

A Guide to

L^AT_EX

and Electronic Publishing

Fourth edition

Helmut Kopka

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Preface

A new edition to *A Guide to L^AT_EX* begs the fundamental question: Has L^AT_EX changed so much since the appearance of the third edition in 1999 that a new release of this manual is justified?

The simple answer to that question is ‘Well . . .’ In 1994, the L^AT_EX world was in upheaval with the issue of the new version L^AT_EX 2_ε, and the second edition of the *Guide* came out just then to act as the bridge between the old and new versions. By 1998, the initial teething problems had been worked out and corrected through semi-annual releases, and the third edition could describe an established, working system. However, homage was still paid to the older 2.09 version since many users still employed its familiar syntax, although they were most likely to be using it in a L^AT_EX 2_ε environment. L^AT_EX has now reached a degree of stability that since 2000 the regular updates have been reduced to annual events, which often appear months after the nominal date, something that does not worry anyone. The old version 2.09 is obsolete and should no longer play any role in such a manual. In this fourth edition, it is reduced to an appendix just to document its syntax and usage.

But if L^AT_EX itself has not changed substantially since 1999, many of its peripherals have. The rise of programs like pdfL^AT_EX and dvi_{pdfm} for PDF output adds new possibilities, which are realized, not in L^AT_EX directly, but by means of more modern *packages* to extend the basic features. The distribution of T_EX/L^AT_EX installations has changed, such that most users are given a complete, ready-to-run setup, with all the ‘extras’ that one used to have to obtain oneself. Those extras include user-contributed packages, many of which are now considered indispensable. Today ‘the L^AT_EX system’ includes much more than the basic kernel by Leslie Lamport, encompassing the contributions of hundreds of other people. This edition reflects this increase in breadth.

The changes to the fourth edition are mainly those of emphasis.

1. The material has been reorganized into ‘Basics’ and ‘Beyond the Basics’ (‘advanced’ sounds too intimidating) while the appendices contain topics that really can be skipped by most everyday users. Exception: Appendix H is an alphabetized command summary that many people find extremely useful (including ourselves).

This reorganizing is meant to stress certain aspects over others. For

example, the section on graphics inclusion and color was originally treated as an exotic freak, relegated to an appendix on extensions; in the third edition, it moved up to be included in a front chapter along with the `picture` environment and floats; now it dominates Chapter 6 all on its own, the floats come in the following Chapter 7, and `picture` is banished to the later Chapter 13. This is not to say that the `picture` features are no good, but only that they are very specialized. We add descriptions of additional drawing possibilities there too.

2. It is stressed as much as possible that \LaTeX is a *markup* language, with separation of content and form. Typographical settings should be placed in the preamble, while the body contains only logical markup. This is in keeping with the modern ideas of XML, where form and content are radically segregated.
3. Throughout this edition, contributed packages are explained at that point in the text where they are most relevant. The `fancyhdr` package comes in the section on page styles, `natbib` where literature citations are explained. This stresses that these ‘extensions’ are part of the \LaTeX system as a whole. However, to remind the user that they must still be explicitly loaded, a marginal note is placed at the start of their descriptions.
4. PDF output is taken for granted throughout the book, in addition to the classical DVI format. This means that the added possibilities of `pdf \TeX` and `dvi pdfm` are explained where they are relevant. A separate Chapter 10 on PostScript and PDF is still necessary, and the best interface to PDF output, the `hyperref` package by Sebastian Rahtz, is explained in detail. PDF is also included in Chapter 15 on presentation material.

On the other hand, the other Web output formats, HTML and XML, are only dealt with briefly in Appendix E, since these are large topics treated in other books, most noticeably the *\LaTeX Web Companion*.

5. This book is being distributed with the \TeX Live CD, with the kind permission of Sebastian Rahtz who maintains it for the \TeX Users Group. It contains a full \TeX and \LaTeX installation for Windows, Macintosh, and Linux, plus many of the myriad extensions that exist.

We once again express our hope that this *Guide* will prove more than useful to all those who wish to find their way through the intricate world of \LaTeX . And with the addition of the \TeX Live CD, that world is brought even closer to their doorsteps.

Helmut Kopka and Patrick W. Daly
June, 2003

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Part I

Basics

Introduction

1.1 Just what is L^AT_EX?

To summarize very briefly:

- L^AT_EX is a comprehensive set of markup commands used with the powerful typesetting program T_EX for the preparation of a wide variety of documents, from scientific articles, reports, to complex books.
- L^AT_EX like T_EX is an open software system, available free of charge. Its core is maintained by the L^AT_EX3 Project Group but it also benefits from extensions written by hundreds of user/contributors, with all the advantages and disadvantages of such a democracy.
- A L^AT_EX document consists of one or more source files containing plain text characters, the actual textual content plus markup commands. These include instructions which can insert graphical material produced by other programs.
- It is processed by the T_EX program to produce a binary file in DVI (*device independent*) format, containing precise directions for the typesetting of each character. This in turn can be viewed on a monitor, or converted into printer instructions, or some other electronic form such as PostScript, HTML, XML, or PDF.
- A variant on the T_EX program called pdfT_EX produces PDF output directly from the source file without going through the DVI intermediary. With this, L^AT_EX can automatically include internal links and bookmarks with little or no extra effort, plus PDF buttons and external links, in addition to graphics in a wide range of common formats.
- T_EX activities are coordinated by the T_EX Users Group, TUG (www.tug.org) who distribute a set of CDs, called T_EXLive, annually to its

members, containing a T_EX/L^AT_EX installation for various computer types.

The rest of this book attempts to fill in the gaps in the above summary. With the help of the included T_EXLive CD for Windows, Macintosh, and Linux, which also contains a directory specific to this book (`\books\Kopka_and_DaLy\`), we hope that the user will have additional pleasure in learning the joys of L^AT_EX.

1.2 Markup Languages

1.2.1 Typographical markup

In the days before computers, an author would prepare a *manuscript* either by hand or by typewriter, which he or she would submit to a publisher. Once accepted for publication (and after several rounds of corrections and modifications, each requiring a rewrite of the paper manuscript), it would be sent to a copy editor, a human being who would decorate the manuscript with *markup*, marginal notes that inform the typesetter (another human being) which fonts and spacings and other typographical features should be used to convert it to the final printed form that one expects of books and articles.

Electronic processing of text today follows a similar procedure, except that the humans have been replaced by computer programs. (So far the author has avoided this fate, but they are working on it.) The markup is normally included directly in the manuscript in such a way that it is converted immediately to its output form and displayed on the computer monitor. This is known as WYSIWYG, or ‘what you see is what you get’.

However, what you see is not always what you’ve got. An alternative that is used more and more by major publishers is *markup languages*, in which the raw text is interspersed with indicators ‘for the typesetter.’ The result as seen on the monitor is much the same as a typewritten manuscript, except that the markup is no longer abbreviated marginal notes, but cryptic code within the actual text. This *source text*, which can be prepared by a simple, dumb *text editor* program, is converted into typographically set output by a separate program.

For example, to code the line

He took a **bold step** forward.

with HTML, the classical markup language of the World Wide Web, one enters in the source text:

He took a `bold step` forward.

In Plain T_EX, the same sentence would be coded as:

He took a `{\bf bold step}` forward.

The first example is to be processed (displayed) by a Web browser program that decides to set everything between `` and `` as bold face. The second example is intended for the \TeX program (Section 1.3). The markup in these two examples follow different rules, different syntax, but the functionality is the same.

