add a squared and b squared to get c squared. Or, using a more mathematical approach: $a^2 + b^2 = c^2$

```
\TeX{} is pronounced as
$\tau\epsilon\chi$\\[5pt]
100~m$^{3}$ of water\\[5pt]
This comes from my $\heartsuit$
```

TEX is pronounced as $\tau\epsilon\chi$

100 m^3 of water

This comes from my ♡

If you want your larger equations to be set apart from the rest of the paragraph, it is preferable to *display* them rather than to break the paragraph apart. To do this, you enclose them between `\begin{equation}` and `\end{equation}`.[2] You can then `\label` an equation number and refer to it somewhere else in the text by using the `\eqref` command. If you want to name the equation something specific, you `\tag` it instead.

```
Add $a$ squared and $b$ squared
to get $c$ squared. Or, using
a more mathematical approach
 \begin{equation}
   a^2 + b^2 = c^2
 \end{equation}
Einstein says
 \begin{equation}
   E = mc^2 \label{clever}
 \end{equation}
He didn't say
 \begin{equation}
  1 + 1 = 3 \tag{dumb}
 \end{equation}
This is a reference to
\eqref{clever}.
```

Add a squared and b squared to get c squared. Or, using a more mathematical approach

$$a^2 + b^2 = c^2 \tag{3.1}$$

Einstein says

$$E = mc^2 \tag{3.2}$$

He didn't say

$$1 + 1 = 3 \tag{dumb}$$

This is a reference to (3.2).

If you don't want LATEX to number the equations, use the starred version of `equation` using an asterisk, `equation*`, or even easier, enclose the equation in `\[` and `\]`:[3]

[2] This is an amsmath command. If you don't have access to the package for some obscure reason, you can use LATEX's own `displaymath` environment instead.

[3] This is again from amsmath. Standard LATEX's has only the `equation` environment without the star.

```
Add $a$ squared and $b$ squared
to get $c$ squared. Or, using
a more mathematical approach
 \begin{equation*}
   a^2 + b^2 = c^2
 \end{equation*}
or you can type less for the
same effect:
 \[ a^2 + b^2 = c^2 \]
```

Add a squared and b squared to get c squared. Or, using a more mathematical approach

$$a^2 + b^2 = c^2$$

or you can type less for the same effect:

$$a^2 + b^2 = c^2$$

While `\[` is short and sweet, it does not allow switching between numbered and not numbered style as easily as `equation` and `equation*`.

Note the difference in typesetting style between text style and display style equations:

```
This is text style:
$\lim_{n \to \infty}
 \sum_{k=1}^n \frac{1}{k^2}
 = \frac{\pi^2}{6}$.
And this is display style:
 \begin{equation}
  \lim_{n \to \infty}
  \sum_{k=1}^n \frac{1}{k^2}
  = \frac{\pi^2}{6}
 \end{equation}
```

This is text style: $\lim_{n\to\infty} \sum_{k=1}^{n} \frac{1}{k^2} = \frac{\pi^2}{6}$. And this is display style:

$$\lim_{n\to\infty} \sum_{k=1}^{n} \frac{1}{k^2} = \frac{\pi^2}{6} \tag{3.3}$$

In text style, enclose tall or deep math expressions or sub expressions in `\smash`. This makes LaTeX ignore the height of these expressions. This keeps the line spacing even.

```
A $d_{e_{e_p}}$ mathematical
expression  followed by a
$h^{i^{g^h}}$ expression. As
opposed to a smashed
\smash{$d_{e_{e_p}}$} expression
followed by a
\smash{$h^{i^{g^h}}$} expression.
```

A $d_{e_{e_p}}$ mathematical expression followed by a $h^{i^{g^h}}$ expression. As opposed to a smashed $d_{e_{e_p}}$ expression followed by a $h^{i^{g^h}}$ expression.

3.2.1 Math Mode

There are also differences between *math mode* and *text mode*. For example, in *math mode*:

1. Most spaces and line breaks do not have any significance, as all spaces are either derived logically from the mathematical expressions, or have to be specified with special commands such as `\,`, `\quad` or `\qquad` (we'll get back to that later, see section 3.7).

2. Empty lines are not allowed. Only one paragraph per formula.

3. Each letter is considered to be the name of a variable and will be typeset as such. If you want to typeset normal text within a formula (normal upright font and normal spacing) then you have to enter the text using the `\text{...}` command (see also section 3.8 on page 60).

```
$\forall x \in \mathbf{R}:
 \qquad x^{2} \geq 0$
```

$\forall x \in \mathbf{R}: \qquad x^2 \geq 0$

```
$x^{2} \geq 0\qquad
 \text{for all }x\in\mathbf{R}$
```

$x^2 \geq 0 \qquad \text{for all } x \in \mathbf{R}$

Mathematicians can be very fussy about which symbols are used: it would be conventional here to use the 'blackboard bold' font, which is obtained using `\mathbb` from the package amssymb.[4] The last example becomes

```
$x^{2} \geq 0\qquad
 \text{for all } x
 \in \mathbb{R}$
```

$x^2 \geq 0 \qquad \text{for all } x \in \mathbb{R}$

See Table 3.14 on page 69 and Table 6.4 on page 109 for more math fonts.

3.3 Building Blocks of a Mathematical Formula

In this section, we describe the most important commands used in mathematical typesetting. Most of the commands in this section will not require amsmath (if they do, it will be stated clearly), but load it anyway.

Lowercase Greek letters are entered as `\alpha`, `\beta`, `\gamma`, ..., uppercase letters are entered as `\Gamma`, `\Delta`, ...[5]

Take a look at Table 3.2 on page 65 for a list of Greek letters.

```
$\lambda,\xi,\pi,\theta,
 \mu,\Phi,\Omega,\Delta$
```

$\lambda, \xi, \pi, \theta, \mu, \Phi, \Omega, \Delta$

Exponents, Superscripts and Subscripts can be specified using the `^` and the `_` characters. Most math mode commands act only on the next

[4] amssymb is not a part of the $\mathcal{AMS}$-LaTeX bundle, but it is perhaps still a part of your LaTeX distribution. Check your distribution or go to `CTAN:/fonts/amsfonts/latex/` to obtain it.

[5] There is no uppercase Alpha, Beta etc. defined in LaTeX 2_ε because it looks the same as a normal roman A, B...

character, so if you want a command to affect several characters, you have to group them together using curly braces: `{...}`.

Table 3.3 on page 66 lists a lot of binary relations like $\subseteq$ and $\perp$.

```
$p^3_{ij} \qquad
 m_\text{Knuth}\qquad
\sum_{k=1}^3 k \\[5pt]
 a^x+y \neq a^{x+y}\qquad
 e^{x^2} \neq {e^x}^2$
```

$$p_{ij}^3 \qquad m_{\text{Knuth}} \qquad \sum_{k=1}^3 k$$
$$a^x + y \neq a^{x+y} \qquad e^{x^2} \neq e^{x^2}$$

The **square root** is entered as `\sqrt`; the n^{th} root is generated with `\sqrt[`n`]`. The size of the root sign is determined automatically by LaTeX. If just the sign is needed, use `\surd`.

See various kinds of arrows like $\hookrightarrow$ and $\rightleftharpoons$ on Table 3.6 on page 67.

```
$\sqrt{x} \Leftrightarrow x^{1/2}
 \quad \sqrt[3]{2}
 \quad \sqrt{x^{2} + \sqrt{y}}
 \quad \surd[x^2 + y^2]$
```

$$\sqrt{x} \Leftrightarrow x^{1/2} \quad \sqrt[3]{2} \quad \sqrt{x^2 + \sqrt{y}} \quad \surd[x^2+y^2]$$

While the **dot** sign to indicate the multiplication operation is normally left out, it is sometimes written to help the eye in grouping a formula. Use `\cdot` to typeset a single centered dot. `\cdots` is three centered **dots** while `\ldots` sets the dots low (on the baseline). Besides that, there are `\vdots` for vertical and `\ddots` for diagonal dots. There are more examples in section 3.6.

```
$\Psi = v_1 \cdot v_2
 \cdot \ldots \qquad
 n! = 1 \cdot 2
 \cdots (n-1) \cdot n$
```

$$\Psi = v_1 \cdot v_2 \cdot \ldots \qquad n! = 1 \cdot 2 \cdots (n-1) \cdot n$$

The commands `\overline` and `\underline` create **horizontal lines** directly over or under an expression:

```
$0.\overline{3} =
 \underline{\underline{1/3}}$
```

$$0.\overline{3} = \underline{\underline{1/3}}$$

The commands `\overbrace` and `\underbrace` create long **horizontal braces** over or under an expression:

```
$\underbrace{\overbrace{a+b+c}^6
 \cdot \overbrace{d+e+f}^7}
 _\text{meaning of life} = 42$
```

$$\underbrace{\overbrace{a+b+c}^{6} \cdot \overbrace{d+e+f}^{7}}_{\text{meaning of life}} = 42$$

To add mathematical accents such as **small arrows** or **tilde** signs to variables, the commands given in Table 3.1 on page 65 might be useful. Wide hats and tildes covering several characters are generated with `\widetilde` and `\widehat`. Notice the difference between `\hat` and `\widehat` and the placement of `\bar` for a variable with subscript. The apostrophe mark `'` gives a prime:

```
$f(x) = x^2 \qquad f'(x)
 = 2x \qquad f''(x) = 2\\[5pt]
 \hat{XY} \quad \widehat{XY}
 \quad \bar{x_0} \quad \bar{x}_0$
```

$f(x) = x^2 \qquad f'(x) = 2x \qquad f''(x) = 2$
$\hat{XY} \quad \widehat{XY} \quad \bar{x_0} \quad \bar{x}_0$

Vectors are often specified by adding small arrow symbols on the tops of variables. This is done with the `\vec` command. The two commands `\overrightarrow` and `\overleftarrow` are useful to denote the vector from A to B:

```
$\vec{a} \qquad
 \vec{AB} \qquad
 \overrightarrow{AB}$
```

$\vec{a} \qquad \vec{AB} \qquad \overrightarrow{AB}$

Names of functions are often typeset in an upright font, and not in italics as variables are, so LaTeX supplies the following commands to typeset the most common function names:

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

```
\begin{equation*}
  \lim_{x \rightarrow 0}
  \frac{\sin x}{x}=1
\end{equation*}
```

$$\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1$$

For functions missing from the list, use the `\DeclareMathOperator` command. There is even a starred version for functions with limits. This command works only in the preamble so the commented lines in the example below must be put into the preamble.

```
%\DeclareMathOperator{\argh}{argh}
%\DeclareMathOperator*{\nut}{Nut}
\begin{equation*}
  3\argh = 2\nut_{x=1}
\end{equation*}
```

$$3 \operatorname{argh} = 2 \operatorname*{Nut}_{x=1}$$

For the modulo function, there are two commands: `\bmod` for the binary operator "a mod b" and `\pmod` for expressions such as "$x \equiv a \pmod{b}$:"

```
$a\bmod b \\
 x\equiv a \pmod{b}$
```

$a \bmod b$
$x \equiv a \pmod{b}$

A built-up **fraction** is typeset with the `\frac{...}{...}` command. In in-line equations, the fraction is shrunk to fit the line. This style is obtainable in display style with `\tfrac`. The reverse, i.e. display style fraction in text, is made with `\dfrac`. Often the slashed form 1/2 is preferable, because it looks better for small amounts of 'fraction material:'

```
In display style:
\begin{equation*}
  3/8 \qquad \frac{3}{8}
  \qquad \tfrac{3}{8}
\end{equation*}
```

In display style:

$$3/8 \qquad \frac{3}{8} \qquad \tfrac{3}{8}$$

```
In text style:
$1\frac{1}{2}$~hours \qquad
$1\dfrac{1}{2}$~hours
```

In text style: $1\frac{1}{2}$ hours $1\dfrac{1}{2}$ hours

Here the `\partial` command for partial derivatives is used:

```
\begin{equation*}
  \sqrt{\frac{x^2}{k+1}}\qquad
  x^\frac{2}{k+1}\qquad
  \frac{\partial^2f}
  {\partial x^2}
\end{equation*}
```

$$\sqrt{\frac{x^2}{k+1}} \qquad x^{\frac{2}{k+1}} \qquad \frac{\partial^2 f}{\partial x^2}$$

To typeset binomial coefficients or similar structures, use the command `\binom` from amsmath:

```
Pascal's rule is
\begin{equation*}
 \binom{n}{k} =\binom{n-1}{k}
 + \binom{n-1}{k-1}
\end{equation*}
```

Pascal's rule is

$$\binom{n}{k} = \binom{n-1}{k} + \binom{n-1}{k-1}$$

For binary relations it may be useful to stack symbols over each other. `\stackrel{#1}{#2}` puts the symbol given in `#1` in superscript-like size over `#2` which is set in its usual position.

```
\begin{equation*}
 f_n(x) \stackrel{*}{\approx} 1
\end{equation*}
```

$$f_n(x) \stackrel{*}{\approx} 1$$

The **integral operator** is generated with `\int`, the **sum operator** with `\sum`, and the **product operator** with `\prod`. The upper and lower limits are specified with `^` and `_` like superscripts and subscripts:

```
\begin{equation*}
\sum_{i=1}^n \qquad
\int_0^{\frac{\pi}{2}} \qquad
\prod_\epsilon
\end{equation*}
```

$$\sum_{i=1}^{n} \qquad \int_{0}^{\frac{\pi}{2}} \qquad \prod_{\epsilon}$$

To get more control over the placement of indices in complex expressions, amsmath provides the `\substack` command:

```
\begin{equation*}
\sum^n_{\substack{0<i<n \\
        j\subseteq i}}
   P(i,j) = Q(i,j)
\end{equation*}
```

$$\sum^{n}_{\substack{0<i<n \\ j\subseteq i}} P(i,j) = Q(i,j)$$

LaTeX provides all sorts of symbols for **bracketing** and other **delimiters** (e.g. [⟨ ‖ ↕). Round and square brackets can be entered with the corresponding keys and curly braces with `\{`, but all other delimiters are generated with special commands (e.g. `\updownarrow`).

```
\begin{equation*}
{a,b,c} \neq \{a,b,c\}
\end{equation*}
```

$$\{a,b,c\} \neq \{a,b,c\}$$

If you put `\left` in front of an opening delimiter and `\right` in front of a closing delimiter, LaTeX will automatically determine the correct size of the delimiter. Note that you must close every `\left` with a corresponding `\right`. If you don't want anything on the right, use the invisible "`\right.`":

```
\begin{equation*}
1 + \left(\frac{1}{1-x^{2}}
    \right)^3 \qquad
\left. \ddagger \frac{~}{~}\right)
\end{equation*}
```

$$1 + \left(\frac{1}{1-x^{2}}\right)^{3} \qquad \left.\ddagger \frac{~}{~}\right)$$

In some cases it is necessary to specify the correct size of a mathematical delimiter by hand, which can be done using the commands `\big`, `\Big`, `\bigg` and `\Bigg` as prefixes to most delimiter commands:

```
$\Big((x+1)(x-1)\Big)^{2}$\\
$\big( \Big( \bigg( \Bigg( \quad
\big\} \Big\} \bigg\} \Bigg\} \quad
\big\| \Big\| \bigg\| \Bigg\| \quad
\big\Downarrow \Big\Downarrow
\bigg\Downarrow \Bigg\Downarrow$
```

$$\Big((x+1)(x-1)\Big)^{2}$$

$$\big(\Big(\bigg(\Bigg(\quad \big\} \Big\} \bigg\} \Bigg\} \quad \big\| \Big\| \bigg\| \Bigg\| \quad \big\Downarrow \Big\Downarrow \bigg\Downarrow \Bigg\Downarrow$$

For a list of all delimiters available, see Table 3.8 on page 68.

3.4 Single Equations that are Too Long: multline

If an equation is too long, we have to wrap it somehow. Unfortunately, wrapped equations are usually less easy to read than not wrapped ones. To improve the readability, there are certain rules on how to do the wrapping:

1. In general one should always wrap an equation **before** an equality sign or an operator.
2. A wrap before an equality sign is preferable to a wrap before any operator.
3. A wrap before a plus- or minus-operator is preferable to a wrap before a multiplication-operator.
4. Any other type of wrap should be avoided if at all possible.

The easiest way to achieve such a wrapping is the use of the `multline` environment:[6]

```
\begin{multline}
  a + b + c + d + e + f
  + g + h + i
  \\
  = j + k + l + m + n
\end{multline}
```

$$a+b+c+d+e+f+g+h+i \\ = j+k+l+m+n \quad (3.4)$$

The difference from the `equation` environment is that an arbitrary line-break (or also multiple line-breaks) can be introduced. This is done by putting a \\ on those places where the equation needs to be wrapped. Similarly to `equation*` there also exists a `multline*` version for preventing an equation number.

Often the `IEEEeqnarray` environment (see section 3.5) will yield better results. Consider the following situation:

```
\begin{equation}
  a = b + c + d + e + f
  + g + h + i + j
  + k + l + m + n + o + p
  \label{eq:equation_too_long}
\end{equation}
```

$$a = b+c+d+e+f+g+h+i+j+k+l+m+n+o+p \quad (3.5)$$

[6] The `multline`-environment is from `amsmath`.

Here it is actually the RHS that is too long to fit on one line. The `multline` environment creates the following output:

```
\begin{multline}
  a = b + c + d + e + f
  + g + h + i + j \\
  + k + l + m + n + o + p
\end{multline}
```

$$a = b + c + d + e + f + g + h + i + j + k + l + m + n + o + p \quad (3.6)$$

This is better than (3.5), but it has the disadvantage that the equality sign loses its natural greater importance with respect to the plus operator in front of k. The better solution is provided by the `IEEEeqnarray` environment that will be discussed in detail in Section 3.5.