1.2.2 Logical markup

The above examples illustrate *typographical markup*, where the inserted commands or tags give direct instructions to alter the appearance of the output, here a change of font. An alternative is to indicate the purpose of the text. For example, HTML recognizes several levels of headings; to place a title into the highest level one enters:

```
<h1>Logical Markup</h1>
```

The equivalent \LaTeX entry would be:

```
\section{Logical Markup}
```

With this *logical markup*, the author concentrates entirely on the content and leaves the typographical considerations to the experts. One merely marks the structure of the document, and has no means of controlling how the logical elements, like section titles, are to be rendered typographically. This information is put into HTML style sheets or \LaTeX classes and packages, which are external to the actual source file. This means that the entire layout of a document can be overhauled with only minimal or even no alterations to the source file.

Today much effort is being put into XML, the Extensible Markup Language, as the ultimate markup system, since it allows the markup, or tags, to be defined as needed, without any indication of how they are to be implemented. That is left to XSL, the Extensible Stylesheet Language. It must be emphasized that neither XML nor XSL are programs at all; they are specifications for how documents and databases may be marked up, and how the markup tags may be translated into real output. Programs still need to be found to do the actual job.

And that is the fundamental idea behind markup languages: that the source text indicates the logical structure of its contents. Such source files, being written in plain ASCII text, are extremely robust, not being married to any particular software package or computer type.

What does all this have to do with \LaTeX ? In the next Section we outline the development of \TeX and \LaTeX , and go on to show that \LaTeX , a product of the mid 1980's, is a programmable markup language that is ideally suited for the modern world of electronic publishing.

1.3 T_EX and its offspring

The most powerful formatting program for producing book quality text of scientific and technical works is that of Donald E. Knuth (Knuth, 1986a, 1986b, 1986c, 1986d, 1986e). The program is called T_EX, which is a rendering in capitals of the Greek letters $\tau\epsilon\chi$. For this reason the last letter is pronounced not as an *x*, but as the *ch* in Scottish *loch* or German *ach*, or as the Spanish *j* or Russian *kh*. The name is meant to emphasize that the printing of mathematical texts is an integral part of the program and not a cumbersome add-on. In addition to T_EX, the same author has developed a further program called METAFONT for the production of character fonts. The standard T_EX program package contains 75 fonts in various design sizes, each of which is also available in up to eight magnification steps. All these fonts were produced with the program METAFONT. With additional applications, further character fonts have been created, such as for Cyrillic, Chinese, and Japanese, with which texts in these alphabets can be printed in book quality.

The T_EX program is free, and the source code is readily available. Anybody may take it and modify it as they like, provided they call the result something other than T_EX. This indeed has occurred, and several T_EX variants do exist, including pdfT_EX which we deal with later in this Chapter. Only Knuth is allowed to alter T_EX itself, which he does only to correct any obvious bugs. Otherwise, he considers T_EX to be completed; the current version number is 3.14159, and with his death, the code will be frozen for all time, and the version number will become exactly π .

1.3.1 The T_EX program

The basic T_EX program only understands a set of very primitive commands that are adequate for the simplest of typesetting operations and programming functions. However, it does allow more complex, higher-level commands to be defined in terms of the primitive ones. In this way, a more user-friendly environment can be constructed out of the low-level building blocks.

During a processing run, the program first reads in a so-called *format file* which contains the definitions of the higher-level commands in terms of the primitive ones, and which also contains the hyphenation patterns for word division. Only then does it read in the author's *source file* containing the actual text to be processed, including formatting commands that are predefined in the format file.

Creating new formats is something that should be left to very knowledgeable programmers. The definitions are written to a source file which is then processed with a special version of the T_EX program called *initex*. It stores the new format file in a compact manner so that it can be read in quickly by the regular T_EX program.

Although the normal user will almost never write such a format, he or she may be presented with a new format source file that will need to be installed with `initex`. For example, this is just what must be done to upgrade L^AT_EX periodically. How to do this is described in Appendix B.

1.3.2 Plain T_EX

Knuth has provided a basic format named *Plain T_EX* to interact with T_EX at its simplest level. This is such a fundamental part of T_EX processing that one tends to forget the distinction between the actual processing program T_EX and this particular format. Most people who claim to ‘work only with T_EX’ really mean that they only work with Plain T_EX.

Plain T_EX is also the basis of every other format, something that only reinforces the impression that T_EX and Plain T_EX are one and the same.

1.3.3 L^AT_EX

The emphasis of Plain T_EX is still very much at the typesetter’s level, rather than the author’s. Furthermore, the exploitation of all its potential demands considerable experience with programming techniques. Its application thus remains the exclusive domain of typographic and programming professionals.

For this reason, the American computer scientist Leslie Lamport has developed the L^AT_EX format (Lamport, 1985), which provides a set of higher-level commands for the production of complex documents. With it, even the user with no knowledge of typesetting or programming is in a position to take extensive advantage of the possibilities offered by T_EX, and to be able to produce a variety of text outputs in book quality within a few days, if not hours. This is especially true for the production of complex tables and mathematical formulas.

As pointed out in Section 1.2.2, L^AT_EX is very much more a *logical* markup language than the original Plain T_EX, on which it is based. It contains provisions for automatic running heads, sectioning, tables of contents, cross-referencing, equation numbering, citations, floating tables and figures, without the author having to know just how these are to be formatted. The layout information is stored in additional *class files* which are referred to but not included in the input text. The predefined layouts may be accepted as they are, or replaced by others with minimal changes to the source file.

Since its introduction in the mid-1980s, L^AT_EX has been periodically updated and revised, like all software products. For many years the version number was fixed at 2.09 and the revisions were only identified by their dates. The last major update occurred on December 1, 1991, with some minor corrections up to March 25, 1992, at which point L^AT_EX 2.09 became frozen.

1.3.4 L^AT_EX 2_ε

The enormous popularity of L^AT_EX and its expansion into fields for which it was not originally intended, together with improvements in computer technology, especially dealing with cheap but powerful laser printers, had created a diversity of formats bearing the L^AT_EX label. In an effort to re-establish a genuine, improved standard, the L^AT_EX3 Project was set up in 1989 by Leslie Lamport, Frank Mittelbach, Chris Rowley, and Rainer Schöpf. Their goal was to construct an optimized and efficient set of basic commands complemented by various *packages* to add specific functionality as needed.

As the name of the project implies, its aim is to achieve a version 3 for L^AT_EX. However, since that is the long-term goal, a first step towards it was the release of L^AT_EX 2_ε in mid-1994 together with the publication of the second edition of Lamport's basic manual (Lamport, 1994) and of an additional book (Goossens *et al.*, 1994) describing many of the extension packages available and L^AT_EX programming in the new system. Since then, two further books have appeared, Goossens *et al.* (1997) dealing with the inclusion of graphics and color, and Goossens and Rahtz (1999) explaining how L^AT_EX may be used with the World Wide Web. Both these topics are also dealt with in this Guide.

Initially updates to L^AT_EX 2_ε were issued twice a year, in June and December, but it has now become so stable that since 2000 the changes are released only once a year, nominally in June.

L^AT_EX 2_ε is now the standard version, and L^AT_EX 2.09 is considered obsolete, although source files intended for the older version may still be processed with the newer one. In this book, unless otherwise indicated, 'L^AT_EX' will always mean L^AT_EX 2_ε.

1.3.5 T_EX fonts

T_EX initially made use of its own set of fonts, called Computer Modern generated by Knuth's METAFONT program. The reason for doing this was that printers at that time (and even today) may contain their own preloaded fonts, but they are often slightly different from printer to printer. Furthermore, they lacked the mathematical character sets that are essential to T_EX's main hallmark, mathematical typesetting. So Knuth created pixel fonts that could be sent to every printer ensuring the same results everywhere.

Today the situation with fonts has changed dramatically. Outline fonts (also known as type 1 fonts) are more compact and versatile than the pixel fonts (type 3). They also have a far superior appearance and are drawn much faster in PDF files. The original Computer Modern fonts have been converted to outline fonts, but there is no reason to stick with them, except possibly for the mathematical symbols. It is L^AT_EX 2_ε with its New

Font Selection Scheme that freed T_EX from its rigid marriage to Computer Modern.

Fonts are discussed in more detail in Appendix G.

1.3.6 The L^AT_EX bazaar: user contributions

Like the T_EX program on which it relies, L^AT_EX is freeware. There may be a prejudice that what is free is not worth anything, but there are other examples in the computer world to contradict this statement. And since the L^AT_EX macros are provided in files containing plain text, there is no problem to exchange, modify, and supplement them. In other words, the user can participate in extending the basic L^AT_EX system.

Taking advantage of a mechanism in L^AT_EX 2.09 that allowed options to the default layouts to be contained in so-called *style option files*, many users began writing their own ‘options’ to provide additional features to the basic L^AT_EX. They then made these available to other users via the Internet. Many were intended for very specific problems, but many more proved to be of such general usefulness that they have become part of the standard L^AT_EX installation. In this way, the users themselves have built up a system that meets their needs.

With L^AT_EX 2_ε, these user contributions acquired official status: they became known as *packages*, they could be entered directly into the document and not by the back door, guidelines were issued for writing them, and additional commands were introduced to assist package programming. Package files bear the extension *.sty* from L^AT_EX 2.09 days, so that the older style option files may still function as packages today.

Those packages that have established themselves as indispensable for sophisticated L^AT_EX processing are described in this book in those sections where they are most relevant. This does not imply that other packages are less worthwhile, but simply that this book does have to make a selection. Many other packages are described fully in *The L^AT_EX Companion* (Goossens *et al.*, 1994) and it would go beyond the bounds of this book to reproduce it here.

1.3.7 L^AT_EX and electronic publishing

The most significant development in computer usage in the last decade is the rise of the World Wide Web (or the hijacking of the Internet by the glitzy society). L^AT_EX makes its own contribution here with

- programs to convert L^AT_EX files to HTML (Appendix E);
- means of creating PDF output, with hypertext features such as links, bookmarks, active buttons (Chapter 10);

- interfacing to XML both by acting as an engine to render XML documents and with programs to convert \LaTeX to XML and vice versa (Appendix E).

All these forms of electronic publishing are alternatives to traditional paper output. We do not expect paper to disappear entirely so quickly, but it is rapidly being replaced by electronic forms, which can always reproduce the paper whenever needed.

1.4 How to use this book

This *Guide* is meant to be a mixture of textbook and reference manual. It explains all the essential elements of the current standard $\text{\LaTeX}2_{\epsilon}$, but compared to L^amport (1985, 1994), it goes into more detail, offers more examples and exercises, and describes many ‘tricks’ based on the authors’ experiences. It explains not only the core \LaTeX installation, but also many of the contributed packages that have become essential to modern \LaTeX processing, and thus quasi-standard. We necessarily have to be selective, for we cannot go to the same extent as *The \LaTeX Companion* (Goossens *et al.*, 1994), *The \LaTeX Graphics Companion* (Goossens *et al.*, 1997), and *The \LaTeX Web Companion* (Goossens and Rahtz, 1999), which are still valid *companions* to this book.

The first part of the book is entitled *The Basics*, and deals with the more fundamental aspects of \LaTeX : inputting text and symbols, document organization, lists and tables, entering mathematics, and customizations by the user. The second part is called *Beyond the Basics*, meaning it presents concepts which may be more advanced but which are still essential to producing complex, sophisticated documents. The distinction is rather arbitrary. Finally, the appendices contain topics that are not directly part of \LaTeX itself, but useful for understanding its applications: installation, error messages, creating packages, World Wide Web, fonts. Appendix H is an alphabetized summary of most of the commands and their use, cross-referenced to their locations in the main text.

1.4.1 Some conventions

In the description of command syntax, typewriter type is used to indicate those parts that must be entered exactly as given, while *italic* is reserved for those parts that are variable or for the text itself. For example, the command to produce tables is presented as follows:

```
\begin{tabular}{col.form} lines \end{tabular}
```

The parts in typewriter type are obligatory, while *col.form* stands for the definition of the column format that must be inserted here. The allowed

values and their combinations are given in the detailed descriptions of the commands. In the above example, *lines* stands for the line entries in the table and are thus part of the text itself.

Package:
sample

Sections describing a package, an extension to basic L^AT_EX, have the name of that package printed as a marginal note, as demonstrated here for this paragraph. In this way, you are reminded that you must include it with `\usepackage` (Section 3.1.2) in order to obtain the additional features. Without it, you are likely to get an error message about undefined commands.



Sections of text that are printed in a smaller typeface together with the boxed exclamation mark at the left are meant as an extension to the basic description. They may be skipped over on a first reading. This information presents deeper insight into the workings of L^AT_EX than is necessary for everyday usage, but which is invaluable for creating more refined control over the output.

1.5 Basics of a L^AT_EX file

1.5.1 Text and commands

The *source file* for L^AT_EX processing, or simply the *L^AT_EX file*, contains the *source text* that is to be processed to produce the printed output. Splitting the text up into lines of equal width, formatting it into *paragraphs*, and breaking it into *pages* with page numbers and running heads are all functions of the processing program and not of the input text itself.

For example, words in the source text are strings of letters terminated by some non-letter, such as *punctuation*, *blanks*, or *end-of-lines* (*hard end-of-lines*, ones that are really there, not the *soft* ones that move with the window width); whereas punctuation marks will be transferred to the output, blanks and end-of-lines merely indicate a gap between words. Multiple blanks in the input, or blanks at the beginning of a line, have no effect on the interword spacing in the output.

Similarly, a new paragraph is indicated in the input text by an empty line; multiple empty lines have the same effect as a single one. In the output, the paragraph may be formatted either by indentation of the first line, or by extra interline spacing, but this is not affected in any way by the number of blank lines or extra spaces in the input.

The source file contains more than just text, however; it is also interspersed with markup commands that control the formatting or indicate the structure. It is therefore necessary for the author to be able to recognize what is text and what is a command. Commands consist either of certain single characters that cannot be used as text characters, or of words preceded immediately by a special character, the backslash (`\`).

The syntax of source text is explained in detail in Chapter 2.

1.5.2 Contents of a L^AT_EX source file

Every L^AT_EX file contains a *preamble* and a *body*.

The preamble is a collection of commands that specify the global processing parameters for the following text, such as the paper format, the height and width of the text, the form of the output page with its pagination and automatic page heads and footlines. As a minimum, the preamble must contain the command `\documentclass` to specify the document's overall processing type. This is the first command in the preamble.

If there are no other commands in the preamble, L^AT_EX selects standard values for the line width, margins, paragraph spacing, page height and width, and much more. By default, these specifications are tailored to the American norms. For European requirements, built-in options exist to alter the text height and width to the A4 standard. Furthermore, there are language-specific packages to translate certain headings such as 'Chapter' and 'Abstract'.

The preamble ends with `\begin{document}`. Everything that follows this command is interpreted as *body*. It consists of the actual text mixed with markup commands. In contrast to those in the preamble, these commands have only a local effect, meaning they apply only to a part of the text, such as *indentation*, *equations*, temporary change of *font*, and so on. The body ends with the command `\end{document}`. This is normally the end of the file as well.

The general syntax of a L^AT_EX file is as follows:

```
\documentclass[options]{class}
    Further global commands and specifications
\begin{document}
    Text mixed with additional commands of local effect
\end{document}
```

The possible *options* and *classes* that may appear in the `\documentclass` command are presented in Section 3.1.1.