3.5 Multiple Equations

In the most general situation we have a sequence of several equalities that do not fit onto one line. Here we need to work with vertical alignment in order to keep the array of equations in a nice and readable structure.

Before we offer our suggestions on how to do this, we start with a few bad examples that show the biggest drawbacks of some common solutions.

3.5.1 Problems with Traditional Commands

To group multiple equations the `align` environment[7] could be used:

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

$$a = b + c \quad (3.7)$$
$$= d + e \quad (3.8)$$

this approach fails once a single line is too long:

```
\begin{align}
  a &= b + c \\
  &= d + e + f + g + h + i
  + j + k + l \nonumber \\
  &+ m + n + o \\
  &= p + q + r + s
\end{align}
```

$$a = b + c \quad (3.9)$$
$$= d + e + f + g + h + i + j + k + l$$
$$+ m + n + o \quad (3.10)$$
$$= p + q + r + s \quad (3.11)$$

[7] The `align`-environment can also be used to group several blocks of equations beside each other. Another excellent use case for the `IEEEeqnarray` environment. Try an argument like `{rCl+rCl}`.

Here $+\,m$ should be below d and not below the equality sign. A TEXpert will point out that `\mathrel{\phantom{=}} \negmedspace {}`, would add the necessary space in front of `+m+n+o`, but since most users lack that kind of imagination, a simpler solution would be nice.

This is the moment where the `eqnarray` environment bursts onto the scene:

```
\begin{eqnarray}
  a & = & b + c \\
  & = & d + e + f + g + h + i
  + j + k + l \nonumber \\
  && +\: m + n + o \\
  & = & p + q + r + s
\end{eqnarray}
```

$$\begin{aligned} a &= b+c && (3.12)\\ &= d+e+f+g+h+i+j+k+l \\ &\quad +m+n+o && (3.13)\\ &= p+q+r+s && (3.14) \end{aligned}$$

It is better but still not optimal. The spaces around the equality signs are too big. Particularly, they are **not** the same as in the `multline` and `equation` environments:

```
\begin{eqnarray}
  a & = & a = a
\end{eqnarray}
```

$$a = a = a \qquad (3.15)$$

...and the expression sometimes overlaps with the equation number even though there would be enough room on the left:

```
\begin{eqnarray}
  a & = & b + c
  \\
  & = & d + e + f + g + h^2
  + i^2 + j
  \label{eq:faultyeqnarray}
\end{eqnarray}
```

$$\begin{aligned} a &= b+c && (3.16)\\ &= d+e+f+g+h^2+i^2+j && (3.17) \end{aligned}$$

While the environment offers a command `\lefteqn` that can be used when the LHS is too long:

```
\begin{eqnarray}
  \lefteqn{a + b + c + d
    + e + f + g + h}\nonumber\\
  & = & i + j + k + l + m
  \\
  & = & n + o + p + q + r + s
\end{eqnarray}
```

$$\begin{aligned} &a+b+c+d+e+f+g+h \\ &\quad = i+j+k+l+m && (3.18)\\ &\quad = n+o+p+q+r+s && (3.19) \end{aligned}$$

This is not optimal either as the RHS is too short and the array is not properly centered:

```
\begin{eqnarray}
  \lefteqn{a + b + c + d
    + e + f + g + h}
  \nonumber \\
  & = & i + j
\end{eqnarray}
```

$$\begin{aligned} a+b+c+d+e+f+g+h \\ = \quad i+j \end{aligned} \tag{3.20}$$

Having badmouthed the competition sufficiently, I can now steer you gently towards the glorious ...

3.5.2 IEEEeqnarray Environment

The `IEEEeqnarray` environment is a very powerful command with many options. Here, we will only introduce its basic functionalities. For more information please refer to the manual.[8]

First of all, in order to be able to use the `IEEEeqnarray` environment one needs to load the package[9] IEEEtrantools. Include the following line in the header of your document:

```
\usepackage{IEEEtrantools}
```

The strength of `IEEEeqnarray` is the ability to specify the number of *columns* in the equation array. Usually, this specification will be `{rCl}`, *i.e.*, three columns, the first column right-justified, the middle one centered with a little more space around it (therefore we specify capital `C` instead of lower-case `c`) and the third column left-justified:

```
\begin{IEEEeqnarray}{rCl}
  a & = & b + c
  \\
  & = & d + e + f + g + h
  + i + j + k \nonumber\\
  && \negmedspace {} + l + m + n + o
  \\
  & = & p + q + r + s
\end{IEEEeqnarray}
```

$$a = b + c \tag{3.21}$$
$$= d + e + f + g + h + i + j + k + l + m + n + o \tag{3.22}$$
$$= p + q + r + s \tag{3.23}$$

Any number of columns can be specified: `{c}` will give only one column with all entries centered, or `{rCll}` would add a fourth, left-justified column to use for comments. Moreover, beside `l`, `c`, `r`, `L`, `C`, `R` for math mode entries there are also `s`, `t`, `u` for left, centered, and right text mode entries. Additional space can be added with `.` and `/` and `?` in increasing order.[10] Note the spaces around the equality signs in contrast to the space produced by the `eqnarray` environment.

[8] The official manual is called CTAN://macros/latex/contrib/IEEEtran/IEEEtran_HOWTO.pdf. The part about `IEEEeqnarray` can be found in Appendix F.

[9] The IEEEtrantools package may not be included in your setup, it can be found on CTAN.

[10] For more spacing types refer to Section 3.9.1.

3.5.3 Common Usage

In the following we will describe how we use `IEEEeqnarray` to solve the most common problems.

If a line overlaps with the equation number as in (3.17), the command

```
\IEEEeqnarraynumspace
```

can be used: it has to be added in the corresponding line and makes sure that the whole equation array is shifted by the size of the equation numbers (the shift depends on the size of the number!): instead of

```
\begin{IEEEeqnarray}{rCl}
  a & = & b + c
  \\
  & = & d + e + f + g + h
  + i + j + k
  \\
  & = & l + m + n
\end{IEEEeqnarray}
```

$$\begin{aligned} a &= b + c && (3.24)\\ &= d + e + f + g + h + i + j + k && (3.25)\\ &= l + m + n && (3.26) \end{aligned}$$

we get

```
\begin{IEEEeqnarray}{rCl}
  a & = & b + c
  \\
  & = & d + e + f + g + h
  + i + j + k
  \IEEEeqnarraynumspace\\
  & = & l + m + n.
\end{IEEEeqnarray}
```

$$\begin{aligned} a &= b + c && (3.27)\\ &= d + e + f + g + h + i + j + k && (3.28)\\ &= l + m + n. && (3.29) \end{aligned}$$

If the LHS is too long, as a replacement for the faulty `\lefteqn` command, `IEEEeqnarray` offers the `\IEEEeqnarraymulticol` command which works in all situations:

```
\begin{IEEEeqnarray}{rCl}
  \IEEEeqnarraymulticol{3}{l}{
    a + b + c + d + e + f
    + g + h
  }\nonumber\\ \quad
  & = & i + j
  \\
  & = & k + l + m
\end{IEEEeqnarray}
```

$$\begin{aligned} &a + b + c + d + e + f + g + h \\ &\quad = i + j && (3.30)\\ &\quad = k + l + m && (3.31) \end{aligned}$$

The usage is identical to the `\multicolumns` command in the `tabular`-environment. The first argument `{3}` specifies that three columns shall be combined into one which will be left-justified `{l}`.

Note that by inserting `\quad` commands one can easily adapt the depth of the equation signs,[11] *e.g.*,

```
\begin{IEEEeqnarray}{rCl}
  \IEEEeqnarraymulticol{3}{l}{
    a + b + c + d + e + f
    + g + h
  }\nonumber\\ \qquad\qquad
  & = & i + j
  \\
  & = & k + l + m
\end{IEEEeqnarray}
```

$$a+b+c+d+e+f+g+h$$
$$= i+j \tag{3.32}$$
$$= k+l+m \tag{3.33}$$

If an equation is split into two or more lines, LaTeX interprets the first + or − as a sign instead of operator. Therefore, it is necessary to add an empty group `{}` before the operator: instead of

```
\begin{IEEEeqnarray}{rCl}
  a & = & b + c
  \\
  & = & d + e + f + g + h
  + i + j + k \nonumber\\
  && + l + m + n + o
  \\
  & = & p + q + r + s
\end{IEEEeqnarray}
```

$$a = b+c \tag{3.34}$$
$$= d+e+f+g+h+i+j+k$$
$$\quad +l+m+n+o \tag{3.35}$$
$$= p+q+r+s \tag{3.36}$$

we should write

```
\begin{IEEEeqnarray}{rCl}
  a & = & b + c
  \\
  & = & d + e + f + g + h
  + i + j + k \nonumber\\
  && \negmedspace {} + l + m + n + o
  \\
  & = & p + q + r + s
\end{IEEEeqnarray}
```

$$a = b+c \tag{3.37}$$
$$= d+e+f+g+h+i+j+k$$
$$\quad +l+m+n+o \tag{3.38}$$
$$= p+q+r+s \tag{3.39}$$

Note the space difference between + and l! The construction `{} + l` forces the +-sign to be an operator rather than just a sign, and the unwanted ensuing space between `{}` and + is compensated by a negative medium space `\negmedspace`.

If a particular line should not have an equation number, the number can be suppressed using `\nonumber` (or `\IEEEnonumber`). If on such a line a label `\label{eq:...}` is defined, then this label is passed on to the next

[11] I think that one quad is the distance that looks good for most cases.

equation number that is not suppressed. Place the labels right before the line-break \\ or the next to the equation it belongs to. Apart from improving the readability of the source code this prevents a compilation error when a `\IEEEmulticol` command follows the label-definition.

There also exists a *-version where all equation numbers are suppressed. In this case an equation number can be made to appear using the command `\IEEEyesnumber`:

```
\begin{IEEEeqnarray*}{rCl}
  a & = & b + c \\
  & = & d + e \IEEEyesnumber\\
  & = & f + g
\end{IEEEeqnarray*}
```

$$\begin{aligned} a &= b + c \\ &= d + e \\ &= f + g \end{aligned} \tag{3.40}$$

Sub-numbers are also easily possible using `\IEEEyessubnumber`:

```
\begin{IEEEeqnarray}{rCl}
  a & = & b + c
  \IEEEyessubnumber\\
  & = & d + e
  \nonumber\\
  & = & f + g
  \IEEEyessubnumber
\end{IEEEeqnarray}
```

$$\begin{aligned} a &= b + c && \text{(3.40a)} \\ &= d + e \\ &= f + g && \text{(3.40b)} \end{aligned}$$

3.6 Arrays and Matrices

To typeset **arrays**, use the `array` environment. It works in a similar way to the `tabular` environment. The \\ command is used to break the lines:

```
\begin{equation*}
  \mathbf{X} = \left(
    \begin{array}{ccc}
      x_1 & x_2 & \ldots \\
      x_3 & x_4 & \ldots \\
      \vdots & \vdots & \ddots
    \end{array} \right)
\end{equation*}
```

$$\mathbf{X} = \left(\begin{array}{ccc} x_1 & x_2 & \ldots \\ x_3 & x_4 & \ldots \\ \vdots & \vdots & \ddots \end{array} \right)$$

The `array` environment can also be used to typeset piecewise functions by using a "." as an invisible `\right` delimiter:

```
\begin{equation*}
  |x| = \left\{
    \begin{array}{rl}
      -x & \text{if } x < 0,\\
      0 & \text{if } x = 0,\\
      x & \text{if } x > 0.
    \end{array} \right.
\end{equation*}
```

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

The `cases` environment from amsmath simplifies the syntax, so it is worth a look:

```
  \begin{equation*}
    |x| =
    \begin{cases}
      -x & \text{if } x < 0,\\
      0 & \text{if } x = 0,\\
      x & \text{if } x > 0.
    \end{cases}
\end{equation*}
```

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

Matrices can be typeset by `array`, but amsmath provides a better solution using the different `matrix` environments. There are six versions with different delimiters: `matrix` (none), `pmatrix` (, `bmatrix` [, `Bmatrix` {, `vmatrix` | and `Vmatrix` ‖. You don't have to specify the number of columns as with `array`. The maximum number is 10, but it is customisable (though it is not very often you need 10 columns!):

```
\begin{equation*}
  \begin{matrix}
    1 & 2 \\
    3 & 4
  \end{matrix} \qquad
  \begin{bmatrix}
    p_{11} & p_{12} & \ldots
    & p_{1n} \\
    p_{21} & p_{22} & \ldots
    & p_{2n} \\
    \vdots & \vdots & \ddots
    & \vdots \\
    p_{m1} & p_{m2} & \ldots
    & p_{mn}
  \end{bmatrix}
\end{equation*}
```

$$\begin{matrix} 1 & 2 \\ 3 & 4 \end{matrix} \qquad \begin{bmatrix} p_{11} & p_{12} & \ldots & p_{1n} \\ p_{21} & p_{22} & \ldots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \ldots & p_{mn} \end{bmatrix}$$

3.7 Spacing in Math Mode

If the spacing within formulae chosen by LaTeX is not satisfactory, it can be adjusted by inserting special spacing commands: `\,` for $\frac{3}{18}$ quad (␣), `\:` for $\frac{4}{18}$ quad (␣) and `\;` for $\frac{5}{18}$ quad (␣). The escaped space character `\␣` generates a medium sized space comparable to the interword spacing and `\quad` (␣) and `\qquad` (␣) produce large spaces. The size of a `\quad` corresponds to the width of the character 'M' of the current font. `\!` produces a negative space of $-\frac{3}{18}$ quad ($-$␣).

```
\begin{equation*}
  \int_1^2 \ln x \mathrm{d}x
  \qquad
  \int_1^2 \ln x \,\mathrm{d}x
\end{equation*}
```

$$\int_1^2 \ln x \mathrm{d}x \qquad \int_1^2 \ln x \,\mathrm{d}x$$

Note that 'd' in the differential is conventionally set in roman. In the next example, we define a new command `\ud` (upright d) which produces "d" (notice the spacing ␣ before the d), so we don't have to write it every time. The `\newcommand` is placed in the preamble.

```
\newcommand{\ud}{\,\mathrm{d}}

\begin{equation*}
 \int_a^b f(x)\ud x
\end{equation*}
```

$$\int_a^b f(x)\,\mathrm{d}x$$

If you want to typeset multiple integrals, you'll discover that the spacing between the integrals is too wide. You can correct it using `\!`, but ams-math provides an easier way for fine-tuning the spacing, namely the `\iint`, `\iiint`, `\iiiint`, and `\idotsint` commands.

```
\newcommand{\ud}{\,\mathrm{d}}

\begin{IEEEeqnarray*}{c}
  \int\int f(x)g(y)
                  \ud x \ud y \\
  \int\!\!\!\int
         f(x)g(y) \ud x \ud y \\
  \iint f(x)g(y)  \ud x \ud y
\end{IEEEeqnarray*}
```

$$\int\int f(x)g(y)\,\mathrm{d}x\,\mathrm{d}y$$
$$\iint f(x)g(y)\,\mathrm{d}x\,\mathrm{d}y$$
$$\iint f(x)g(y)\,\mathrm{d}x\,\mathrm{d}y$$

See the electronic document `testmath.tex` (distributed with $\mathcal{AMS}$-LaTeX) or Chapter 8 of *The LaTeX Companion* [3] for further details.

3.7.1 Phantoms

When vertically aligning text using ^ and _ LaTeX is sometimes just a little too helpful. Using the `\phantom` command you can reserve space for characters that do not show up in the final output. The easiest way to understand this is to look at an example:

```
\begin{equation*}
{}^{14}_{6}\text{C}
\qquad \text{versus} \qquad
{}^{14}_{\phantom{1}6}\text{C}
\end{equation*}
```

$$ {}^{14}_{6}\text{C} \qquad \text{versus} \qquad {}^{14}_{6}\text{C} $$

If you want to typeset a lot of isotopes as in the example, the mhchem package is very useful for typesetting isotopes and chemical formulae too.

3.8 Fiddling with the Math Fonts

Different math fonts are listed on Table 3.14 on page 69.

```
$\Re \qquad
 \mathcal{R} \qquad
 \mathfrak{R} \qquad
 \mathbb{R} \qquad $
```

$$ \Re \qquad \mathcal{R} \qquad \mathfrak{R} \qquad \mathbb{R} \qquad $$

The last two require amssymb or amsfonts.

Sometimes you need to tell LaTeX the correct font size. In math mode, this is set with the following four commands:

`\displaystyle` (123), `\textstyle` (123), `\scriptstyle` (123) and `\scriptscriptstyle` (123).

If $\sum$ is placed in a fraction, it'll be typeset in text style unless you tell LaTeX otherwise:

```
\begin{equation*}
 P = \frac{\displaystyle{
   \sum_{i=1}^n (x_i- x)
   (y_i- y)}}
   {\displaystyle{\left[
   \sum_{i=1}^n(x_i-x)^2
   \sum_{i=1}^n(y_i- y)^2
   \right]^{1/2}}}
\end{equation*}
```

$$ P = \frac{\displaystyle\sum_{i=1}^{n}(x_i - x)(y_i - y)}{\displaystyle\left[\sum_{i=1}^{n}(x_i - x)^2 \sum_{i=1}^{n}(y_i - y)^2\right]^{1/2}} $$

Changing styles generally affects the way big operators and limits are displayed.