A minimal L^AT_EX file named `hi.tex` contains just the following lines:

```
\documentclass{article}
\begin{document}
  Hi!
\end{document}
```

1.5.3 Extending L^AT_EX with packages

Packages are a very important feature of L^AT_EX. These are extensions to the basic L^AT_EX commands that are written to files with names that end in `.sty` and are loaded with the command `\usepackage` in the preamble. Packages can be classified by their origin:

core packages are an integral part of the L^AT_EX basic installation and are therefore fully standard;

tools packages are a set written by members of the L^AT_EX3 Team, and should always be in the installation;

graphics packages are a standardized set for including pictures generated by other programs, and for handling color; they are on the same level as the tools packages;

A_MS-L^AT_EX packages published by the American Mathematical Society, should be in any installation;

contributed packages have been submitted by actual users; certain of these have established themselves as ‘essential’ to standard L^AT_EX usage, but all are useful.

Only a limited number of these packages are described in this book, those that we consider indispensable. However, there is nothing to prevent the user from obtaining and incorporating any others that should prove beneficial for his or her purposes.

There are over 1000 contributed packages on the included T_EXLive CD. How can one begin to get an overview of what they offer? Graham Williams has compiled a list of brief descriptions which can be found online and on the T_EXLive CD at

```
\texmf\doc\html\catalogue\catalogue.html
```

How to load packages into the L^AT_EX source file is explained in Section 3.1.2.

Documentation of contributed packages is somewhat haphazard, depending on how much the author has put into it. The preferred method for distributing packages is to integrate the documentation with the code into a single file with extension `.dtx`. A special program `DocStrip` (Section D.7.1) is used to extract the actual package file or files, while L^AT_EXing the original `.dtx` file produces the instruction manual. Most ready-to-run installations will already have done all this for the user, with the resulting manuals stored as DVI or PDF files somewhere in `\texmf\doc\latex\...`. However, you might have to generate the documentation output yourself by processing the `.dtx` file, which should be found in `\texmf\source\latex\...` (Section B.3 explains the organization of the T_EX directory system.)

Some package authors write their manuals as an extra `.tex` file, the output of which may or may not be prestored in DVI or PDF form. Others provide HTML files. And still others simply add the instructions as comments in the package file itself. (This illustrates some of the joys of an open system.)

1.6 T_EX processing procedure

Since L^AT_EX is a set of definitions for the T_EX program, L^AT_EX processing itself is in fact T_EX processing with the L^AT_EX format. What T_EX does with this is the same as for any other of the many formats available (of which L^AT_EX is perhaps the most popular). All the typesetting work is done by T_EX, while L^AT_EX handles the conversion from the logical markup to the typesetting commands. It also enables cross-referencing, running headlines, table of contents, literature citations and bibliography, indexing, and more. However, the processing of the source file to final output is T_EX's task, regardless of the format being used.

1.6.1 In the good old days

T_EX arose over 20 years ago before there were such things as PCs, graphical displays, and before computers were infected with windows or mice. T_EX and its support programs were invoked from a command line, not with a mouse click. This may sound very old fashioned, but it did guarantee portability to all computer types.

The processing steps that were taken in those days still exist with today's graphical interfaces, but are now executed more conveniently. One can still open a 'command prompt window' and run them from the command line.

The first step is of course to use a *text editor* program to write the source file containing the actual text and markup. The rules for entering this source text are explained in Chapter 2. It goes into a text file, or what is often called an 'ASCII' file containing only standard punctuation marks, numbers, unaccented letters, upper and lower case. In other words, the text is that which can be produced from a standard English typewriter.

The name of the source file normally has the extension `.tex`; it is then processed by T_EX to produce a new file with the same base name and the extension `.dvi`, for *device independent* file. This is a binary file (all codes possible, not a text file) containing precise instructions for the selection and placement of every symbol, a coded description of the final printed page. The command to invoke T_EX with the source file `hi.tex` is

```
tex &latex hi
```

meaning run the T_EX program with the format `latex`. Usually the installation has defined a shortcut named `latex` to do this, so

```
latex hi
```

should be sufficient. It is only necessary to specify the extension of the source file name if it is something other than `.tex`.

During the processing, T_EX writes information, warnings, error messages to the computer monitor, and to a *transcript* file with the extension `.log`. It is well worth inspecting this file when unexpected results appear.

The final step is to produce the printed pages from the DVI file. This requires another program, a *driver*, to generate the instructions specific to the given printer. For example, to produce a PostScript file, one runs

```
dvips hi
```

to obtain `hi.ps` from `hi.dvi`. And then one sends `hi.ps` to the PostScript printer with the regular command for that computer system.

Previewing the DVI file on a computer monitor before printing was a later development, requiring high quality graphics displays. These programs are essentially special drivers that send the output directly to the monitor rather than to a printer or printer file. One very popular previewer is called with

```
xdvi hi
```

to view `hi.dvi` before committing it to paper.

1.6.2 And today

The various steps for L^AT_EX processing described above are still necessary today, and one can open up a command prompt window and carry them out just as before. However, there now exist intelligent editors with L^AT_EX-savvy that not only assist writing the source text, but also will call the various programs, T_EX, previewer, printer driver, BibT_EX, MakeIndex (these are explained later) with a mouse click.

One such editor for Windows, available on the enclosed T_EXLive CD in the `support` directory, is called *WinShell*, written by Ingo H. de Boer (www.winshell.de). Although free of charge, its author appreciates donations to offset his expenses.

Another such editor and L^AT_EX interface is *WinEdt* by Aleksander Simonic (www.winedt.com). A sample window with the opening text of this chapter is shown in Figure 1.1. This program is available for a 30-day trial period, after which one must pay a nominal fee to obtain a licence. It is the editor that we ourselves use and we can highly recommend it.

An alternative is L_yX, a free, open source software for document processing in near WYSIWYG, acting as a front-end to L^AT_EX, where the user need not know anything about L^AT_EX. See its home page at www.lyx.org.

It must be stressed that all the above are *interfaces* to an existing L^AT_EX installation. On the other hand, there are also commercial packages which include both the T_EX/L^AT_EX installation and a graphics interface. These are listed in Section B.1.1.

1.6.3 Alternative to T_EX: pdfT_EX

As we mentioned earlier, it is permitted to use the T_EX source code to generate something else, as long as it bears another name. One such

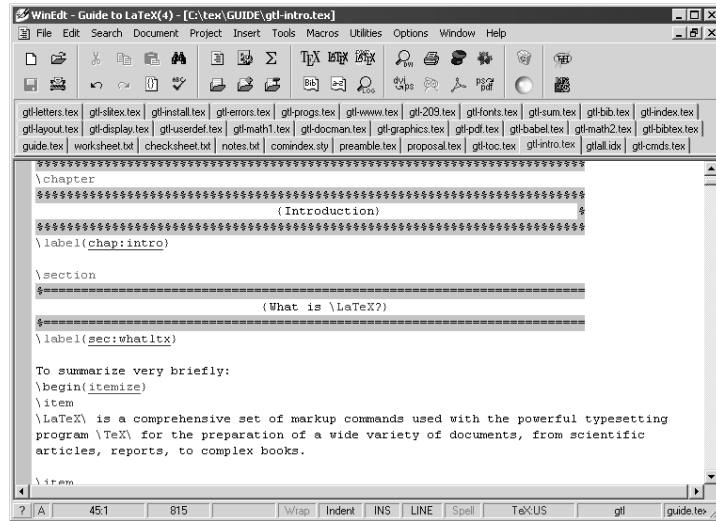


Figure 1.1: Sample display with the WinEdt editor for interfacing to \LaTeX .

modification is called $\text{pdf}\TeX$, created by Hàn Thê Thành. This program does everything \TeX does, but it optionally writes its output directly to a PDF file, bypassing the DVI output of regular \TeX . It therefore combines the \TeX program with a DVI-to-PDF driver program. Normally this option is also the default.

There are many advantages to producing PDF output directly this way, apart from saving a step. The PDF file is generated in exactly the same way as the DVI file with \TeX , and can be viewed immediately with the Acrobat Reader or other PDF viewer. The results can be sent directly to a printer without going through the DVI-to-Printer program. It is also much easier to include the hypertext features of a true active PDF file, as we explain in Section 10.2.4.

Adding the \LaTeX macros to $\text{pdf}\TeX$ produces something one could call $\text{pdf}\LaTeX$. This distinction is only meaningful for invoking the program-plus-format to process the \LaTeX source file. Except for some things that we note in Section 10.2.3, \LaTeX commands are identical whether used with \TeX or with $\text{pdf}\TeX$. This makes the conversion extremely easy.

The rest of this book deals essentially with \LaTeX itself, regardless of what the end product is to be: paper, HTML, XML, or PDF.

2

Text, Symbols, and Commands

The text that is to be the input to a \LaTeX processing run is written to a *source file* with a name ending in `.tex`, the file name extension. This file is prepared with a *text editor*, either one that handles straightforward plain text, or one that is configured to assist the writing and processing of \LaTeX files. In either case, the contents of this file are plain ASCII characters only, with no special symbols, no accented letters, preferably displayed in a fixed width typewriter font, with no frills like bold or italics, all in one size. All these aspects of true typesetting are produced afterwards by the \TeX processing program with the help of *markup* commands inserted visibly into the actual text. It is therefore vital to know how commands are distinguished from text that is to be printed, and, of course, how they function.

(However, for languages other than English, native keyboard input may indeed be used, as shown in Section 2.5.9.)

2.1 Command names and arguments

A *command* is an instruction to \LaTeX to do something special, like print some symbol or text not available to the restricted character set used in the input file, or to change the current typeface or other formatting properties. There are three types of command names:

- the single characters `#` `$` `&` `~` `_` `^` `%` `{` `}` all have special meanings that are explained later in this chapter;
- the backslash character `\` plus a single non-letter character; for example `\$` to print the \$ sign; all the special characters listed above have a corresponding two-character command to print them literally;
- the backslash character `\` plus a sequence of letters, ending with the first non-letter; for example, `\large` to switch to a larger typeface.

Command names are case sensitive, so `\large`, `\Large` and `\LARGE` are distinct commands.

Many commands operate on some short piece of text, which then appears as an *argument* in curly braces following the command name. For example, `\emph{stress}` is given to print the word `stress` in an emphasized typeface (here italic) as *stress*. Such arguments are said to be *mandatory* because they must always be given.

Some commands take *optional* arguments, which are normally employed to modify the effects of the command somehow. The optional arguments appear in square braces.


In this book we present the general syntax of commands as

$$\backslash\textit{name}[optional]\{\textit{mandatory}\}$$

where typewriter characters must be typed exactly as illustrated and italic text indicates something that must be substituted for. Optional arguments are put into square brackets [] and the mandatory ones into curly braces { }. A command may have several optional arguments, each one in its set of brackets in the specified sequence. If none of the optional arguments is used, the square brackets may be omitted. Any number of blanks, or even a single new line, may appear between the command name and the arguments, to improve legibility.

Some commands have several mandatory arguments. Each one must be put into a { } pair and their sequence must be maintained as given in the command description. For example,

$$\backslash\textit{rule}[lift]\{\textit{width}\}\{\textit{height}\}$$

produces a black rectangle of size *width* and *height*, raised by an amount *lift* above the current baseline. A rectangle of width 10 mm and height 3 mm is made with `\rule{10mm}{3mm}`. Since the optional argument *lift* is omitted, the rectangle is set on the baseline with no lifting, as . The arguments must appear in the order specified by the syntax and may not be interchanged.

Some commands have a so-called **-form* in addition to their normal appearance. A *** is added to their name to modify their functionality somehow. For example, the `\section` command has a **-form* `\section*` which, unlike the regular form, does not print an automatic section number. For each such command, the difference between the normal and **-form* will be explained in the description of the individual commands.

Command names consist only of letters, with the first non-letter indicating the end of the name. If there are optional or mandatory arguments following the command name, then it ends before the [or { bracket, since these characters are not letters. Many commands, however, possess no arguments and are composed of only a name, such as the command `\LaTeX` to produce the \LaTeX logo. If such a command is followed by

a punctuation mark, such as comma or period, it is obvious where the command ends. *If it is followed by a normal word, the blank between the command name and the next word is interpreted as the command terminator:* The `\LaTeX` logo results in ‘The L^AT_EX logo’, that is, the blank was seen only as the end of the command and not as spacing between two words. This is a result of the special rules for blanks, described in Section 2.5.1.

In order to insert a space after a command that consists only of a name, either an empty structure `{}` or a space command (`\` and `blank`) must be placed after the command. The proper way to produce ‘The L^AT_EX logo’ is to type either `The \LaTeX{} logo` or `The \LaTeX\ logo`. Alternatively, the command itself may be put into curly braces, as `The {\TeX} logo`, which also yields the right output with the inserted blank: ‘The T_EX logo’. Incidentally, the L^AT_EX 2_ε logo is produced with `\LaTeXe`. Can you see why this logo command cannot be named `\LaTeX2e`?

2.2 Environments

An *environment* is initiated with the command `\begin{name}` and is terminated by `\end{name}`.

An environment has the effect that the text within it is treated differently according to the environment parameters. It is possible to alter (temporarily) certain processing features, such as indentation, line width, typeface, and much more. The changes apply only within the environment. For example, with the `quote` environment,

```

previous text
\begin{quote}
text1 \small text2 \bfseries text3
\end{quote}
following text

```

the left and right margins are increased relative to those of the previous and following texts. In the example, this applies to the three texts *text1*, *text2*, and *text3*. After *text1* comes the command `\small`, which has the effect of setting the next text in a smaller typeface. After *text2*, there is an additional command `\bfseries` to switch to bold face type. Both these commands only remain in effect up to the `\end{quote}`.

The three texts within the `quote` environment are indented on both sides relative to the previous and following texts. The *text1* appears in the normal typeface, the same one as outside the environment. The *text2* and *text3* appear in a smaller typeface, and *text3* furthermore appears in bold face.

After the end of the `quote` environment, the subsequent text appears in the same typeface that was in effect beforehand.

Note that if the names of the environment in the `\begin{...}\end{...}` pair do not match, an error message will be issued on processing.

Most declaration command names (see next section) may also be used as environment names. In this case the command name is used *without* the preceding `\` character. For example, the command `\em` switches to an emphatic typeface, usually *italic*, and the corresponding environment `\begin{em}` will set all the text in *italic* until `\end{em}` is reached.

A nameless environment can be simulated by a `{...}` pair. The effect of any command within it ends with the closing curly brace.

The user can even create his or her own environments, as described in Section 8.4.

2.3 Declarations

A *declaration* is a command that changes the values or meanings of certain parameters or commands without printing any text. The effect of the declaration begins immediately and ends when another declaration of the same type is encountered. However, if the declaration occurs within an environment or a `{...}` pair, its scope extends only to the corresponding `\end` command, or to the closing brace `}`. The commands `\bfseries` and `\small` mentioned in the previous section are examples of such non-printing declarations that alter the current typeface.

Some declarations have associated arguments, such as the command `\setlength` which assigns a value to a *length parameter* (see Sections 2.4 and 8.2).