3.8.1 Bold Symbols

It is quite difficult to get bold symbols in LaTeX; this is probably intentional as amateur typesetters tend to overuse them. The font change command `\mathbf` gives bold letters, but these are roman (upright) whereas mathematical symbols are normally italic, and furthermore it doesn't work on lower case Greek letters. There is a `\boldmath` command, but *this can only be used outside math mode*. It works for symbols too, though:

```
$\mu, M \qquad
\mathbf{\mu}, \mathbf{M}$
\qquad \boldmath{$\mu, M$}
```

μ, M $\mu, \mathbf{M}$ $\boldsymbol{\mu, M}$

The package amsbsy (included by amsmath) as well as the package bm from the `tools` bundle make this much easier as they include a `\boldsymbol` command:

```
$\mu, M \qquad
\boldsymbol{\mu}, \boldsymbol{M}$
```

μ, M $\boldsymbol{\mu, M}$

3.9 Theorems, Lemmas, ...

When writing mathematical documents, you probably need a way to typeset "Lemmas", "Definitions", "Axioms" and similar structures.

`\newtheorem{`*name*`}[`*counter*`]{`*text*`}[`*section*`]`

The *name* argument is a short keyword used to identify the "theorem". With the *text* argument you define the actual name of the "theorem", which will be printed in the final document.

The arguments in square brackets are optional. They are both used to specify the numbering used on the "theorem". Use the *counter* argument to specify the *name* of a previously declared "theorem". The new "theorem" will then be numbered in the same sequence. The *section* argument allows you to specify the sectional unit within which the "theorem" should get its numbers.

After executing the `\newtheorem` command in the preamble of your document, you can use the following command within the document.

```
\begin{name}[text]
This is my interesting theorem
\end{name}
```

The amsthm package (part of $\mathcal{AMS}$-LaTeX) provides the `\theoremstyle{`*style*`}` command which lets you define what the theorem is all about by picking from

three predefined styles: `definition` (fat title, roman body), `plain` (fat title, italic body) or `remark` (italic title, roman body).

This should be enough theory. The following examples should remove any remaining doubt, and make it clear that the `\newtheorem` environment is way too complex to understand.

First define the theorems:

```
\theoremstyle{definition} \newtheorem{law}{Law}
\theoremstyle{plain}      \newtheorem{jury}[law]{Jury}
\theoremstyle{remark}     \newtheorem*{marg}{Margaret}
```

```
\begin{law} \label{law:box}
Don't hide in the witness box
\end{law}
\begin{jury}[The Twelve]
It could be you! So beware and
see law~\ref{law:box}.\end{jury}
\begin{jury}
You will disregard the last
statement.\end{jury}
\begin{marg}No, No, No\end{marg}
\begin{marg}Denis!\end{marg}
```

Law 1. Don't hide in the witness box

Jury 2 (The Twelve)**.** *It could be you! So beware and see law 1.*

Jury 3. *You will disregard the last statement.*

Margaret. No, No, No

Margaret. Denis!

The "Jury" theorem uses the same counter as the "Law" theorem, so it gets a number that is in sequence with the other "Laws". The argument in square brackets is used to specify a title or something similar for the theorem.

```
\newtheorem{mur}{Murphy}[section]

\begin{mur} If there are two or
more ways to do something, and
one of those ways can result in
a catastrophe, then someone
will do it.\end{mur}
```

Murphy 3.9.1. If there are two or more ways to do something, and one of those ways can result in a catastrophe, then someone will do it.

The "Murphy" theorem gets a number that is linked to the number of the current section. You could also use another unit, for example chapter or subsection.

If you want to customize your theorems down to the last dot, the ntheorem package offers a plethora of options.

3.9.1 Proofs and End-of-Proof Symbol

The amsthm package also provides the `proof` environment.

```
\begin{proof}
 Trivial, use
 \begin{equation*}
   E=mc^2.
 \end{equation*}
\end{proof}
```

Proof. Trivial, use

$$E = mc^2.$$

□

With the command `\qedhere` you can move the 'end of proof' symbol around for situations where it would end up alone on a line.

```
\begin{proof}
 Trivial, use
 \begin{equation*}
   E=mc^2. \qedhere
 \end{equation*}
\end{proof}
```

Proof. Trivial, use

$$E = mc^2. \qquad \square$$

Unfortunately, this correction does not work for `IEEEeqnarray`:

```
\begin{proof}
  This is a proof that ends
  with an equation array:
  \begin{IEEEeqnarray*}{rCl}
    a & = & b + c \\
    & = & d + e. \qedhere
  \end{IEEEeqnarray*}
\end{proof}
```

Proof. This is a proof that ends with an equation array:

$$\begin{aligned} a &= b + c \\ &= d + e. \end{aligned} \quad \square$$

The reason for this is the internal structure of `IEEEeqnarray`: it always puts two invisible columns at both sides of the array that only contain a stretchable space. By this `IEEEeqnarray` ensures that the equation array is horizontally centered. The `\qedhere` command should actually be put *outside* this stretchable space, but this does not happen as these columns are invisible to the user.

There is a very simple remedy. Define the stretching explicitly!

```
\begin{proof}
  This is a proof that ends
  with an equation array:
  \begin{IEEEeqnarray*}{+rCl+x*}
    a & = & b + c \\
    & = & d + e. & \qedhere
  \end{IEEEeqnarray*}
\end{proof}
```

Proof. This is a proof that ends with an equation array:

$$\begin{aligned} a &= b + c \\ &= d + e. \end{aligned} \qquad \square$$

Note that the `+` in `{+rCl+x*}` denotes stretchable spaces, one on the left of the equations (which, if not specified, will be done automatically by `IEEEeqnarray`!) and one on the right of the equations. But now on the

right, *after* the stretching column, we add an empty column `x`. This column will only be needed on the last line if the `\qedhere` command is put there. Finally, we specify a `*`. This is a null-space that prevents `IEEEeqnarray` from adding another unwanted +-space!

In the case of equation numbering, there is a similar problem. Comparing

```
\begin{proof}
  This is a proof that ends
  with a numbered equation:
  \begin{equation}
    a = b + c.
  \end{equation}
\end{proof}
```

Proof. This is a proof that ends with a numbered equation:

$$a = b + c. \tag{3.41}$$

□

with

```
\begin{proof}
  This is a proof that ends
  with a numbered equation:
  \begin{equation}
    a = b + c. \qedhere
  \end{equation}
\end{proof}
```

Proof. This is a proof that ends with a numbered equation:

$$a = b + c. \tag{3.42}$$

□

you notice that in the (correct) second version the □ is much closer to the equation than in the first version.

Similarly, the correct way of putting the QED-symbol at the end of an equation array is as follows:

```
\begin{proof}
  This is a proof that ends
  with an equation array:
  \begin{IEEEeqnarray}{+rCl+x*}
    a & = & b + c \\
    & = & d + e. \\
    &&& \qedhere\nonumber
  \end{IEEEeqnarray}
\end{proof}
```

Proof. This is a proof that ends with an equation array:

$$\begin{aligned} a &= b + c && (3.43)\\ &= d + e. && (3.44) \end{aligned}$$

□

which contrasts with

```
\begin{proof}
  This is a proof that ends
  with an equation array:
  \begin{IEEEeqnarray}{rCl}
    a & = & b + c \\
    & = & d + e.
  \end{IEEEeqnarray}
\end{proof}
```

Proof. This is a proof that ends with an equation array:

$$\begin{aligned} a &= b + c && (3.45)\\ &= d + e. && (3.46) \end{aligned}$$

□

3.10 List of Mathematical Symbols

The following tables demonstrate all the symbols normally accessible from *math mode*.

Note that some tables show symbols only accessible after loading the amssymb package in the preamble of your document[12]. If the $\mathcal{AMS}$ package and fonts are not installed on your system, have a look at `CTAN:pkg/amslatex`. An even more comprehensive list of symbols can be found at `CTAN:info/symbols/comprehensive`.

Table 3.1: Math Mode Accents.

$\hat{a}$	`\hat{a}`	$\check{a}$	`\check{a}`	$\tilde{a}$	`\tilde{a}`
$\grave{a}$	`\grave{a}`	$\dot{a}$	`\dot{a}`	$\ddot{a}$	`\ddot{a}`
$\bar{a}$	`\bar{a}`	$\vec{a}$	`\vec{a}`	$\widehat{AAA}$	`\widehat{AAA}`
$\acute{a}$	`\acute{a}`	$\breve{a}$	`\breve{a}`	$\widetilde{AAA}$	`\widetilde{AAA}`
$\mathring{a}$	`\mathring{a}`				

Table 3.2: Greek Letters.

There is no uppercase of some of the letters like `\Alpha`, `\Beta` and so on, because they look the same as normal roman letters: A, B...

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

[12] The tables were derived from `symbols.tex` by David Carlisle and subsequently changed extensively as suggested by Josef Tkadlec.

Table 3.3: Binary Relations.

You can negate the following symbols by prefixing them with a `\not` command.

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

[a] Use the latexsym package to access this symbol

Table 3.4: Binary Operators.

$+$	`+`	$-$	`-`		
$\pm$	`\pm`	$\mp$	`\mp`	$\triangleleft$	`\triangleleft`
$\cdot$	`\cdot`	$\div$	`\div`	$\triangleright$	`\triangleright`
$\times$	`\times`	$\setminus$	`\setminus`	$\star$	`\star`
$\cup$	`\cup`	$\cap$	`\cap`	$*$	`\ast`
$\sqcup$	`\sqcup`	$\sqcap$	`\sqcap`	$\circ$	`\circ`
$\vee$	`\vee` , `\lor`	$\wedge$	`\wedge` , `\land`	$\bullet$	`\bullet`
$\oplus$	`\oplus`	$\ominus$	`\ominus`	$\diamond$	`\diamond`
$\odot$	`\odot`	$\oslash$	`\oslash`	$\uplus$	`\uplus`
$\otimes$	`\otimes`	$\bigcirc$	`\bigcirc`	$\amalg$	`\amalg`
$\bigtriangleup$	`\bigtriangleup`	$\bigtriangledown$	`\bigtriangledown`	$\dagger$	`\dagger`
$\lhd$ [a]	`\lhd` [a]	$\rhd$ [a]	`\rhd` [a]	$\ddagger$	`\ddagger`
$\unlhd$ [a]	`\unlhd` [a]	$\unrhd$ [a]	`\unrhd` [a]	$\wr$	`\wr`

Table 3.5: BIG Operators.

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

Table 3.6: Arrows.

$\leftarrow$	\leftarrow or \gets	$\longleftarrow$	\longleftarrow
$\rightarrow$	\rightarrow or \to	$\longrightarrow$	\longrightarrow
$\leftrightarrow$	\leftrightarrow	$\longleftrightarrow$	\longleftrightarrow
$\Leftarrow$	\Leftarrow	$\Longleftarrow$	\Longleftarrow
$\Rightarrow$	\Rightarrow	$\Longrightarrow$	\Longrightarrow
$\Leftrightarrow$	\Leftrightarrow	$\Longleftrightarrow$	\Longleftrightarrow
$\mapsto$	\mapsto	$\longmapsto$	\longmapsto
$\hookleftarrow$	\hookleftarrow	$\hookrightarrow$	\hookrightarrow
$\leftharpoonup$	\leftharpoonup	$\rightharpoonup$	\rightharpoonup
$\leftharpoondown$	\leftharpoondown	$\rightharpoondown$	\rightharpoondown
$\rightleftharpoons$	\rightleftharpoons	$\iff$	\iff (bigger spaces)
$\uparrow$	\uparrow	$\downarrow$	\downarrow
$\updownarrow$	\updownarrow	$\Uparrow$	\Uparrow
$\Downarrow$	\Downarrow	$\Updownarrow$	\Updownarrow
$\nearrow$	\nearrow	$\searrow$	\searrow
$\swarrow$	\swarrow	$\nwarrow$	\nwarrow
$\leadsto$ [a]	\leadsto		

[a] Use the latexsym package to access this symbol

Table 3.7: Arrows as Accents.

$\overrightarrow{AB}$	\overrightarrow{AB}	$\underrightarrow{AB}$	\underrightarrow{AB}
$\overleftarrow{AB}$	\overleftarrow{AB}	$\underleftarrow{AB}$	\underleftarrow{AB}
$\overleftrightarrow{AB}$	\overleftrightarrow{AB}	$\underleftrightarrow{AB}$	\underleftrightarrow{AB}

Table 3.8: Delimiters.

(	(	)	)	↑	\uparrow
[	[or \lbrack	]	] or \rbrack	↓	\downarrow
{	\{ or \lbrace	}	\} or \rbrace	↕	\updownarrow
⟨	\langle	⟩	\rangle	⇑	\Uparrow
∣	| or \vert	∥	\\| or \Vert	⇓	\Downarrow
/	/	\	\backslash	⇕	\Updownarrow
⌊	\lfloor	⌋	\rfloor		
⌉	\rceil	⌈	\lceil		

Table 3.9: Large Delimiters.

⎧	\lgroup	⎫	\rgroup	⎰	\lmoustache
⎪	\arrowvert	⎪⎪	\Arrowvert	⎪	\bracevert
⎱	\rmoustache				

Table 3.10: Miscellaneous Symbols.

…	\dots	⋯	\cdots	⋮	\vdots	⋱	\ddots
ℏ	\hbar	𝚤	\imath	𝚥	\jmath	ℓ	\ell
ℜ	\Re	ℑ	\Im	ℵ	\aleph	℘	\wp
∀	\forall	∃	\exists	℧	\mho [a]	∂	\partial
′	'	′	\prime	∅	\emptyset	∞	\infty
∇	\nabla	△	\triangle	□	\Box [a]	◇	\Diamond [a]
⊥	\bot	⊤	\top	∠	\angle	√	\surd
♢	\diamondsuit	♡	\heartsuit	♣	\clubsuit	♠	\spadesuit
¬	\neg or \lnot	♭	\flat	♮	\natural	♯	\sharp

[a] Use the latexsym package to access this symbol

Table 3.11: Non-Mathematical Symbols.

These symbols can also be used in text mode.

†	\dag	§	\S	©	\copyright	®	\textregistered
‡	\ddag	¶	\P	£	\pounds	%	\%

Table 3.12: $\mathcal{AMS}$ Delimiters.

⌜	\ulcorner	⌝	\urcorner	⌞	\llcorner	⌟	\lrcorner
|	\lvert	|	\rvert	‖	\lVert	‖	\rVert

Table 3.13: $\mathcal{AMS}$ Greek and Hebrew.

F	\digamma	$\varkappa$	\varkappa	ב	\beth	ג	\gimel	ד	\daleth

Table 3.14: Math Alphabets.

See Table 6.4 on 109 for other math fonts.

Example	Command	Required package
ABCDEabcde1234	\mathrm{ABCDE abcde 1234}	
ABCDEabcde1234	\mathit{ABCDE abcde 1234}	
*ABCDEabcde*1234	\mathnormal{ABCDE abcde 1234}	
$\mathcal{ABCDE}$	\mathcal{ABCDE abcde 1234}	
$\mathscr{ABCDE}$	\mathscr{ABCDE abcde 1234}	mathrsfs
𝔄𝔅ℭ𝔇𝔈abcde1234	\mathfrak{ABCDE abcde 1234}	amsfonts or amssymb
𝔸𝔹ℂ𝔻𝔼ℶℷℸℵ	\mathbb{ABCDE abcde 1234}	amsfonts or amssymb

Table 3.15: $\mathcal{AMS}$ Binary Operators.

∔	\dotplus	∙	\centerdot		
⋉	\ltimes	⋊	\rtimes	⋇	\divideontimes
⋓	\doublecup	⋒	\doublecap	⧹	\smallsetminus
⩒	\veebar	⩛	\barwedge	⩖	\doublebarwedge
⊞	\boxplus	⊟	\boxminus	⊝	\circleddash
⊠	\boxtimes	⊡	\boxdot	⊚	\circledcirc
⊺	\intercal	⊛	\circledast	⋏	\rightthreetimes
⋎	\curlyvee	⋏	\curlywedge	⋋	\leftthreetimes

Table 3.16: $\mathcal{AMS}$ Binary Relations.

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

Table 3.17: $\mathcal{AMS}$ Arrows.

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

Table 3.18: $\mathcal{AMS}$ Negated Binary Relations and Arrows.

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

Table 3.19: $\mathcal{AMS}$ Miscellaneous.

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

Chapter 4

Specialities

When putting together a large document, LaTeX will help with some special features like index generation, bibliography management, and other things. A much more complete description of specialities and enhancements possible with LaTeX can be found in the *LaTeX Manual* [1] and *The LaTeX Companion* [3].

4.1 Bibliography

Produce a bibliography with the `thebibliography` environment. Each entry starts with

`\bibitem[`*label*`]{`*marker*`}`

The *marker* is then used to cite the book, article or paper within the document.

`\cite{`*marker*`}`

If you do not use the *label* option, the entries will get enumerated automatically. The parameter after the `\begin{thebibliography}` command defines how much space to reserve for the number of labels. In the example below, `{99}` tells LaTeX to expect that none of the bibliography item numbers will be wider than the number 99.

```
Partl~\cite{pa} has
proposed that \ldots
\begin{thebibliography}{99}
\bibitem{pa} H.~Partl:
\emph{German \TeX},
TUGboat Volume~9, Issue~1 (1988)
\end{thebibliography}
```

Partl [1] has proposed that ...

Bibliography

[1] H. Partl: *German TEX*, TUGboat Volume 9, Issue 1 (1988)

For larger projects, you might want to check out the BibTEX program. BibTEX is included with most TEX distributions. It allows you to maintain a bibliographic database and then extract the references relevant to things you cited in your paper. The visual presentation of BibTEX-generated bibliographies is based on a style-sheets concept that allows you to create bibliographies following a wide range of established designs.

4.2 Indexing

A very useful feature of many books is their index. With LATEX and the support program `makeindex`,[1] an index can be generated quite easily. This introduction will only explain the basic index generation commands. For a more in-depth view, please refer to *The LATEX Companion* [3].

To enable their indexing feature of LATEX, the makeidx package must be loaded in the preamble with

```
\usepackage{makeidx}
```

and the special indexing commands must be enabled by putting the

```
\makeindex
```

command in the preamble.

[1] On systems not necessarily supporting filenames longer than 8 characters, the program may be called `makeidx`.

Table 4.1: Index Key Syntax Examples.

Example	Index Entry	Comment
`\index{hello}`	hello, 1	Plain entry
`\index{hello!Peter}`	Peter, 3	Subentry under 'hello'
`\index{Sam@\textsl{Sam}}`	*Sam*, 2	Formatted entry
`\index{Lin@\textbf{Lin}}`	**Lin**, 7	Formatted entry
`\index{Kaese@K\"ase}`	**Käse**, 33	Formatted entry
`\index{ecole@\'ecole}`	école, 4	Formatted entry
`\index{Jenny|textbf}`	Jenny, **3**	Formatted page number
`\index{Joe|textit}`	Joe, *5*	Formatted page number

The content of the index is specified with

`\index{`*key*`@`*formatted_ entry*`}`

commands, where *formatted_ entry* will appear in the index and *key* will be used for sorting. The *formatted_ entry* is optional. If it is missing the *key* will be used. You enter the index commands at the points in the text that you want the final index entries to point to. Table 4.1 explains the syntax with several examples.

When the input file is processed with LaTeX, each `\index` command writes an appropriate index entry, together with the current page number, to a special file. The file has the same name as the LaTeX input file, but a different extension (`.idx`). This `.idx` file can then be processed with the `makeindex` program:

`makeindex` *filename*

The `makeindex` program generates a sorted index with the same base file name, but this time with the extension `.ind`. If now the LaTeX input file is processed again, this sorted index gets included into the document at the point where LaTeX finds

`\printindex`

The showidx package that comes with LaTeX 2$_\varepsilon$ prints out all index entries in the left margin of the text. This is quite useful for proofreading a document and verifying the index.

Note that the `\index` command can affect your layout if not used carefully.

```
My Word \index{Word}. As opposed
to Word\index{Word}. Note the
position of the full stop.
```

My Word . As opposed to Word. Note the position of the full stop.

makeindex has no clue about characters outside the ASCII range. To get the sorting correct, use the @ character as shown in the Käse and école examples above.

4.3 Fancy Headers

The fancyhdr package,[2] written by Piet van Oostrum, provides a few simple commands that allow you to customize the header and footer lines of your document. Look at the top of this page, for an application of this package.

```
\documentclass{book}
\usepackage{fancyhdr}
\pagestyle{fancy}
% with this we ensure that the chapter and section
% headings are in lowercase.
\renewcommand{\chaptermark}[1]{%
        \markboth{#1}{}}
\renewcommand{\sectionmark}[1]{%
        \markright{\thesection\ #1}}
\fancyhf{}  % delete current header and footer
\fancyhead[LE,RO]{\bfseries\thepage}
\fancyhead[LO]{\bfseries\rightmark}
\fancyhead[RE]{\bfseries\leftmark}
\renewcommand{\headrulewidth}{0.5pt}
\renewcommand{\footrulewidth}{0pt}
\addtolength{\headheight}{0.5pt} % space for the rule
\fancypagestyle{plain}{%
   \fancyhead{} % get rid of headers on plain pages
   \renewcommand{\headrulewidth}{0pt} % and the line
}
```

Figure 4.1: Example fancyhdr Setup.

The tricky problem when customising headers and footers is to get things like running section and chapter names in there. LaTeX accomplishes this with a two-stage approach. In the header and footer definition, you use the commands \rightmark and \leftmark to represent the current section

[2] Available from CTAN://macros/latex/contrib/supported/fancyhdr.

and chapter heading, respectively. The values of these two commands are overwritten whenever a chapter or section command is processed.

For ultimate flexibility, the `\chapter` command and its friends do not redefine `\rightmark` and `\leftmark` themselves. They call yet another command (`\chaptermark`, `\sectionmark`, or `\subsectionmark`) that is responsible for redefining `\rightmark` and `\leftmark`.

If you want to change the look of the chapter name in the header line, you need only "renew" the `\chaptermark` command.

Figure 4.1 shows a possible setup for the fancyhdr package that makes the headers look about the same as they look in this booklet. In any case, I suggest you fetch the documentation for the package at the address mentioned in the footnote.

4.4 The Verbatim Package

Earlier in this book, you got to know the `verbatim` *environment*. In this section, you are going to learn about the verbatim *package*. The verbatim package is basically a re-implementation of the `verbatim` environment that works around some of the limitations of the original `verbatim` environment. This by itself is not spectacular, but the implementation of the verbatim package added new functionality, which is why I am mentioning the package here. The verbatim package provides the

`\verbatiminput{`*filename*`}`

command, which allows you to include raw ASCII text into your document as if it were inside a `verbatim` environment.

As the verbatim package is part of the 'tools' bundle, you should find it pre-installed on most systems. If you want to know more about this package, make sure to read [10].

4.5 Installing Extra Packages

Most LaTeX installations come with a large set of pre-installed style packages, but many more are available on the net. The main place to look for style packages on the Internet is CTAN (`http://www.ctan.org/`).

Packages such as geometry, hyphenat, and many others are typically made up of two files: a file with the extension `.ins` and another with the extension `.dtx`. There will often be a `readme.txt` with a brief description of the package. You should of course read this file first.

In any event, once you have copied the package files onto your machine, you still have to process them in a way that (a) tells your TeX distribution

about the new style package and (b) gives you the documentation. Here's how you do the first part:

1. Run LaTeX on the `.ins` file. This will extract a `.sty` file.
2. Move the `.sty` file to a place where your distribution can find it. Usually this is in your `…/localtexmf/tex/latex` subdirectory (Windows or OS/2 users should feel free to change the direction of the slashes).
3. Refresh your distribution's file-name database. The command depends on the LaTeXdistribution you use: TeXlive – `texhash`; web2c – `maktexlsr`; MiKTeX – `initexmf --update-fndb` or use the GUI.

Now extract the documentation from the `.dtx` file:

1. Run XeLaTeX on the `.dtx` file. This will generate a `.pdf` file. Note that you may have to run XeLaTeX several times before it gets the cross-references right.
2. Check to see if LaTeX has produced a `.idx` file among the various files you now have. If you do not see this file, then the documentation has no index. Continue with step 5.
3. In order to generate the index, type the following:
   `makeindex -s gind.ist name`
   (where *name* stands for the main-file name without any extension).
4. Run LaTeX on the `.dtx` file once again.
5. Last but not least, make a `.ps` or `.pdf` file to increase your reading pleasure.

Sometimes you will see that a `.glo` (glossary) file has been produced. Run the following command between step 4 and 5:
`makeindex -s gglo.ist -o name.gls name.glo`
Be sure to run LaTeX on the `.dtx` one last time before moving on to step 5.

4.6 LaTeX and PDF

By Daniel Flipo <Daniel.Flipo@univ-lille1.fr>

PDF is a portable hypertext document format. Much as in a web page, some words in the document are marked as hyperlinks. They link to other places in the document or even to other documents. If you click on such a hyperlink you get transported to the destination of the link. In the context of LaTeX, this means that all occurrences of `\ref` and `\pageref` become hyperlinks. Additionally, the table of contents, the index and all the other similar structures become collections of hyperlinks.

Most web pages you find today are written in HTML *(HyperText Markup Language)*. This format has two significant disadvantages when writing scientific documents:

1. Including mathematical formulae into HTML documents is not generally supported. While there is a standard for it, most browsers used today do not support it, or lack the required fonts.

2. Printing HTML documents is possible, but the results vary widely between platforms and browsers. The results are miles removed from the quality we have come to expect in the LaTeX world.

There have been many attempts to create translators from LaTeX to HTML. Some were even quite successful in the sense that they are able to produce legible web pages from a standard LaTeX input file. But all of them cut corners left and right to get the job done. As soon as you start using more complex LaTeX features and external packages things tend to fall apart. Authors wishing to preserve the unique typographic quality of their documents even when publishing on the web turn to PDF *(Portable Document Format)*, which preserves the layout of the document and permits hypertext navigation. Most modern browsers come with plugins that allow the direct display of PDF documents.

All modern TeX engines can generate PDF files out of the box. If you worked through this introduction until here you will already be familiar with the process.

4.6.1 Hypertext Links

The hyperref adds two cool features to your LaTeX PDF files:

1. The paper size is set according to your specification in the document class call.

2. All references in your your document turn into hyperlinks.

Just add `\usepackage{hyperref}` as the *last* command into the preamble of your document.

Many options are available to customize the behaviour of the hyperref package:

- either as a comma separated list after the pdftex option `\usepackage{hyperref}`
- or on individual lines with the command `\hypersetup{`*options*`}`.

In the following list the default values are written in an upright font.

bookmarks (=true,*false*) show or hide the bookmarks bar when displaying the document

unicode (=false,*true*) allows the use of characters of non-Latin based languages in Acrobat's bookmarks

pdftoolbar (=true,*false*) show or hide Acrobat's toolbar

pdfmenubar (=true,*false*) show or hide Acrobat's menu

pdffitwindow (=false,*true*) adjust the initial magnification of the PDF when displayed

pdftitle (={text}) define the title that gets displayed in the `Document Info` window of Acrobat

pdfauthor (={text}) the name of the PDF's author

pdfnewwindow (=false,*true*) define whether a new window should be opened when a link leads out of the current document

colorlinks (=false,*true*) surround the links by colour frames (`false`) or colour the text of the links (`true`). The colour of these links can be configured using the following options (default colours are shown):

linkcolor (=red) colour of internal links (sections, pages, etc.)

citecolor (=green) colour of citation links (bibliography)

filecolor (=magenta) colour of file links

urlcolor (=cyan) colour of URL links (mail, web)

If you are happy with the defaults, use

```
\usepackage{hyperref}
```

To have the bookmark list open and links in colour (the `=true` values are optional):

```
\usepackage[bookmarks,colorlinks]{hyperref}
```

When creating PDFs destined for printing, coloured links are not a good thing as they end up in gray in the final output, making it difficult to read. Use colour frames, which are not printed:

```
\usepackage{hyperref}
\hypersetup{colorlinks=false}
```

or make links black:

```
\usepackage{hyperref}
\hypersetup{colorlinks,%
            citecolor=black,%
            filecolor=black,%
            linkcolor=black,%
            urlcolor=black,%
            pdftex}
```

When you just want to provide information for the `Document Info` section of the PDF file:

```
\usepackage[pdfauthor={Pierre Desproges},%
            pdftitle={Des femmes qui tombent},%
            pdftex]{hyperref}
```

In addition to the automatic hyperlinks for cross references, it is possible to embed explicit links using

`\href{`*url*`}{`*text*`}`

The code

```
The \href{http://www.ctan.org}{CTAN} website.
```

produces the output "CTAN"; a click on the word "CTAN" will take you to the CTAN website.

If the destination of the link is not a URL but a local file, use the `\href` command without the 'http://' bit:

```
The complete document is \href{manual.pdf}{here}
```

which produces the text "The complete document is here". A click on the word "here" will open the file `manual.pdf`. (The filename is relative to the location of the current document).

The author of an article might want her readers to easily send email messages by using the `\href` command inside the `\author` command on the title page of the document:

```
\author{Mary Oetiker $<$\href{mailto:mary@oetiker.ch}%
       {mary@oetiker.ch}$>$
```

Note that I have put the link so that my email address appears not only in the link but also on the page itself. I did this because the link
`\href{mailto:mary@oetiker.ch}{Mary Oetiker}`
would work well within Acrobat, but once the page is printed the email address would not be visible anymore.

4.6.2 Problems with Links

Messages like the following:

```
! pdfTeX warning (ext4): destination with the same
  identifier (name{page.1}) has been already used,
  duplicate ignored
```

appear when a counter gets reinitialized, for example by using the command `\mainmatter` provided by the `book` document class. It resets the page number counter to 1 prior to the first chapter of the book. But as the preface of the book also has a page number 1 all links to "page 1" would not be unique anymore, hence the notice that "`duplicate` has been `ignored`."

The counter measure consists of putting `plainpages=false` into the hyperref options. This unfortunately only helps with the page counter. An even more radical solution is to use the option `hypertexnames=false`, but this will cause the page links in the index to stop working.

4.6.3 Problems with Bookmarks

The text displayed by bookmarks does not always look like you expect it to look. Because bookmarks are "just text," fewer characters are available for bookmarks than for normal LaTeX text. Hyperref will normally notice such problems and put up a warning:

```
Package hyperref Warning:
Token not allowed in a PDFDocEncoded string:
```

Work around this problem by providing a text string for the bookmarks, which replaces the offending text:

`\texorpdfstring{`*TEX text*`}{`*Bookmark Text*`}`

Math expressions are a prime candidate for this kind of problem:

```
\section{\texorpdfstring{$E=mc^2$}%
        {E = mc ** 2}}
```

which turns `\section{$E=mc^2$}` to "E = mc ** 2" in the bookmark area.

If you write your document in Unicode and use the `unicode` option for the hyperref package to use Unicode characters in bookmarks, this will give you a much larger selection of characters to pick from when when using `\texorpdfstring`.

4.7 Working with XeLaTeX and PDF

By Axel Kielhorn <A.Kielhorn@web.de>

Most of the things said in the previous section are valid for XeLaTeX as well.

There is a Wiki at http://wiki.xelatex.org/doku.php that collects information relevant to XeTeX and XeLaTeX.

4.7.1 The Fonts

In addition to the normal `tfm` based fonts, XeLaTeX is able to use any font known to the operating system. If you have the `Linux Libertine` fonts installed, you can simply say

```
\usepackage{fontspec}
\setmainfont[Ligatures=TeX]{Linux Libertine}
```

in the preamble. This will normally detect the italic and bold versions as well, so `\textit` and `\textbf` will work as usual. When the font is using OpenType technology you have access to many features which required switching to a separate font or using virtual fonts in the past. The main feature is the extended character set; a font may contain Latin, Greek and Cyrillic characters and the corresponding ligatures.

Many fonts contain at least two kinds of numerals, the normal lining numerals and so called old style (or lower case) numerals, which partly extend below the baseline. They may contain proportional numerals (the "1" takes less space than the "0") or monospaced numerals which are suitable for tables.

```
\newfontfamily\LLln[Numbers=Lining]{(font)}
\newfontfamily\LLos[Numbers=OldStyle]{(font)}
\newfontfamily\LLlnm[Numbers=Lining,Numbers=Monospaced]{(font)}
\newfontfamily\LLosm[Numbers=OldStyle,Numbers=Monospaced]{(font)}
```

Almost all OpenType fonts contain the standard ligatures (fl fi ffi) but there are also some rare or historical ligatures like st, ct and tz. You may not want to use them in a technical report but they are fine for a novel. To enable these ligatures use either of the following lines:

```
\setmainfont[Ligatures=Rare]{(font)}
\setmainfont[Ligatures=Historic]{(font)}
\setmainfont[Ligatures=Historic,Ligatures=Rare]{(font)}
```

Not every font contains both sets of ligature, consult the font documentation or just try it out. Sometimes these ligatures are language dependent; for example a ligature used in Polish (fk) is not used in English. You have to add

```
\setmainfont[Language=Polish]{(font)}
```

to enable the Polish ligatures.

Some fonts (like the commercial Adobe Garamond Premier Pro) contain alternative glyphs that are activated by default in XeLaTeX distributed with TeXLive 2010[3]. The result is a stylish "Q" with a descender reaching below the following "u". To disable this feature you have to define the font with disabled contextuals:

```
\setmainfont[Contextuals=NoAlternate]{(font)}
```

To learn about fonts in XeLaTeX read the fontspec manual.

Where do I get OpenType fonts?

If you have TeXLive installed, you already have some at .../texmf-dist/fonts/opentype, just install them in your operating system. This collection does not include DejaVu, which is available at http://dejavu-fonts.org/.

Make sure that each font is only installed *once*, otherwise interesting results may happen.

You can use every font installed on your computer, but remember that other users may not have these fonts. The Zapfino font used in the fontspec manual is included in Mac OSX, but is not available on Windows computers.[4]

Entering Unicode Characters

The number of characters in a font has grown but the number of keys on a regular keyboard has not. So, how do I enter non-ASCII characters?

If you write a large amount of text in a foreign language, you can install a keyboard for that language and print out the character positions. (Most operatings system have some sort of virtual keyboard, just make a screenshot.)

If you rarely need an exotic character, you can simply pick it in the character palette.

Some environments (e. g. the X Window System) offer many methods to enter non-ASCII characters. Some editors (e. g. Vim and Emacs) offer ways to enter these characters. Read the manual for the tools you are using.

4.7.2 Compatibility Between XeLaTeX and pdfLaTeX

There are a few things that are different between XeLaTeX and pdfLaTeX.

[3] The behavior has changed with this version, it was off by default in earlier releases.

[4] A commercial version of the font called Zapfino Extra is available.

- A XeLaTeX document has to be written in Unicode (UTF-8) while pdfLaTeX may use different input encodings.
- The microtype packages does not work with XeLaTeX yet, support for character protrusion is already under development.
- Everything font related has to be reviewed. (Unless you want to stick to Latin Modern.)