Examples:

`{\bfseries This text appears in bold face}` The `\bfseries` declaration changes the typeface: **This text appears in bold face**. The effect of this declaration ends with the closing brace `}`.

`\setlength{\parindent}{0.5cm}` The paragraph indentation is set to 0.5 cm. The effect of this declaration ends with the next encounter of the command `\setlength{\parindent}`, or at the latest with the `\end` command that terminates the current environment.

`\pagenumbering{roman}` The page numbering is to be printed in Roman numerals.

Some declarations, such as the last example, are global, that is, their effects are not limited to the current environment. The following declarations are of this nature, the meanings of which are given later:

<code>\newcounter</code>	<code>\pagenumbering</code>	<code>\newlength</code>
<code>\setcounter</code>	<code>\thispagestyle</code>	<code>\newsavebox</code>
<code>\addtocounter</code>		

Declarations made with these commands are effective right away and remain so until they are overridden by a new declaration of the same type. In the last example above, page numbering will be done in Roman numerals until countermanded by a new `\pagenumbering{arabic}` command.

2.4 Lengths

2.4.1 Fixed lengths

Lengths consist of a decimal number with a possible sign in front (+ or -) followed by a mandatory dimensional unit. Permissible units and their abbreviated names are:

cm	centimeter,
mm	millimeter,
in	inch (1 in = 2.54 cm),
pt	point (1 in = 72.27 pt),
bp	big point (1 in = 72 bp),
pc	pica (1 pc = 12 pt),
dd	didôt point (1157 dd = 1238 pt),
cc	cicero (1 cc = 12 dd),
em	a font-specific size, the width of the capital M,
ex	another font-related size, the height of the letter x.

Decimal numbers in \TeX and \LaTeX may be written in either the English or European manner, with a *period* or a *comma*: both 12.5cm and 12,5cm are permitted.

Note that 0 is not a legitimate length since the unit specification is missing. To give a zero length it is necessary to add some unit, such as 0pt or 0cm.

Values are assigned to a length parameter by means of the \LaTeX command `\setlength`, which is described in Section 8.2 along with other commands for dealing with lengths. Its syntax is:

```
\setlength{\length_name}{length_spec}
```

For example, the width of a line of text is specified by the parameter `\textwidth`, which is normally set to a default value depending on the class, paper type, and font size. To change the line width to be 12.5 cm, one would give:

```
\setlength{\textwidth}{12.5cm}
```

2.4.2 Rubber lengths

Some parameters expect a *rubber* length. These are lengths that can be stretched or shrunk by a certain amount. The syntax for a rubber length is:

nominal.value plus *stretch.value* minus *shrink.value*

where the *nominal.value*, *stretch.value*, and *shrink.value* are each a length. For example,

```
\setlength{\parskip}{1ex plus0.5ex minus0.2ex}
```

means: the extra line spacing between paragraphs, called `\parskip`, is to be the height of the *x* in the current font, but it may be increased to 1.5 or reduced to 0.8 times that size.

One special *rubber* length is `\filll`. This has the natural length of *zero* but can be stretched to any size.

2.5 Special characters

2.5.1 Spaces

The *space* or *blank* character has some properties different from those of normal characters, some of which have already been mentioned in Section 2.1. During processing, blanks in the input text are replaced by rubber lengths (Section 2.4.2) in order to allow the line to fill up to the full line width. As a result, some peculiar effects can occur if one is not aware of the following rules:

- one blank is the same as a thousand, only the first one counts;
- blanks at the beginning of an input line are ignored;
- blanks terminating a command name are removed;
- the end of a line is treated as a blank.

Some of the consequences of these rules are that there may be as many blanks as desired between words or at the beginning of a line (to make the input text more legible) and that a word may come right at the end of a line without the spacing between it and the next word disappearing. To force a space to appear where it would otherwise be ignored, one must give the command `_` (a `\` followed by a space character, made visible here by the symbol `_`).

To ensure that certain words remain together on the same line, a *protected space* is inserted between them with the `~` character (Section 2.7.1, page 28). Multiple protected spaces are all printed out, in contrast to normal spaces.

Sometimes it is necessary to suppress the space that appears because of the new line. In this case, the last character in the line must be the *comment* character `%` (Section 4.11).

Paragraphs are separated in the source text by blank lines. As for blank characters, one blank line is the same as a thousand.

Instead of a blank line, the command `\par` may also be used to indicate the end of a paragraph.

2.5.2 Quotation marks

The *quotation marks* found on the typewriter " are not used in book printing. Instead different characters are used at the beginning and end, such as 'single quotes' and "double quotes". Single quotes are produced with ' and ', while double quotes are made by typing the respective characters twice: ‘ for “ and ’ for ”. Furthermore the typewriter character " will also generate the double closing quote ". However, it should be avoided since it can lead to confusion.

2.5.3 Hyphens and dashes

In book printing, the character that appears on the typewriter as - comes in various lengths: -, -, —. The smallest of these, the *hyphen*, is used for compound words such as *father-in-law* and for word division at the end of a line; the middle-sized one, the *en dash*, is used in ranges of numbers, for example, pages 33–36; and the largest, the *em dash*, is used as punctuation—what is normally called the *dash*. These are generated by typing the hyphen character one, two, or three times, so that - yields -, while -- makes –, and --- produces —. A fourth type of dash is the minus sign −, which is entered in math mode as $\$-$ (Chapter 5).

2.5.4 Printing command characters

As mentioned in Section 2.1, the characters # \$ ~ _ ^ % { } are interpreted as commands. To print them as text, one must give a command consisting of \ plus that character.

$$\$ = \backslash\$ \quad \& = \backslash\& \quad \% = \backslash\% \quad \# = \backslash\# \quad _ = \backslash_ \quad \{ = \backslash\{ \quad \} = \backslash\}$$

2.5.5 The special characters §, †, ‡, ¶, © and £

These special characters do not exist on the computer keyboard. They can however be generated by special commands as follows:

$$\S = \backslash\$ \quad \dagger = \backslash\text{dag} \quad \ddagger = \backslash\text{ddag} \quad \P = \backslash\text{P} \quad \text{©} = \backslash\text{copyright} \quad \text{£} = \backslash\text{pounds}$$

The production of Greek letters and other mathematical symbols is described in Chapter 5.

2.5.6 Non-English letters

Special letters that exist in languages other than English can also be generated with T_EX. These are:

œ={\oe} OE={\OE} æ={\ae} Æ={\AE} å={\aa} Å={\AA} ¡='
ø={\o} Ø={\O} ł={\l} Ł={\L} ß={\ss} SS={\SS} ¿='

Ångström may be written as `{\AA}ngstr{\o}m` while *Karlstraße* can be input as `Karłstra{\ss}e`. The ‘letter’ `\SS` is the upper case equivalent of `\ss`, used for automatic conversion between upper and lower case.

However, see Section 2.5.9 for the possibility of entering such characters directly.

2.5.7 Accents

In non-English languages, there is a multiplicity of *diacritical marks* or *accents*, most of which can be printed with T_EX:

ò =\‘{o} ó =\’{o} ô =\^{o} ö =\''{o} õ =\~{o}
ō =\={o} ô =\.{o} õ =\u{o} ö =\v{o} ô =\H{o}
ôo=\t{oo} q=\c{o} q=\d{o} q=\b{o} ô=\r{o}

The *o* above is given merely as an example: any letter may be used. With *i* and *j* it should be pointed out that the dot must first be removed. This is carried out by prefixing these letters with a backslash: the commands `\i` and `\j` yield *i* and *j*. In this way *ï* and *ĵ* are formed by typing `\u{\i}` and `\H{\j}`.

The accent commands consisting of a non-letter may also be given without the curly braces:

ò =\‘o ó =\’o ô =\^{o} ö =\''o õ =\~o ô =\=o ô =\.o

The letter accent commands should always be used with the curly braces.