4.8 Creating Presentations

By Daniel Flipo <Daniel.Flipo@univ-lille1.fr>

You can present the results of your scientific work on a blackboard, with transparencies, or directly from your laptop using some presentation software.

pdfLaTeX combined with the beamer class allows you to create presentations in PDF, looking much like something you might be able to generate with LibreOffice or PowerPoint if you had a very good day, but much more portable because PDF readers are available on many more systems.

The beamer class uses graphicx, color and hyperref with options adapted to screen presentations.

When you compile the code presented in figure 4.2 with pdfLaTeX you get a PDF file with a title page and a second page showing several items that will be revealed one at a time as you step though your presentation.

One of the advantages of the beamer class is that it produces a PDF file that is directly usable without first going through a PostScript stage like prosper or requiring additional post processing like presentations created with the ppower4 package.

With the beamer class you can produce several versions (modes) of your document from the same input file. The input file may contain special instructions for the different modes in angular brackets. The following modes are available:

beamer for the presentation PDF discussed above.

trans for transparencies.

handout for the printed version.

The default mode is `beamer`, change it by setting a different mode as a global option, like `\documentclass[10pt,handout]{beamer}` to print the handouts for example.

The look of the screen presentation depends on the theme you choose. Pick one of the themes shipped with the beamer class or create your own. See the beamer class documentation in `beameruserguide.pdf` for more information on this.

```
\documentclass[10pt]{beamer}
\mode<beamer>{%
  \usetheme[hideothersubsections,
            right,width=22mm]{Goettingen}
}

\title{Simple Presentation}
\author[D. Flipo]{Daniel Flipo}
\institute{U.S.T.L. \& GUTenberg}
\titlegraphic{\includegraphics[width=20mm]{USTL}}
\date{2005}

\begin{document}

\begin{frame}<handout:0>
  \titlepage
\end{frame}

\section{An Example}

\begin{frame}
  \frametitle{Things to do on a Sunday Afternoon}
  \begin{block}{One could \ldots}
    \begin{itemize}
      \item walk the dog\dots \pause
      \item read a book\pause
      \item confuse a cat\pause
    \end{itemize}
  \end{block}
  and many other things
\end{frame}
\end{document}
```

Figure 4.2: Sample code for the beamer class

Let's have a closer look at the code in figure 4.2.

For the screen version of the presentation `\mode<beamer>` we have chosen the *Goettingen* theme to show a navigation panel integrated into the table of contents. The options allow us to choose the size of the panel (22 mm in this case) and its position (on the right side of the body text). The option *hideothersubsections*, shows the chapter titles, but only the subsections of the present chapter. There are no special settings for `\mode<trans>` and `\mode<handout>`. They appear in their standard layout.

The commands `\title{}`, `\author{}`, `\institute{}`, and `\titlegraphic{}` set the content of the title page. The optional arguments of `\title[]{}` and `\author[]{}` let you specify a special version of the title and the author name to be displayed on the panel of the *Goettingen* theme.

The titles and subtitles in the panel are created with normal `\section{}` and `\subsection{}` commands that you place *outside* the `frame` environment.

The tiny navigation icons at the bottom of the screen also allow to navigate the document. Their presence is not dependent on the theme you choose.

The contents of each slide or screen has to be placed inside a `frame` environment. There is an optional argument in angular brackets (< and >), it allows us to suppress a particular frame in one of the versions of the presentation. In the example the first page would not be shown in the handout version due to the `<handout:0>` argument.

It is highly recommended to set a title for each slide apart from the title slide. This is done with the command `\frametitle{}`. If a subtitle is necessary use the `block` environment as shown in the example. Note that the sectioning commands `\section{}` and `\subsection{}` do not produce output on the slide proper.

The command `\pause` in the itemize environment lets you reveal the items one by one. For other presentation effects check out the commands `\only`, `\uncover`, `\alt` and `\temporal`. In many place it is possible to use angular brackets to further customize the presentation.

In any case make sure to read through the beamer class documentation `beameruserguide.pdf` to get a complete picture of what is in store for you. This package is being actively developed, check out their website to get the latest information. (http://latex-beamer.sourceforge.net/)

Chapter 5

Producing Mathematical Graphics

Most people use LaTeX for typesetting their text. And since the structure oriented approach to authoring is so convenient, LaTeX also offers a, if somewhat restricted, means for producing graphical output from textual descriptions. Furthermore, quite a number of LaTeX extensions have been created in order to overcome these restrictions. In this section, you will learn about a few of them.

5.1 Overview

Creating graphical output with LaTeX has a long tradition. It started out with the `picture` environment which allows you to create graphics by cleverly placing predefined elements onto the canvas. A complete description can be found in the *LaTeX Manual* [1]. The `picture` environment of LaTeX 2_ε brings with it the `\qbezier` command, "q" meaning "quadratic". Many frequently used curves such as circles, ellipses, or catenaries can be satisfactorily approximated by quadratic Bézier curves, although this may require some mathematical toil. If, in addition, a programming language is used to generate `\qbezier` blocks of LaTeX input files, the `picture` environment becomes quite powerful.

Although programming pictures directly in LaTeX is severely restricted, and often rather tiresome, there are still reasons for doing so. The documents thus produced are "small" with respect to bytes, and there are no additional graphics files to be dragged along.

This has been the state of things until a few years ago when Till Tantau of beamer fame came up with the Portable Graphics Format pgf and its companion package TikZ (tikz). This system lets you create high quality vector graphics with all current TeX systems including full support for pdf.

Building on these basics, numerous packages have been written for specific purposes. A wide variety of these packages is described in detail in *The LaTeX Graphics Companion* [4].

Perhaps the most advanced graphical tool related with LaTeX is MetaPost. It is a stand-alone application based on Donald E. Knuth's MetaFont. MetaPost has the very powerful and mathematically sophisticated programming language of MetaFont but contrary to MetaFont, it generates encapsulated PostScript files, which can be imported in LaTeX and even pdfLaTeX. For an introduction, see *A User's Manual for MetaPost* [14], or the tutorial on [16].

A very thorough discussion of LaTeX and TeX strategies for graphics (and fonts) can be found in *TeX Unbound* [15].

5.2 The `picture` Environment

By Urs Oswald <osurs@bluewin.ch>

As mentioned above the picture environment is part of standard LaTeX and it is great for simple tasks and also if you want to control the exact positioning of individual elements on a page. But if you are about to do any serious graphics work, you should look at TikZ as presented in section 5.3 on page 99.

5.2.1 Basic Commands

A `picture` environment[1] is created with one of the two commands

```
\begin{picture}(x,y)...\end{picture}
```

or

```
\begin{picture}(x,y)(x0,y0)...\end{picture}
```

The numbers x, y, x_0, y_0 refer to `\unitlength`, which can be reset any time (but not within a `picture` environment) with a command such as

```
\setlength{\unitlength}{1.2cm}
```

The default value of `\unitlength` is `1pt`. The first pair, (x, y), effects the reservation, within the document, of rectangular space for the picture. The optional second pair, (x_0, y_0), assigns arbitrary coordinates to the bottom left corner of the reserved rectangle.

[1] Believe it or not, the picture environment works out of the box, with standard LaTeX 2ε no package loading necessary.

Most drawing commands have one of the two forms

\put(x, y){*object*}

or

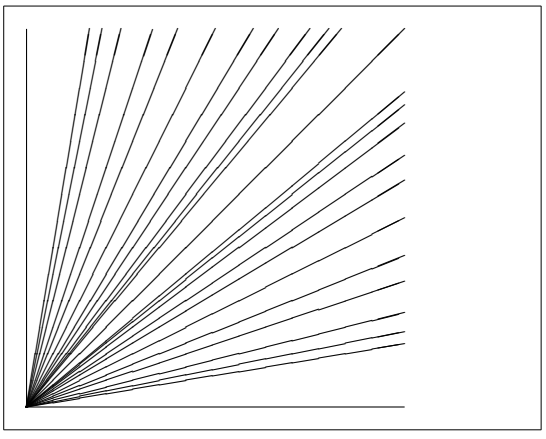
\multiput(x, y)($\Delta x, \Delta y$){n}{*object*}

Bézier curves are an exception. They are drawn with the command

\qbezier(x_1, y_1)(x_2, y_2)(x_3, y_3)

5.2.2 Line Segments

```
\setlength{\unitlength}{5cm}
\begin{picture}(1,1)
  \put(0,0){\line(0,1){1}}
  \put(0,0){\line(1,0){1}}
  \put(0,0){\line(1,1){1}}
  \put(0,0){\line(1,2){.5}}
  \put(0,0){\line(1,3){.3333}}
  \put(0,0){\line(1,4){.25}}
  \put(0,0){\line(1,5){.2}}
  \put(0,0){\line(1,6){.1667}}
  \put(0,0){\line(2,1){1}}
  \put(0,0){\line(2,3){.6667}}
  \put(0,0){\line(2,5){.4}}
  \put(0,0){\line(3,1){1}}
  \put(0,0){\line(3,2){1}}
  \put(0,0){\line(3,4){.75}}
  \put(0,0){\line(3,5){.6}}
  \put(0,0){\line(4,1){1}}
  \put(0,0){\line(4,3){1}}
  \put(0,0){\line(4,5){.8}}
  \put(0,0){\line(5,1){1}}
  \put(0,0){\line(5,2){1}}
  \put(0,0){\line(5,3){1}}
  \put(0,0){\line(5,4){1}}
  \put(0,0){\line(5,6){.8333}}
  \put(0,0){\line(6,1){1}}
  \put(0,0){\line(6,5){1}}
\end{picture}
```



Line segments are drawn with the command

`\put(`x, y`){\line(`x_1, y_1`){`*length*`}}`

The `\line` command has two arguments:

1. a direction vector,
2. a length.

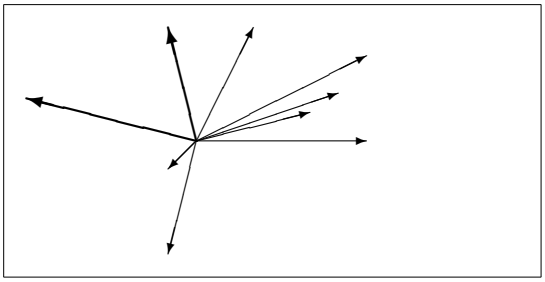
The components of the direction vector are restricted to the integers

$$-6,\ -5,\ \ldots,\ 5,\ 6,$$

and they have to be coprime (no common divisor except 1). The figure illustrates all 25 possible slope values in the first quadrant. The length is relative to `\unitlength`. The length argument is the vertical coordinate in the case of a vertical line segment, the horizontal coordinate in all other cases.

5.2.3 Arrows

```
\setlength{\unitlength}{0.75mm}
\begin{picture}(60,40)
  \put(30,20){\vector(1,0){30}}
  \put(30,20){\vector(4,1){20}}
  \put(30,20){\vector(3,1){25}}
  \put(30,20){\vector(2,1){30}}
  \put(30,20){\vector(1,2){10}}
  \thicklines
  \put(30,20){\vector(-4,1){30}}
  \put(30,20){\vector(-1,4){5}}
  \thinlines
  \put(30,20){\vector(-1,-1){5}}
  \put(30,20){\vector(-1,-4){5}}
\end{picture}
```



Arrows are drawn with the command

`\put(`x, y`){\vector(`x_1, y_1`){`*length*`}}`

For arrows, the components of the direction vector are even more narrowly restricted than for line segments, namely to the integers

$$-4,\ -3,\ \ldots,\ 3,\ 4.$$

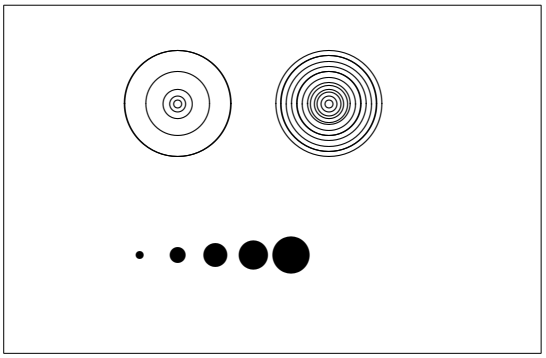
Components also have to be coprime (no common divisor except 1). Notice the effect of the `\thicklines` command on the two arrows pointing to the upper left.

5.2.4 Circles

```
\setlength{\unitlength}{1mm}
\begin{picture}(60, 40)
  \put(20,30){\circle{1}}
  \put(20,30){\circle{2}}
  \put(20,30){\circle{4}}
  \put(20,30){\circle{8}}
  \put(20,30){\circle{16}}
  \put(20,30){\circle{32}}

  \put(40,30){\circle{1}}
  \put(40,30){\circle{2}}
  \put(40,30){\circle{3}}
  \put(40,30){\circle{4}}
  \put(40,30){\circle{5}}
  \put(40,30){\circle{6}}
  \put(40,30){\circle{7}}
  \put(40,30){\circle{8}}
  \put(40,30){\circle{9}}
  \put(40,30){\circle{10}}
  \put(40,30){\circle{11}}
  \put(40,30){\circle{12}}
  \put(40,30){\circle{13}}
  \put(40,30){\circle{14}}

  \put(15,10){\circle*{1}}
  \put(20,10){\circle*{2}}
  \put(25,10){\circle*{3}}
  \put(30,10){\circle*{4}}
  \put(35,10){\circle*{5}}
\end{picture}
```



The command

`\put(`x, y`){\circle{`*diameter*`}}`

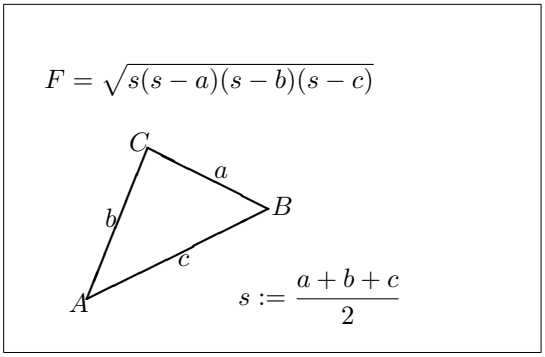
draws a circle with center (x, y) and diameter (not radius) *diameter*. The `picture` environment only admits diameters up to approximately 14 mm, and even below this limit, not all diameters are possible. The `\circle*` command produces disks (filled circles).

As in the case of line segments, one may have to resort to additional packages, such as eepic or pstricks. For a thorough description of these packages, see *The LaTeX Graphics Companion* [4].

There is also a possibility within the `picture` environment. If one is not afraid of doing the necessary calculations (or leaving them to a program), arbitrary circles and ellipses can be patched together from quadratic Bézier curves. See *Graphics in LaTeX 2ε* [16] for examples and Java source files.

5.2.5 Text and Formulas

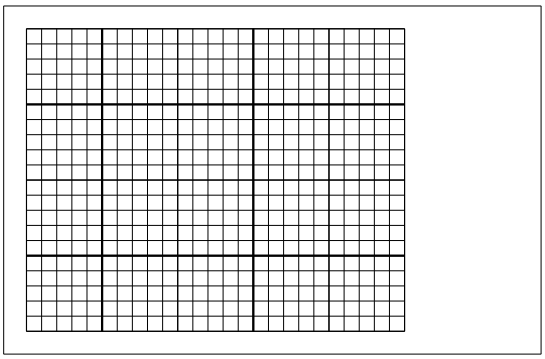
```
\setlength{\unitlength}{0.8cm}
\begin{picture}(6,5)
  \thicklines
  \put(1,0.5){\line(2,1){3}}
  \put(4,2){\line(-2,1){2}}
  \put(2,3){\line(-2,-5){1}}
  \put(0.7,0.3){$A$}
  \put(4.05,1.9){$B$}
  \put(1.7,2.95){$C$}
  \put(3.1,2.5){$a$}
  \put(1.3,1.7){$b$}
  \put(2.5,1.05){$c$}
  \put(0.3,4){$F=
    \sqrt{s(s-a)(s-b)(s-c)}$}
  \put(3.5,0.4){$\displaystyle
    s:=\frac{a+b+c}{2}$}
\end{picture}
```



As this example shows, text and formulas can be written into a `picture` environment with the `\put` command in the usual way.

5.2.6 `\multiput` and `\linethickness`

```
\setlength{\unitlength}{2mm}
\begin{picture}(30,20)
  \linethickness{0.075mm}
  \multiput(0,0)(1,0){26}%
    {\line(0,1){20}}
  \multiput(0,0)(0,1){21}%
    {\line(1,0){25}}
  \linethickness{0.15mm}
  \multiput(0,0)(5,0){6}%
    {\line(0,1){20}}
  \multiput(0,0)(0,5){5}%
    {\line(1,0){25}}
  \linethickness{0.3mm}
  \multiput(5,0)(10,0){2}%
    {\line(0,1){20}}
  \multiput(0,5)(0,10){2}%
    {\line(1,0){25}}
\end{picture}
```



The command

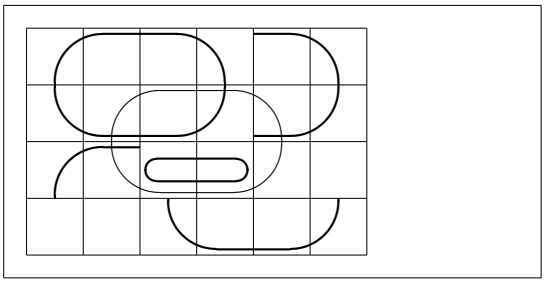
`\multiput`$(x,y)(\Delta x,\Delta y)\{n\}\{$*object*$\}$

has 4 arguments: the starting point, the translation vector from one ob-

ject to the next, the number of objects, and the object to be drawn. The \linethickness command applies to horizontal and vertical line segments, but neither to oblique line segments, nor to circles. It does, however, apply to quadratic Bézier curves!

5.2.7 Ovals

```
\setlength{\unitlength}{0.75cm}
\begin{picture}(6,4)
  \linethickness{0.075mm}
  \multiput(0,0)(1,0){7}%
    {\line(0,1){4}}
  \multiput(0,0)(0,1){5}%
    {\line(1,0){6}}
  \thicklines
  \put(2,3){\oval(3,1.8)}
  \thinlines
  \put(3,2){\oval(3,1.8)}
  \thicklines
  \put(2,1){\oval(3,1.8)[tl]}
  \put(4,1){\oval(3,1.8)[b]}
  \put(4,3){\oval(3,1.8)[r]}
  \put(3,1.5){\oval(1.8,0.4)}
\end{picture}
```



The command

\put(x,y){\oval(w,h)}

or

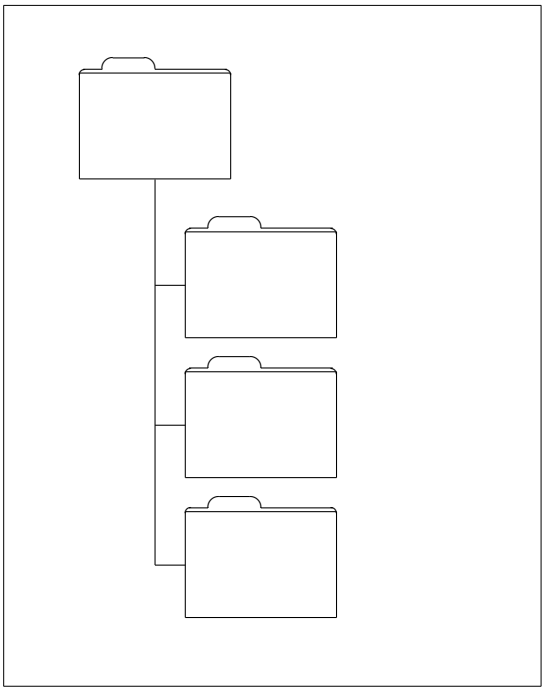
\put(x,y){\oval(w,h)[*position*]}

produces an oval centered at (x, y) and having width w and height h. The optional *position* arguments `b`, `t`, `l`, `r` refer to "top", "bottom", "left", "right", and can be combined, as the example illustrates.

Line thickness can be controlled by two kinds of commands: \linethickness{*length*} on the one hand, \thinlines and \thicklines on the other. While \linethickness{*length*} applies only to horizontal and vertical lines (and quadratic Bézier curves), \thinlines and \thicklines apply to oblique line segments as well as to circles and ovals.

5.2.8 Multiple Use of Predefined Picture Boxes

```
\setlength{\unitlength}{0.5mm}
\begin{picture}(120,168)
\newsavebox{\foldera}
\savebox{\foldera}
  (40,32)[bl]{% definition
  \multiput(0,0)(0,28){2}
    {\line(1,0){40}}
  \multiput(0,0)(40,0){2}
    {\line(0,1){28}}
  \put(1,28){\oval(2,2)[tl]}
  \put(1,29){\line(1,0){5}}
  \put(9,29){\oval(6,6)[tl]}
  \put(9,32){\line(1,0){8}}
  \put(17,29){\oval(6,6)[tr]}
  \put(20,29){\line(1,0){19}}
  \put(39,28){\oval(2,2)[tr]}
}
\newsavebox{\folderb}
\savebox{\folderb}
  (40,32)[l]{%         definition
  \put(0,14){\line(1,0){8}}
  \put(8,0){\usebox{\foldera}}
}
\put(34,26){\line(0,1){102}}
\put(14,128){\usebox{\foldera}}
\multiput(34,86)(0,-37){3}
  {\usebox{\folderb}}
\end{picture}
```



A picture box can be *declared* by the command

`\newsavebox{`*name*`}`

then *defined* by

`\savebox{`*name*`}(`*width,height*`)[`*position*`]{`*content*`}`

and finally arbitrarily often be *drawn* by

`\put(`x, y`){\usebox{`*name*`}}`

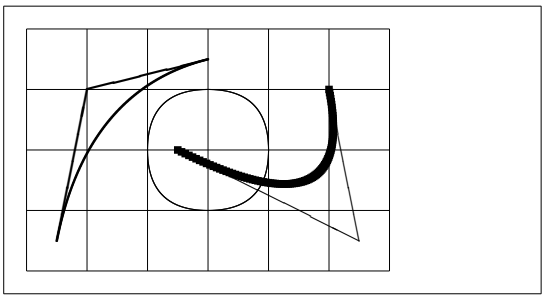
The optional *position* parameter has the effect of defining the 'anchor point' of the savebox. In the example it is set to `bl` which puts the anchor point into the bottom left corner of the savebox. The other position specifiers are `top` and `right`.

The *name* argument refers to a LaTeX storage bin and therefore is of a command nature (which accounts for the backslashes in the current example). Boxed pictures can be nested: In this example, `\foldera` is used within the definition of `\folderb`.

The `\oval` command had to be used as the `\line` command does not work if the segment length is less than about 3 mm.

5.2.9 Quadratic Bézier Curves

```
\setlength{\unitlength}{0.8cm}
\begin{picture}(6,4)
  \linethickness{0.075mm}
  \multiput(0,0)(1,0){7}
    {\line(0,1){4}}
  \multiput(0,0)(0,1){5}
    {\line(1,0){6}}
  \thicklines
  \put(0.5,0.5){\line(1,5){0.5}}
  \put(1,3){\line(4,1){2}}
  \qbezier(0.5,0.5)(1,3)(3,3.5)
  \thinlines
  \put(2.5,2){\line(2,-1){3}}
  \put(5.5,0.5){\line(-1,5){0.5}}
  \linethickness{1mm}
  \qbezier(2.5,2)(5.5,0.5)(5,3)
  \thinlines
  \qbezier(4,2)(4,3)(3,3)
  \qbezier(3,3)(2,3)(2,2)
  \qbezier(2,2)(2,1)(3,1)
  \qbezier(3,1)(4,1)(4,2)
\end{picture}
```



As this example illustrates, splitting up a circle into 4 quadratic Bézier curves is not satisfactory. At least 8 are needed. The figure again shows the effect of the `\linethickness` command on horizontal or vertical lines, and of the `\thinlines` and the `\thicklines` commands on oblique line segments. It also shows that both kinds of commands affect quadratic Bézier curves, each command overriding all previous ones.

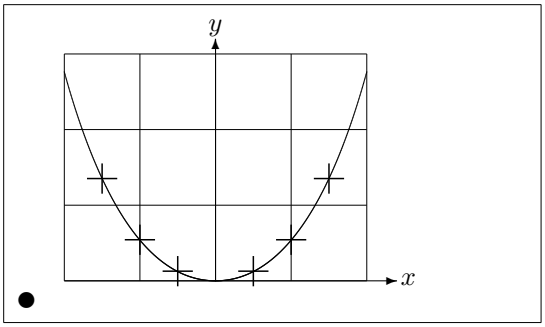
Let $P_1 = (x_1, y_1)$, $P_2 = (x_2, y_2)$ denote the end points, and m_1, m_2 the respective slopes, of a quadratic Bézier curve. The intermediate control point $S = (x, y)$ is then given by the equations

$$\begin{cases} rclx = & \dfrac{m_2 x_2 - m_1 x_1 - (y_2 - y_1)}{m_2 - m_1}, \\ y = & y_i + m_i(x - x_i) \qquad (i = 1, 2). \end{cases} \tag{5.1}$$

See *Graphics in LaTeX 2ε* [16] for a Java program which generates the necessary `\qbezier` command line.

5.2.10 Catenary

```
\setlength{\unitlength}{1cm}
\begin{picture}(4.3,3.6)(-2.5,-0.25)
\put(-2,0){\vector(1,0){4.4}}
\put(2.45,-.05){$x$}
\put(0,0){\vector(0,1){3.2}}
\put(0,3.35){\makebox(0,0){$y$}}
\qbezier(0.0,0.0)(1.2384,0.0)
  (2.0,2.7622)
\qbezier(0.0,0.0)(-1.2384,0.0)
  (-2.0,2.7622)
\linethickness{.075mm}
\multiput(-2,0)(1,0){5}
  {\line(0,1){3}}
\multiput(-2,0)(0,1){4}
  {\line(1,0){4}}
\linethickness{.2mm}
\put( .3,.12763){\line(1,0){.4}}
\put(.5,-.07237){\line(0,1){.4}}
\put(-.7,.12763){\line(1,0){.4}}
\put(-.5,-.07237){\line(0,1){.4}}
\put(.8,.54308){\line(1,0){.4}}
\put(1,.34308){\line(0,1){.4}}
\put(-1.2,.54308){\line(1,0){.4}}
\put(-1,.34308){\line(0,1){.4}}
\put(1.3,1.35241){\line(1,0){.4}}
\put(1.5,1.15241){\line(0,1){.4}}
\put(-1.7,1.35241){\line(1,0){.4}}
\put(-1.5,1.15241){\line(0,1){.4}}
\put(-2.5,-0.25){\circle*{0.2}}
\end{picture}
```



In this figure, each symmetric half of the catenary $y = \cosh x - 1$ is approximated by a quadratic Bézier curve. The right half of the curve ends in the point (2, 2.7622), the slope there having the value $m = 3.6269$. Using again equation (5.1), we can calculate the intermediate control points. They turn out to be (1.2384, 0) and (−1.2384, 0). The crosses indicate points of the *real* catenary. The error is barely noticeable, being less than one percent.

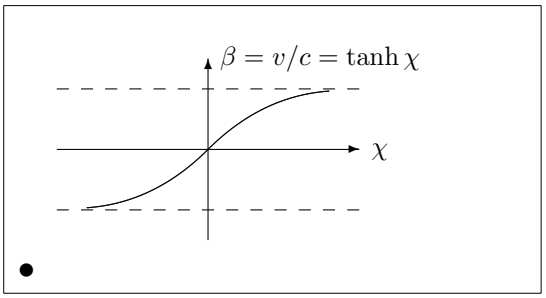
This example points out the use of the optional argument of the `\begin{picture}` command. The picture is defined in convenient "mathematical" coordinates, whereas by the command

```
\begin{picture}(4.3,3.6)(-2.5,-0.25)
```

its lower left corner (marked by the black disk) is assigned the coordinates (−2.5, −0.25).

5.2.11 Rapidity in the Special Theory of Relativity

```
\setlength{\unitlength}{0.8cm}
\begin{picture}(6,4)(-3,-2)
  \put(-2.5,0){\vector(1,0){5}}
  \put(2.7,-0.1){$\chi$}
  \put(0,-1.5){\vector(0,1){3}}
  \multiput(-2.5,1)(0.4,0){13}
    {\line(1,0){0.2}}
  \multiput(-2.5,-1)(0.4,0){13}
    {\line(1,0){0.2}}
  \put(0.2,1.4)
    {$\beta=v/c=\tanh\chi$}
  \qbezier(0,0)(0.8853,0.8853)
    (2,0.9640)
  \qbezier(0,0)(-0.8853,-0.8853)
    (-2,-0.9640)
  \put(-3,-2){\circle*{0.2}}
\end{picture}
```



The control points of the two Bézier curves were calculated with formulas (5.1). The positive branch is determined by $P_1 = (0, 0)$, $m_1 = 1$ and $P_2 = (2, \tanh 2)$, $m_2 = 1/\cosh^2 2$. Again, the picture is defined in mathematically convenient coordinates, and the lower left corner is assigned the mathematical coordinates $(-3, -2)$ (black disk).

5.3 The PGF and TikZ Graphics Packages

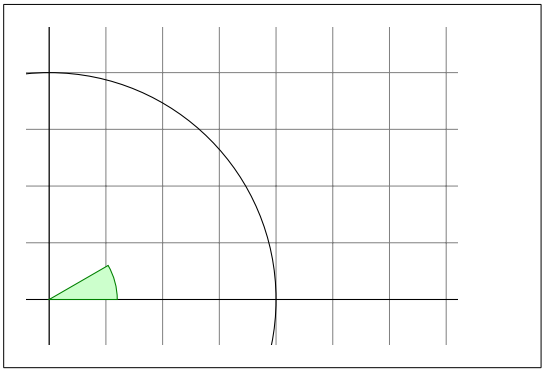
Today every LaTeX output generation system can create nice vector graphics, it's just the interfaces that are rather diverse. The pgf package provides an abstraction layer over these interface. The pgf package comes with a large manual/tutorial of its own [17]. So we are only going to scratch the surface of the package with this little section.

The pgf package comes with a high level access language provided by the tikz package. TikZ provides highly efficient commands to draw graphics right from inside your document. Use the `tikzpicture` environment to wrap your TikZ commands.

As mentioned above, there is an excellent manual for pgf and friends. So instead of actually explaining how it works, I will just show you a few examples so that you can get a first impression of how this tool works.

First a simple nonsense diagram.

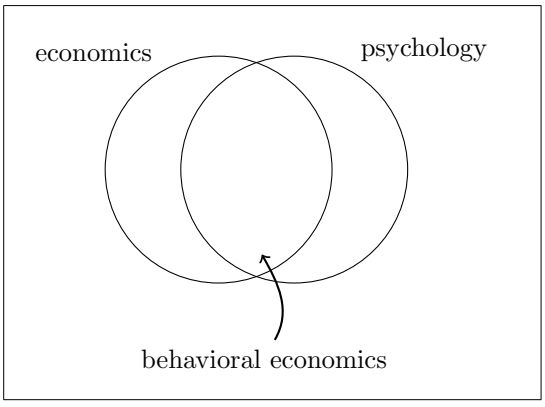
```
\begin{tikzpicture}[scale=3]
  \clip (-0.1,-0.2)
     rectangle (1.8,1.2);
  \draw[step=.25cm,gray,very thin]
       (-1.4,-1.4) grid (3.4,3.4);
  \draw (-1.5,0) -- (2.5,0);
  \draw (0,-1.5) -- (0,1.5);
  \draw (0,0) circle (1cm);
  \filldraw[fill=green!20!white,
            draw=green!50!black]
    (0,0) -- (3mm,0mm)
         arc (0:30:3mm) -- cycle;
\end{tikzpicture}
```



Note the semicolon (;) character. It separates the individual commands.

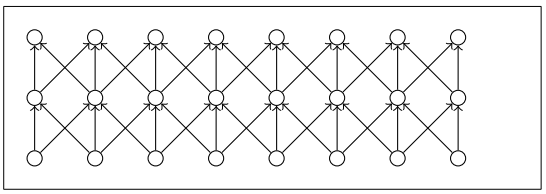
A simple Venn diagram.

```
\begin{tikzpicture}
  \node[circle,draw,
        minimum size=3cm,
        label=120:{economics}]
         at (0,0) {};
  \node[circle,draw,
        minimum size=3cm,
        label=60:{psychology}]
         at (1,0) {};
  \node (i) at (0.5,-1) {};
  \node at (0.6,-2.5)
    {behavioral economics}
    edge[->,thick,
         out=60,in=-60] (i);
\end{tikzpicture}
```



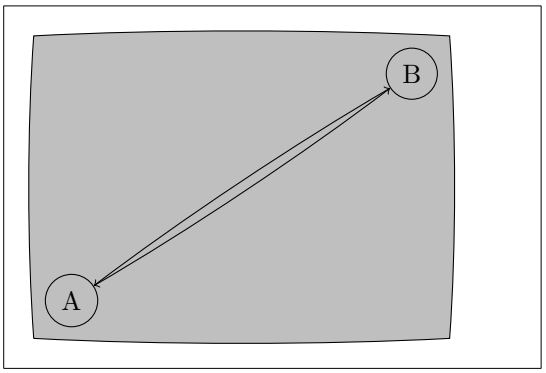
Note the foreach loops in the next example.

```
\begin{tikzpicture}[scale=0.8]
  \tikzstyle{v}=[circle, minimum size=2mm,inner sep=0pt,draw]
  \foreach \i in {1,...,8}
    \foreach \j in {1,...,3}
      \node[v]
        (G-\i-\j) at (\i,\j) {};
  \foreach \i in {1,...,8}
    \foreach \j/\o in {1/2,2/3}
      \draw[->]
        (G-\i-\j) -- (G-\i-\o);
  \foreach \i/\n in
    {1/2,2/3,3/4,4/5,5/6,6/7,7/8}
    \foreach \j/\o in {1/2,2/3} {
       \draw[->] (G-\i-\j) -- (G-\n-\o);
       \draw[->] (G-\n-\j) -- (G-\i-\o);
    }
\end{tikzpicture}
```

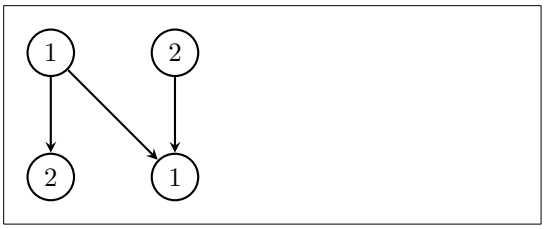


With the `\usetikzlibrary` command in the preamble you can enable a wide variety of additional features for drawing special shapes, like this box which is slightly bent.