2.5.8 The euro symbol

The euro symbol € (or €) is too new to be part of the original L^AT_EX, but it can be produced with the help of some additional fonts and contributed packages. Just which package you may use depends on your installation, and whether you have access to these additional fonts.

The *Text Companion* fonts, described in Section G.4.4, do contain a euro symbol. Since these fonts should be part of every modern L^AT_EX installation, you should be able to use their euro symbol if all else fails.

Package: The package `textcomp` must be loaded in the preamble with
`textcomp`

```
\usepackage{textcomp}
```

which defines many commands including `\texteuro` to print the symbol €. Since the European Commission originally dictated that it should only be printed in a sans serif font, it is better to issue `\textsf{\texteuro}` to produce €. (The font selection commands are described in Section 4.1.4.) If you are going to use this very frequently, you might want to define a shortcut named `\euro` with

```
\newcommand{\euro}{\textsf{\texteuro}}
```

as described in Section 8.3 on defining commands.

Package: A better solution is presented by the `eurosym` package by Henrik Theiling and the associated fonts that come with it, which bear the names `feymr10`, `feybr10`, and so on. This package defines the `\euro` command to print €, which changes automatically to bold € and slanted € as needed.

Package: The `europs` package by Joern Clausen interfaces to the type 1 (PostScript) euro fonts published by Adobe. For licensing reasons, these fonts may only be obtained from Adobe directly, even though free of charge (see Section B.2). This package provides the command `\EUR` for a symbol that varies with font family (Roman €25, sans serif €25, and `typewriter` €25) as well as for bold €25 and slanted €25. There is also a command `\EURofc` for the invariable symbol €.

Package: Finally, the package `eurosans` by Walter Schmidt also addresses the Adobe euro fonts, again with the command `\euro`, with the same behavior as that of `eurosym`: always sans serif family, but changes with the other font attributes.

The table below summarizes the above packages:

Package	Command	Fonts	Notes
<code>textcomp</code>	<code>\texteuro</code>	Text Companion	Non standard symbol
<code>eurosym</code>	<code>\euro</code>	Eurosym	Sans serif, variable
<code>europs</code>	<code>\EUR</code> <code>\EURofc</code>	PostScript	Varies with font family Invariable, official
<code>eurosans</code>	<code>\euro</code>	PostScript	Sans serif, variable

So which package should one use? That really depends on the fonts available. Since the Adobe fonts can never be distributed with a \TeX installation, they must be actively fetched and installed. However, it is worth doing so, because the European Commission has revised its initial directive and now allows the euro symbol to be typographically matched to the text, which is also standard practice in Europe today. This strengthens the case for the `europs` package and the `\EUR` command for €, at least for Roman fonts.

2.5.9 Typing special symbols directly

!

The commands for producing the special characters and accented letters in the previous sections may be suitable for typing isolated ‘foreign’ words, but become quite tedious for inputting large amounts of text making regular use of such characters. Most computer systems provide non-English keyboards with appropriate fonts for typing these national variants directly. Unfortunately, the coding of such extra symbols is by no means standard, depending very much on the computer system.

For example, the text Gauß meets Ampère entered with an MS-DOS editor (code page 437 or 850) appears in a Windows application as Gauá meets AmpŠre and on a Macintosh as Gau. meets Ampäre. Since L^AT_EX is intended to run on all systems, it simply ignores all such extra character codes on the grounds that they are not properly defined.

Package: The `inputenc` package solves this problem. It not only informs L^AT_EX which input coding scheme is being used, it also tells it what to do with the extra characters. One invokes it with

```
\usepackage[code]{inputenc}
```

where *code* is the name of the coding scheme to be used. The current list of allowed values for *code* (more are added with each L^AT_EX update) can be found in Table D.1 on page 462. For most users, the most interesting codes are:

<code>cp437</code>	IBM code page 437 (DOS, North America)
<code>cp850</code>	IBM code page 850 (DOS, Western Europe)
<code>applemac</code>	Macintosh encoding
<code>ansinew</code>	Windows ANSI encoding

In short, you should select `applemac` for a Macintosh, and `ansinew` for Windows, and one of the others if you are working with DOS.

Documents making use of this package are fully portable to other computer systems. The source text produced with a DOS editor may still look very strange to a human user reading it on a Macintosh, but when the Macintosh L^AT_EX processes it, the proper DOS interpretations will be applied so that the end result is what the author intended.

See Section D.5 for more details.

2.5.10 Ligatures

In book printing, certain combinations of letters are not printed as individuals but as a single symbol, a so-called *ligature*. T_EX processes the letter combinations `ff`, `fi`, `fl`, `ffi`, and `ffl` not as

`ff`, `fi`, `fl`, `ffi`, `ffl` but rather as `ff`, `fi`, `fl`, `ffi`, `ffl`

Ligatures may be broken, that is, forced to be printed as separate letters, by inserting `\/` between the letters. This is sometimes desired for such words as *shelfful* (`she\l\fu\l`), which looks rather strange when printed with the normal *ff* ligature, *shelfful*.

2.5.11 The date

The current date can be placed at any point in the text with the command `\today`. The standard form for the date is the American style of month, day, year (for example, January 15, 2004). The British form (15th January 2004) or the date in other languages can be generated with the help of the \TeX commands `\day`, `\month`, and `\year`, which return the current values of these parameters as numbers. Examples of how such a new `\today` command may be made are shown on page 461 in Section D.4.2.

It is in fact better to enter the date explicitly, rather than to rely on `\today`. Reprocessing a two-year-old \LaTeX source file will yield a document with the processing date, not the date when the text was written.

2.6 Exercises

Exercise 2.1: *This exercise tests the basic operations of running the \LaTeX program with a short piece of text. A few simple commands are also included. Use a text editor to produce the following source text and store it in a file named `exer.tex`.*

```
\documentclass{article}
\begin{document}
Today (\today) the rate of exchange between the British
pound and American dollar is \pounds 1 = \$1.58, an
increase of 1\% over yesterday.
\end{document}
```

Process this source file with \LaTeX by clicking the appropriate icon, or by issuing `latex exer` in a command window. If the processing occurs without any error messages, the `.dvi` file `exer.dvi` will have been successfully created and may be viewed by a `dvi` previewer or sent to a printer. The final printed result should look as follows except that your current date will appear:

Today (January 15, 2004) the rate of exchange between the British pound and American dollar is £1 = \$1.58, an increase of 1% over yesterday.

Note the following points about the commands used:

- *no blank is necessary after `\today` because the `)` suffices to terminate it;*
- *the blank after `\pounds` is optional and it is not printed in the output;*
- *the commands `\$` and `\%` do not require blanks to terminate them; if blanks are given, they will be printed.*

Exercise 2.2: *Take some text of about 3/4 of a page long out of a book or journal article and type it into a \LaTeX source file. Pay attention that the paragraphs are separated by blank lines. Use the same set of commands as in Exercise 2.1, that is, put the text between the commands `\begin{document}`...`\end{document}` and repeat the procedures for obtaining the output.*

Exercise 2.3: If you are likely to need the euro symbol in your work, try redoing Exercise 2.1 as follows:

```
\documentclass{article}
\usepackage{eurosym}
\begin{document}
Today (\today) the rate of exchange between the British
pound and European euro is \pounds 1 = \euro1.46, an
increase of 1\% over yesterday.
\end{document}
```

If this fails, try one of the other packages described in Section 2.5.8, substituting `\textsf{\texteuro}` or `\EUR` for `\euro` as required.