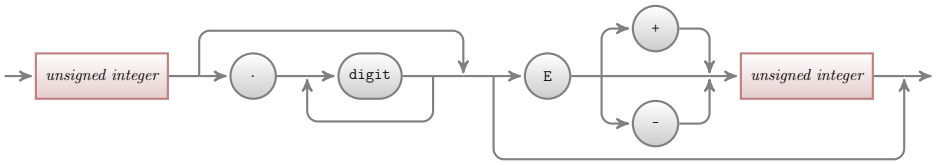
```
\usetikzlibrary{%
  decorations.pathmorphing}
\begin{tikzpicture}[
     decoration={bent,aspect=.3}]
 \draw [decorate,fill=lightgray]
        (0,0) rectangle (5.5,4);
 \node[circle,draw]
        (A) at (.5,.5) {A};
 \node[circle,draw]
        (B) at (5,3.5) {B};
 \draw[->,decorate] (A) -- (B);
 \draw[->,decorate] (B) -- (A);
\end{tikzpicture}
```



```
\usetikzlibrary{positioning}
\begin{tikzpicture}[xscale=6,
     yscale=8,>=stealth]
  \tikzstyle{v}=[circle,
     minimum size=1mm,draw,thick]
  \node[v] (a) {$1$};
  \node[v] (b) [right=of a] {$2$};
  \node[v] (c) [below=of a] {$2$};
  \node[v] (d) [below=of b] {$1$};
  \draw[thick,->]
        (a) to node {} (c);
  \draw[thick,->]
        (a) to node {} (d);
  \draw[thick,->]
        (b) to node {} (d);
\end{tikzpicture}
```



You can even draw syntax diagrams that look as if they came straight from a book on Pascal programming. The code is a bit more daunting than the example above, so I will just show you the result. If you have a look at the pgf documentation you will find a detailed tutorial on drawing this exact diagram.



And there is more, if you have to draw plots of numerical data or functions, you should have a closer look at the pgfplot package. It provides everything you need to draw plots. It can even call the external `gnuplot` command to evaluate actual functions you wrote into the graph.

For more inspiration make sure to visit Kjell Magne Fauske's excellent http://www.texample.net/tikz/. it contains an ever expanding store of beautiful graphs and other LaTeX code. On TeXample.net you will also find a list of tools to work with PGF/TikZ so that you do not have to write all that code by hand.

Chapter 6

Customising LaTeX

Documents produced with the commands you have learned up to this point will look acceptable to a large audience. While they are not fancy-looking, they obey all the established rules of good typesetting, which will make them easy to read and pleasant to look at.

However, there are situations where LaTeX does not provide a command or environment that matches your needs, or the output produced by some existing command may not meet your requirements.

In this chapter, I will try to give some hints on how to teach LaTeX new tricks and how to make it produce output that looks different from what is provided by default.

6.1 New Commands, Environments and Packages

You may have noticed that all the commands I introduce in this book are typeset in a box, and that they show up in the index at the end of the book. Instead of directly using the necessary LaTeX commands to achieve this, I have created a package in which I defined new commands and environments for this purpose. Now I can simply write:

```
\begin{lscommand}
\ci{dum}
\end{lscommand}
```

In this example, I am using both a new environment called `lscommand`, which is responsible for drawing the box around the command, and a new command named `\ci`, which typesets the command name and makes a corresponding entry in the index. Check this out by looking up the

`\dum` command in the index at the back of this book, where you'll find an entry for `\dum`, pointing to every page where I mentioned the `\dum` command.

If I ever decide that I do not like having the commands typeset in a box any more, I can simply change the definition of the `lscommand` environment to create a new look. This is much easier than going through the whole document to hunt down all the places where I have used some generic LaTeX commands to draw a box around some word.

6.1.1 New Commands

To add your own commands, use the

`\newcommand{`*name*`}[`*num*`]{`*definition*`}`

command. Basically, the command requires two arguments: the *name* of the command you want to create, and the *definition* of the command. The *num* argument in square brackets is optional and specifies the number of arguments the new command takes (up to 9 are possible). If missing it defaults to 0, i.e. no argument allowed.

The following two examples should help you to get the idea. The first example defines a new command called `\tnss`. This is short for "The Not So Short Introduction to LaTeX 2_ε." Such a command could come in handy if you had to write the title of this book over and over again.

```
\newcommand{\tnss}{The not
    so Short Introduction to
    \LaTeXe}
This is ``\tnss'' \ldots{}
``\tnss''
```

This is "The not so Short Introduction to LaTeX 2_ε" ... "The not so Short Introduction to LaTeX 2_ε"

The next example illustrates how to define a new command that takes two arguments. The `#1` tag gets replaced by the first argument you specify, `#2` with the second argument, and so on.

```
\newcommand{\txsit}[2]
 {This is the \emph{#1}
  #2 Introduction to \LaTeXe}
% in the document body:
\begin{itemize}
\item \txsit{not so}{short}
\item \txsit{very}{long}
\end{itemize}
```

- This is the *not so* short Introduction to LaTeX 2_ε
- This is the *very* long Introduction to LaTeX 2_ε

LaTeX will not allow you to create a new command that would overwrite an existing one. But there is a special command in case you explicitly want this: `\renewcommand`. It uses the same syntax as the `\newcommand` command.

In certain cases you might also want to use the `\providecommand` command. It works like `\newcommand`, but if the command is already defined, LaTeX 2ε will silently ignore it.

There are some points to note about whitespace following LaTeX commands. See page 5 for more information.

6.1.2 New Environments

Just as with the `\newcommand` command, there is a command to create your own environments. The `\newenvironment` command uses the following syntax:

`\newenvironment{`*name*`}[`*num*`]{`*before*`}{`*after*`}`

Again `\newenvironment` can have an optional argument. The material specified in the *before* argument is processed before the text in the environment gets processed. The material in the *after* argument gets processed when the `\end{`*name*`}` command is encountered.

The example below illustrates the usage of the `\newenvironment` command.

```
\newenvironment{king}
 {\rule{1ex}{1ex}%
      \hspace{\stretch{1}}}
 {\hspace{\stretch{1}}%
      \rule{1ex}{1ex}}

\begin{king}
My humble subjects \ldots
\end{king}
```

■ My humble subjects ... ■

The *num* argument is used the same way as in the `\newcommand` command. LaTeX makes sure that you do not define an environment that already exists. If you ever want to change an existing command, use the `\renewenvironment` command. It uses the same syntax as the `\newenvironment` command.

The commands used in this example will be explained later. For the `\rule` command see page 119, for `\stretch` go to page 113, and more information on `\hspace` can be found on page 113.

6.1.3 Extra Space

When creating a new environment you may easily get bitten by extra spaces creeping in, which can potentially have fatal effects, for example when you want to create a title environment which supresses its own indentation as well as the one on the following paragraph. The `\ignorespaces` command in the

begin block of the environment will make it ignore any space after executing the begin block. The end block is a bit more tricky as special processing occurs at the end of an environment. With the `\ignorespacesafterend` LaTeX will issue an `\ignorespaces` after the special 'end' processing has occurred.

```
\newenvironment{simple}%
 {\noindent}%
 {\par\noindent}

\begin{simple}
See the space\\to the left.
\end{simple}
Same\\here.
```

See the space
to the left.

Same
here.

```
\newenvironment{correct}%
 {\noindent\ignorespaces}%
 {\par\noindent%
   \ignorespacesafterend}

\begin{correct}
No space\\to the left.
\end{correct}
Same\\here.
```

No space
to the left.

Same
here.

6.1.4 Command-line LaTeX

If you work on a Unix-like OS, you might be using Makefiles to build your LaTeX projects. In that connection it might be interesting to produce different versions of the same document by calling LaTeX with command-line parameters. If you add the following structure to your document:

```
\usepackage{ifthen}
\ifthenelse{\equal{\blackandwhite}{true}}{
  % "black and white" mode; do something..
}{
  % "color" mode; do something different..
}
```

Now call LaTeX like this:

```
latex '\newcommand{\blackandwhite}{true}\input{test.tex}'
```

First the command `\blackandwhite` gets defined and then the actual file is read with input. By setting `\blackandwhite` to false the color version of the document would be produced.

6.1.5 Your Own Package

If you define a lot of new environments and commands, the preamble of your document will get quite long. In this situation, it is a good idea to create a LaTeX package containing all your command and environment definitions. Use the \usepackage command to make the package available in your document.

```
% Demo Package by Tobias Oetiker
\ProvidesPackage{demopack}
\newcommand{\tnss}{The not so Short Introduction
                   to \LaTeXe}
\newcommand{\txsit}[1]{The \emph{#1} Short
                       Introduction to \LaTeXe}
\newenvironment{king}{\begin{quote}}{\end{quote}}
```

Figure 6.1: Example Package.

Writing a package basically consists of copying the contents of your document preamble into a separate file with a name ending in .sty. There is one special command,

\ProvidesPackage{*package name*}

for use at the very beginning of your package file. \ProvidesPackage tells LaTeX the name of the package and will allow it to issue a sensible error message when you try to include a package twice. Figure 6.1 shows a small example package that contains the commands defined in the examples above.

6.2 Fonts and Sizes

6.2.1 Font Changing Commands

LaTeX chooses the appropriate font and font size based on the logical structure of the document (sections, footnotes, ...). In some cases, one might like to change fonts and sizes by hand. To do this, use the commands listed in Tables 6.1 and 6.2. The actual size of each font is a design issue and depends on the document class and its options. Table 6.3 shows the absolute point size for these commands as implemented in the standard document classes.

```
{\small The small and
\textbf{bold} Romans ruled}
{\Large all of great big
\textit{Italy}.}
```

The small and **bold** Romans ruled all of great big *Italy*.

One important feature of LaTeX 2_ε is that the font attributes are independent. This means that issuing size or even font changing commands, and still keep bold or slant attributes set earlier.

In *math mode* use the font changing *commands* to temporarily exit *math mode* and enter some normal text. If you want to switch to another font for math typesetting you need another special set of commands; refer to Table 6.4.

In connection with the font size commands, curly braces play a significant role. They are used to build *groups*. Groups limit the scope of most LaTeX commands.

```
He likes {\LARGE large and
{\small small} letters}.
```

He likes large and small letters.

The font size commands also change the line spacing, but only if the paragraph ends within the scope of the font size command. The closing curly brace `}` should therefore not come too early. Note the position of the

Table 6.1: Fonts.

`\textrm{...}`	roman	`\textsf{...}`	sans serif
`\texttt{...}`	typewriter		
`\textmd{...}`	medium	`\textbf{...}`	**bold face**
`\textup{...}`	upright	`\textit{...}`	*italic*
`\textsl{...}`	*slanted*	`\textsc{...}`	Small Caps
`\emph{...}`	*emphasized*	`\textnormal{...}`	document font

Table 6.2: Font Sizes.

`\tiny`	tiny font	`\Large`	larger font
`\scriptsize`	very small font	`\LARGE`	very large font
`\footnotesize`	quite small font	`\huge`	huge
`\small`	small font	`\Huge`	largest
`\normalsize`	normal font		
`\large`	large font		

Table 6.3: Absolute Point Sizes in Standard Classes.

size	10pt (default)	11pt option	12pt option
`\tiny`	5pt	6pt	6pt
`\scriptsize`	7pt	8pt	8pt
`\footnotesize`	8pt	9pt	10pt
`\small`	9pt	10pt	11pt
`\normalsize`	10pt	11pt	12pt
`\large`	12pt	12pt	14pt
`\Large`	14pt	14pt	17pt
`\LARGE`	17pt	17pt	20pt
`\huge`	20pt	20pt	25pt
`\Huge`	25pt	25pt	25pt

Table 6.4: Math Fonts.

`\mathrm{...}`	Roman Font
`\mathbf{...}`	**Boldface Font**
`\mathsf{...}`	Sans Serif Font
`\mathtt{...}`	`Typewriter Font`
`\mathit{...}`	*Italic Font*
`\mathcal{...}`	$\mathcal{CALLIGRAPHIC\ FONT}$
`\mathnormal{...}`	*Normal Font*

\par command in the next two examples. [1]

```
{\Large Don't read this!
 It is not true.
 You can believe me!\par}
```

{Large Don't read this! It is not true. You can believe me!\par}

```
{\Large This is not true either.
But remember I am a liar.}\par
```

{Large This is not true either. But remember I am a liar.}\par

If you want to activate a size changing command for a whole paragraph of text or even more, you might want to use the environment syntax for font changing commands.

```
\begin{Large}
This is not true.
But then again, what is these
days \ldots
\end{Large}
```

\begin{Large}
This is not true.
But then again, what is these
days \ldots
\end{Large}

This will save you from counting lots of curly braces.

6.2.2 Danger, Will Robinson, Danger

As noted at the beginning of this chapter, it is dangerous to clutter your document with explicit commands like this, because they work in opposition to the basic idea of LaTeX, which is to separate the logical and visual markup of your document. This means that if you use the same font changing command in several places in order to typeset a special kind of information, you should use \newcommand to define a "logical wrapper command" for the font changing command.

```
\newcommand{\oops}[1]{%
 \textbf{#1}}
Do not \oops{enter} this room,
it's occupied by \oops{machines}
of unknown origin and purpose.
```

\newcommand{\oops}[1]{%
\textbf{#1}}
Do not \oops{enter} this room,
it's occupied by \oops{machines}
of unknown origin and purpose.

This approach has the advantage that you can decide at some later stage that you want to use a visual representation of danger other than \textbf, without having to wade through your document, identifying all the occurrences of \textbf and then figuring out for each one whether it was used for pointing out danger or for some other reason.

[1] \par is equivalent to a blank line

Please note the difference between telling LaTeX to *emphasize* something and telling it to use a different *font*. The `\emph` command is context aware, while the font commands are absolute.

```
\textit{You can also
  \emph{emphasize} text if
  it is set in italics,}
\textsf{in a
  \emph{sans-serif} font,}
\texttt{or in
  \emph{typewriter} style.}
```

You can also emphasize text if it is set in italics, in a *sans-serif* font, or in *typewriter* style.

6.2.3 Advice

To conclude this journey into the land of fonts and font sizes, here is a little word of advice:

Remember! *The* MO RE fonts YOU use **in** a document, *the* more READABLE and *beautiful it becomes*.

6.3 Spacing

6.3.1 Line Spacing

If you want to use larger inter-line spacing in a document, change its value by putting the

`\linespread{`*factor*`}`

command into the preamble of your document. Use `\linespread{1.3}` for "one and a half" line spacing, and `\linespread{1.6}` for "double" line spacing. Normally the lines are not spread, so the default line spread factor is 1.

Note that the effect of the `\linespread` command is rather drastic and not appropriate for published work. So if you have a good reason for chang-

ing the line spacing you might want to use the command:

```
\setlength{\baselineskip}{1.5\baselineskip}
```

```
{\setlength{\baselineskip}%
           {1.5\baselineskip}
This paragraph is typeset with
the baseline skip set to 1.5 of
what it was before. Note the par
command at the end of the
paragraph.\par}

This paragraph has a clear
purpose, it shows that after the
curly brace has been closed,
everything is back to normal.
```

This paragraph is typeset with the baseline skip set to 1.5 of what it was before. Note the par command at the end of the paragraph.

This paragraph has a clear purpose, it shows that after the curly brace has been closed, everything is back to normal.

6.3.2 Paragraph Formatting

In LaTeX, there are two parameters influencing paragraph layout. By placing a definition like

```
\setlength{\parindent}{0pt}
\setlength{\parskip}{1ex plus 0.5ex minus 0.2ex}
```

in the preamble of the input file, you can change the layout of paragraphs. These two commands increase the space between two paragraphs while setting the paragraph indent to zero.

The `plus` and `minus` parts of the length above tell TeX that it can compress and expand the inter-paragraph skip by the amount specified, if this is necessary to properly fit the paragraphs onto the page.

In continental Europe, paragraphs are often separated by some space and not indented. But beware, this also has its effect on the table of contents. Its lines get spaced more loosely now as well. To avoid this, you might want to move the two commands from the preamble into your document to some place below the command `\tableofcontents` or to not use them at all, because you'll find that most professional books use indenting and not spacing to separate paragraphs.

If you want to indent a paragraph that is not indented, use

```
\indent
```

at the beginning of the paragraph.[2] Obviously, this will only have an effect

[2] To indent the first paragraph after each section head, use the indentfirst package in the 'tools' bundle.

when \parindent is not set to zero.

To create a non-indented paragraph, use

\noindent

as the first command of the paragraph. This might come in handy when you start a document with body text and not with a sectioning command.

6.3.3 Horizontal Space

LaTeX determines the spaces between words and sentences automatically. To add horizontal space, use:

\hspace{*length*}

If such a space should be kept even if it falls at the end or the start of a line, use \hspace* instead of \hspace. The *length* in the simplest case is just a number plus a unit. The most important units are listed in Table 6.5.

```
This\hspace{1.5cm}is a space
of 1.5 cm.
```

This is a space of 1.5 cm.

The command

\stretch{*n*}

generates a special rubber space. It stretches until all the remaining space on a line is filled up. If multiple \hspace{\stretch{*n*}} commands are issued on the same line, they occupy all available space in proportion of their respective stretch factors.

```
x\hspace{\stretch{1}}
x\hspace{\stretch{3}}x
```

x x x

When using horizontal space together with text, it may make sense to make the space adjust its size relative to the size of the current font. This can be done by using the text-relative units em and ex:

```
{\Large{}big\hspace{1em}y}\\
{\tiny{}tin\hspace{1em}y}
```

big y
tin y

Table 6.5: TeX Units.

`mm`	millimetre ≈ 1/25 inch	␣
`cm`	centimetre = 10 mm	␣␣
`in`	inch = 25.4 mm	␣␣␣
`pt`	point ≈ 1/72 inch ≈ $\frac{1}{3}$ mm	‖
`em`	approx width of an 'M' in the current font	␣
`ex`	approx height of an 'x' in the current font	␣

6.3.4 Vertical Space

The space between paragraphs, sections, subsections, ... is determined automatically by LaTeX. If necessary, additional vertical space *between two paragraphs* can be added with the command:

`\vspace{`*length*`}`

This command should normally be used between two empty lines. If the space should be preserved at the top or at the bottom of a page, use the starred version of the command, `\vspace*`, instead of `\vspace`.

The `\stretch` command, in connection with `\pagebreak`, can be used to typeset text on the last line of a page, or to centre text vertically on a page.

```
Some text \ldots

\vspace{\stretch{1}}
This goes onto the last line of the page.\pagebreak
```

Additional space between two lines of *the same* paragraph or within a table is specified with the

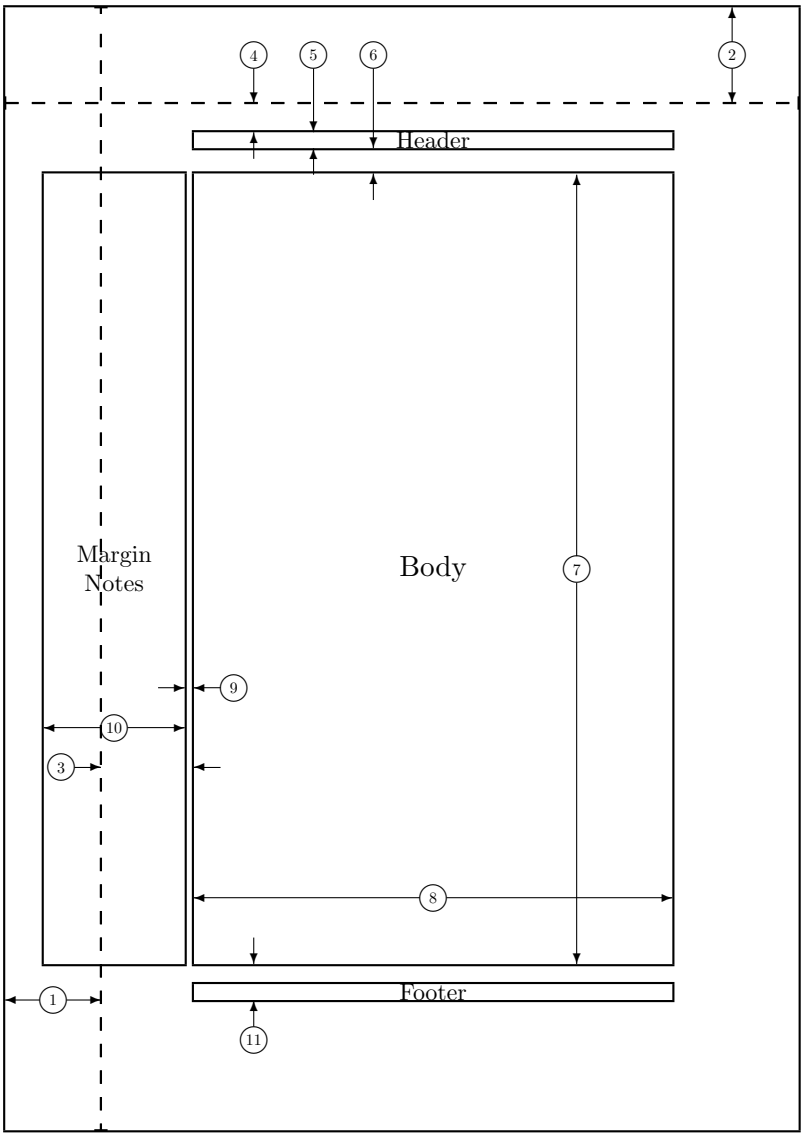
`\\[`*length*`]`

command.

With `\bigskip` and `\smallskip` you can skip a predefined amount of vertical space without having to worry about exact numbers.

6.4 Page Layout

LaTeX 2$_\varepsilon$ allows you to specify the paper size in the `\documentclass` command. It then automatically picks the right text margins, but sometimes



1	one inch + \hoffset	2	one inch + \voffset
3	\oddsidemargin = 22pt or \evensidemargin	4	\topmargin = 22pt
5	\headheight = 12pt	6	\headsep = 19pt
7	\textheight = 595pt	8	\textwidth = 360pt
9	\marginparsep = 7pt	10	\marginparwidth = 106pt
11	\footskip = 27pt		\marginparpush = 5pt (not shown)
	\hoffset = 0pt		\voffset = 0pt
	\paperwidth = 597pt		\paperheight = 845pt

Figure 6.2: Layout parameters for this book. Try the layouts package to print the layout of your own document.

you may not be happy with the predefined values. Naturally, you can change them. Figure 6.2 shows all the parameters that can be changed. The figure was produced with the layout package from the tools bundle.[3]

WAIT! ...before you launch into a "Let's make that narrow page a bit wider" frenzy, take a few seconds to think. As with most things in LaTeX, there is a good reason for the page layout to be as it is.

Sure, compared to your off-the-shelf MS Word page, it looks awfully narrow. But take a look at your favourite book[4] and count the number of characters on a standard text line. You will find that there are no more than about 66 characters on each line. Now do the same on your LaTeX page. You will find that there are also about 66 characters per line. Experience shows that the reading gets difficult as soon as there are more characters on a single line. This is because it is difficult for the eyes to move from the end of one line to the start of the next one. This is also why newspapers are typeset in multiple columns.

So if you increase the width of your body text, keep in mind that you are making life difficult for the readers of your paper. But enough of the cautioning, I promised to tell you how you do it ...

LaTeX provides two commands to change these parameters. They are usually used in the document preamble.

The first command assigns a fixed value to any of the parameters:

`\setlength{`*parameter*`}{`*length*`}`

The second command adds a length to any of the parameters:

`\addtolength{`*parameter*`}{`*length*`}`

This second command is actually more useful than the `\setlength` command, because it works relative to the existing settings. To add one centimetre to the overall text width, I put the following commands into the document preamble:

```
\addtolength{\hoffset}{-0.5cm}
\addtolength{\textwidth}{1cm}
```

In this context, you might want to look at the calc package. It allows you to use arithmetic operations in the argument of `\setlength` and other places where numeric values are entered into function arguments.

[3] `pkg/tools`

[4] I mean a real printed book produced by a reputable publisher.

6.5 More Fun With Lengths

Whenever possible, I avoid using absolute lengths in LaTeX documents. I rather try to base things on the width or height of other page elements. For the width of a figure this could be `\textwidth` in order to make it fill the page.

The following 3 commands allow you to determine the width, height and depth of a text string.

```
\settoheight{variable}{text}
\settodepth{variable}{text}
\settowidth{variable}{text}
```

The example below shows a possible application of these commands.

```
\flushleft
\newenvironment{vardesc}[1]{%
  \settowidth{\parindent}{#1:\ }
  \makebox[0pt][r]{#1:\ }}{}

\begin{displaymath}
a^2+b^2=c^2
\end{displaymath}

\begin{vardesc}{Where}$a$,
$b$ -- are adjacent to the right
angle of a right-angled triangle.

$c$ -- is the hypotenuse of
the triangle and feels lonely.

$d$ -- finally does not show up
here at all. Isn't that puzzling?
\end{vardesc}
```

$$a^2 + b^2 = c^2$$

Where: a, b – are adjacent to the right angle of a right-angled triangle.

c – is the hypotenuse of the triangle and feels lonely.

d – finally does not show up here at all. Isn't that puzzling?

6.6 Boxes

LaTeX builds up its pages by pushing around boxes. At first, each letter is a little box, which is then glued to other letters to form words. These are again glued to other words, but with special glue, which is elastic so that a series of words can be squeezed or stretched as to exactly fill a line on the page.

I admit, this is a very simplistic version of what really happens, but the point is that TeX operates on glue and boxes. Letters are not the only things that can be boxes. You can put virtually everything into a box, including

other boxes. Each box will then be handled by LaTeX as if it were a single letter.

In earlier chapters you encountered some boxes, although I did not tell you. The `tabular` environment and the `\includegraphics`, for example, both produce a box. This means that you can easily arrange two tables or images side by side. You just have to make sure that their combined width is not larger than the textwidth.

You can also pack a paragraph of your choice into a box with either the

`\parbox[`*pos*`]{`*width*`}{`*text*`}`

command or the

`\begin{minipage}[`*pos*`]{`*width*`}` text `\end{minipage}`

environment. The `pos` parameter can take one of the letters `c`, `t` or `b` to control the vertical alignment of the box, relative to the baseline of the surrounding text. `width` takes a length argument specifying the width of the box. The main difference between a `minipage` and a `\parbox` is that you cannot use all commands and environments inside a `parbox`, while almost anything is possible in a `minipage`.

While `\parbox` packs up a whole paragraph doing line breaking and everything, there is also a class of boxing commands that operates only on horizontally aligned material. We already know one of them; it's called `\mbox`. It simply packs up a series of boxes into another one, and can be used to prevent LaTeX from breaking two words. As boxes can be put inside boxes, these horizontal box packers give you ultimate flexibility.

`\makebox[`*width*`][`*pos*`]{`*text*`}`

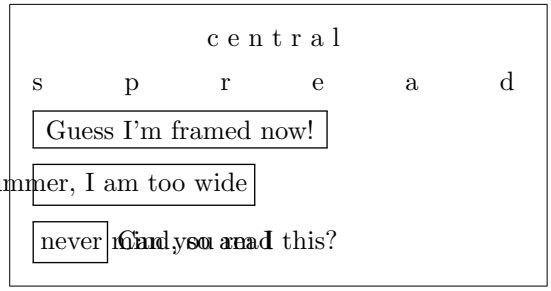
`width` defines the width of the resulting box as seen from the outside.[5] Besides the length expressions, you can also use `\width`, `\height`, `\depth`, and `\totalheight` in the width parameter. They are set from values obtained by measuring the typeset *text*. The *pos* parameter takes a one letter value: **c**enter, flush**l**eft, flush**r**ight, or **s**pread the text to fill the box.

The command `\framebox` works exactly the same as `\makebox`, but it draws a box around the text.

The following example shows you some things you could do with the `\makebox` and `\framebox` commands.

[5] This means it can be smaller than the material inside the box. You can even set the width to 0pt so that the text inside the box will be typeset without influencing the surrounding boxes.

```
\makebox[\textwidth]{%
    c e n t r a l}\par
\makebox[\textwidth][s]{%
    s p r e a d}\par
\framebox[1.1\width]{Guess I'm
    framed now!} \par
\framebox[0.8\width][r]{Bummer,
    I am too wide} \par
\framebox[1cm][l]{never
    mind, so am I}
Can you read this?
```

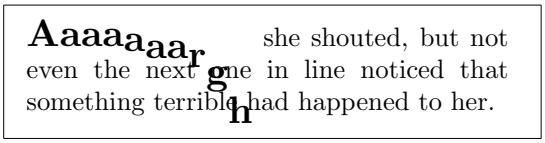


Now that we control the horizontal, the obvious next step is to go for the vertical.[6] No problem for LaTeX. The

`\raisebox{`*lift*`}[`*extend-above-baseline*`][`*extend-below-baseline*`]{`*text*`}`

command lets you define the vertical properties of a box. You can use `\width`, `\height`, `\depth`, and `\totalheight` in the first three parameters, in order to act upon the size of the box inside the *text* argument.

```
\raisebox{0pt}[0pt][0pt]{\Large%
\textbf{Aaaa\raisebox{-0.3ex}{a}%
\raisebox{-0.7ex}{aa}%
\raisebox{-1.2ex}{r}%
\raisebox{-2.2ex}{g}%
\raisebox{-4.5ex}{h}}}
she shouted, but not even the next
one in line noticed that something
terrible had happened to her.
```



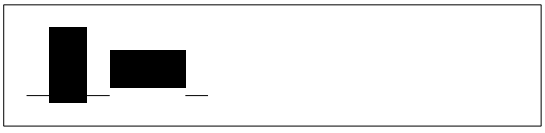
6.7 Rules

A few pages back you may have noticed the command

`\rule[`*lift*`]{`*width*`}{`*height*`}`

In normal use it produces a simple black box.

```
\rule{3mm}{.1pt}%
\rule[-1mm]{5mm}{1cm}%
\rule{3mm}{.1pt}%
\rule[1mm]{1cm}{5mm}%
\rule{3mm}{.1pt}
```



[6] Total control is only to be obtained by controlling both the horizontal and the vertical ...

This is useful for drawing vertical and horizontal lines. The line on the title page, for example, has been created with a `\rule` command.

The End.

Appendix A

Installing LaTeX

Knuth published the source to TeX back in a time when nobody knew about Open Source and/or Free Software. The License that comes with TeX lets you do whatever you want with the source, but you can only call the result of your work TeX if the program passes a set of tests Knuth has also provided. This has lead to a situation where we have free TeX implementations for almost every Operating System under the sun. This chapter will give some hints on what to install on Linux, macOS and Windows, to get a working TeX setup.

A.1 What to Install

To use LaTeX on any computer system, you need several programs.

1. The TeX/LaTeX program for processing your LaTeX source files into typeset PDF or DVI documents.
2. A text editor for editing your LaTeX source files. Some products even let you start the LaTeX program from within the editor.
3. A PDF/DVI viewer program for previewing and printing your documents.
4. A program to handle PostScript files and images for inclusion into your documents.

For every platforms there are several programs that fit the requirements above. Here we just tell about the ones we know, like and have some experience with.

A.2 Cross Platform Editor

While TeX is available on many different computing platforms, LaTeX editors have long been highly platform specific.

Over the past few years I have come to like Texmaker quite a lot. Apart from being very a useful editor with integrated pdf-preview and syntax highlighting, it has the advantage of running on Windows, Mac and Unix/Linux equally well. See http://www.xm1math.net/texmaker for further information. There is also a forked version of Texmaker called TeXstudio on http://texstudio.sourceforge.net/. It also seems well maintained and is also available for all three major platforms.

You will find some platform specific editor suggestions in the OS sections below.

A.3 TeX on macOS

A.3.1 TeX Distribution

Just download MacTeX. It is a pre-compiled LaTeX distribution for macOS. MacTeX provides a full LaTeX installation plus a number of additional tools. Get MacTeX from http://www.tug.org/mactex/.

A.3.2 macOS TeX Editor

If you are not happy with our cross-platform suggestion Texmaker (section A.2).

The most popular open source editor for LaTeX on the mac seems to be TeXshop. Get a copy from http://www.uoregon.edu/~koch/texshop. It is also contained in the MacTeX distribution.

Recent TeXLive distributions contain the TeXworks editor http://texworks.org/ which is a multi-platform editor based on the TeXShop design. Since TeXworks uses the Qt toolkit, it is available on any platform supported by this toolkit (macOS, Windows, Linux).

A.3.3 Treat yourself to PDFView

Use PDFView for viewing PDF files generated by LaTeX, it integrates tightly with your LaTeX text editor. PDFView is an open-source application, available from the PDFView website on
http://pdfview.sourceforge.net/. After installing, open PDFViews preferences dialog and make sure that the *automatically reload documents* option is enabled and that PDFSync support is set appropriately.

A.4 TeX on Windows

A.4.1 Getting TeX

First, get a copy of the excellent MiKTeX distribution from
http://www.miktex.org/. It contains all the basic programs and files re-

quired to compile LATEX documents. The coolest feature in my eyes, is that MiKTEX will download missing LATEX packages on the fly and install them magically while compiling a document. Alternatively you can also use the TeXlive distribution which exists for Windows, Unix and Mac OS to get your base setup going http://www.tug.org/texlive/.

A.4.2 A LATEX editor

If you are not happy with our cross-platform suggestion Texmaker (section A.2).

TeXnicCenter uses many concepts from the programming-world to provide a nice and efficient LATEX writing environment in Windows. Get your copy from
http://www.texniccenter.org/. TeXnicCenter integrates nicely with MiKTeX.

Recent TEXLive distributions contain the TEXworks Editor http://texworks.org/. It supports Unicode and requires at least Windows XP.

A.4.3 Document Preview

You will most likely be using Yap for DVI preview as it gets installed with MikTeX. For PDF you may want to look at Sumatra PDF http://blog.kowalczyk.info/software/sumatrapdf/. I mention Sumatra PDF because it lets you jump from any position in the pdf document back into corresponding position in your source document.

A.4.4 Working with graphics

Working with high quality graphics in LATEX means that you have to use Encapsulated PostScript (eps) or PDF as your picture format. The program that helps you deal with this is called GhostScript. You can get it, together with its own front-end GhostView, from http://www.cs.wisc.edu/~ghost/.

If you deal with bitmap graphics (photos and scanned material), you may want to have a look at the open source Photoshop alternative Gimp, available from http://gimp-win.sourceforge.net/.

A.5 TEX on Linux

If you work with Linux, chances are high that LATEX is already installed on your system, or at least available on the installation source you used to setup. Use your package manager to install the following packages:

- texlive – the base TEX/LATEX setup.

- emacs (with AUCTeX) – an editor that integrates tightly with LaTeX through the add-on AUCTeX package.
- ghostscript – a PostScript preview program.
- xpdf and acrobat – a PDF preview program.
- imagemagick – a free program for converting bitmap images.
- gimp – a free Photoshop look-a-like.
- inkscape – a free illustrator/corel draw look-a-like.

If you are looking for a more windows like graphical editing environment, check out Texmaker. See section A.2.

Most Linux distros insist on splitting up their TeX environments into a large number of optional packages, so if something is missing after your first install, go check again.

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