2.7 Fine-tuning text

The subject of the section concerns pure typographical markup, and has nothing to do with the logical markup that we wish to stress in this book. Unfortunately, there are times when the author or editor does have to help the typesetting program to achieve good appearance.

2.7.1 Word and character spacing

The spacing between words and characters is normally set automatically by $\text{T}_{\text{E}}\text{X}$, which not only makes use of the natural width of the characters but also takes into account alterations for certain character combinations. For example, an A followed by a V does not appear as AV but rather as AV; that is, they are moved together slightly for a more pleasing appearance. Interword spacing within one line is uniform, and is chosen so that the right and left ends match exactly with the side margins. This is called left and right *justification*. $\text{T}_{\text{E}}\text{X}$ also attempts to keep the word spacing for different lines as nearly the same as possible.

Words that end with a punctuation mark are given extra spacing, depending on the character: following a period '.' or exclamation mark '!', there is more space than after a comma ','. This corresponds to the rule in English typesetting that there should be extra spacing between sentences. In certain cases, the automatic procedures do not work properly, or it is desirable to override them, as described in the next sections.

Sentence termination and periods

$\text{T}_{\text{E}}\text{X}$ interprets a period following a lower case letter to be the end of a sentence where additional interword spacing is to be inserted. This leads to confusion with abbreviations such as *i. e.*, *Prof. Jones*, or *Phys. Rev.*, where the normal spacing is required. This can be achieved by using the characters `~` or `_` instead of the normal blank. (The character `_` is

simply a symbol for the blank which is otherwise invisible.) Both these methods insert the normal interword spacing; in addition, `~` is a *protected space* that prevents the line from being broken at this point. The above examples should be typed in as `i.~e., Prof.~Jones, and Phys.\ Rev.,` producing *i. e., Prof. Jones, and Phys. Rev.* with the correct spacing and forcing the first two to be all on one line. In the third case, there is nothing wrong with putting *Phys.* and *Rev.* on different lines.

A period following an upper case letter is not interpreted as the end of a sentence, but as an abbreviation. If it really is the end of a sentence, then it is necessary to add `\@` before the period in order to achieve the extra spacing. For example, this sentence ends with NASA. It is typed in as `This sentence ends with NASA\@.`

French spacing

The additional interword spacing between sentences can be switched off with the command `\frenchspacing`, which remains in effect until countermanded with `\nonfrenchspacing`. In this case, the command `\@` is ignored and may be omitted. This paragraph has been printed with `\frenchspacing` turned on, so that all word spacings within one line are the same. It corresponds to the normal rule for non-English typesetting.

Character combinations “ ‘ and ’ ”

A small spacing is produced with the command `\,.` This may be used, for example, to separate the double quotes “ and ” from the corresponding single quotes ‘ and ’ when they appear together. For example, the text `‘\, ‘Beginning’ and ‘End’\, ’` produces “ ‘Beginning’ and ‘End’ ”.

Inserting arbitrary spacing

Spacing of any desired size may be inserted into the text with the commands

```
\hspace{space}
\hspace*{space}
```

where *space* is the length specification for the amount of spacing, for example `1.5cm` or `3em`. (Recall that one *em* is the width of the letter M in the current typeface.)

This command puts blank space of width *space* at that point in the text where it appears. The standard form (without `*`) has no effect if it should come at the beginning of an output line, just as normal blanks are removed at the beginning of lines. The `*`-form, on the other hand, inserts the spacing no matter where it occurs.

A blank before or after the command will also be included:

This is\hspace{1cm}1cm	This is	1cm
This is \hspace{1cm}1cm	This is	1cm
This is \hspace{1cm} 1cm	This is	1cm

The length specification may be negative, in which case the command works as a backspace for overprinting characters with other ones, or moving them closer together. For example, there is an energy unit in physics called *electron volt*, abbreviated ‘eV’, which looks much better if the two letters are nearer together, as ‘eV’, with `e\hspace{-.12em}V`.

The command `\hfill` is an abbreviation for `\hspace{\fill}` (see Section 2.4.2). It inserts enough space at that point to force the text on either side to be pushed over to the left and right margins. With `Left\hfill Right` one produces

Left Right

Multiple occurrences of `\hfill` within one line will each insert the same amount of spacing so that the line becomes left and right justified. For example, the text `Left\hfill Center\hfill Right` generates

Left Center Right

If `\hfill` comes at the beginning of a line, the spacing is suppressed in accordance with the behavior of the standard form for `\hspace`. If a rubber space is really to be added at the beginning or end of a line, `\hspace*{\fill}` must be used instead. However, \LaTeX also offers a number of commands and environments to simplify most such applications (see Section 4.2.2).

A number of other fixed horizontal spacing commands are available:

`\quad` *and* `\qquad`

The command `\quad` inserts a horizontal space equal to the current type size, that is, 10 pt for a 10 pt typeface, whereas `\qquad` inserts twice as much.

Inserting variable and _____ sequences

Two commands that work exactly the same way as `\hfill` are

`\dotfill` *and* `\hrulefill`

Instead of inserting empty space, these commands fill the gap with dots or a ruled line, as follows:

Start `\dotfill`\ Finish\\ and
 Left `\hrulefill`\ Center `\hrulefill`\ Right\\ produce

Start Finish
 Left _____ Center _____ Right

Any combination of `\hfill`, `\dotfill`, and `\hrulefill` may be given on one line. If any of these commands appears more than once at one location, the corresponding filling will be printed that many more times than for a single occurrence.

```
Departure \dotfill\dotfill\dotfill\ 8:30 \hfill\hfill
```

```
Arrival \hrulefill\ 11:45\
```

```
Departure ..... 8:30                Arrival _____ 11:45
```

2.7.2 Line breaking

Breaking text into lines is done automatically in \TeX and \LaTeX . However, there are times when a line break must be forced or encouraged, or when a line break is to be suppressed.

The command `\`

A new line with or without additional line spacing can be achieved with the command `\`. Its syntax is

```
\[space]  
\*[space]
```

The optional argument *space* is a length that specifies how much additional line spacing is to be put between the lines. If it is necessary to start a new page, the additional line spacing is not included and the new page begins with the next line of text. The `*`-form prevents a new page from occurring between the two lines.

With `*[10cm]`, the current line is ended and a vertical spacing of 10 cm is inserted before the next line, which is forced to be on the same page as the current line. If a page break is necessary, it will be made before the current line, which is then positioned at the top of the new page together with the 10 cm vertical spacing and the next text line.

The command `\newline` is identical to `\` without the option *space*. That is, a new line is started with no additional spacing and a page break is possible at that point.

Both commands may be given only within a paragraph, and not between them where they would be meaningless.

Further line-breaking commands

The command `\linebreak` is used to encourage or force a line break at a certain point in the text. Its form is

```
\linebreak[num]
```

where *num* is an optional argument, a number between 0 and 4 that specifies how important a line break is. The command recommends a line break, and the higher the number the stronger the recommendation. A value of 0 allows a break where it otherwise would not occur (like in the middle of a word), whereas 4 compels a line break, as does `\linebreak` without *num*. The difference between this command and `\` or `\newline` is that the current line will be fully justified, that is, interword spacing will be added so that the text fills the line completely. With `\` and `\newline`, however, the line is filled with empty space after the last word and the interword spacing remains normal.

The opposite command

```
\nolinebreak[num]
```

discourages a line break at the given position, with *num* specifying the degree of discouragement. Again, `\nolinebreak` without a *num* argument has the same effect as `\nolinebreak[4]`, that is, a line break is absolutely impossible here.

Another way of forcing text to stay together on one line is with the command `\mbox{text}`. This is convenient for expressions such as ‘Voyager-1’ to stop a line break at the hyphen.

2.7.3 Vertical spacing

It is possible to add extra vertical spacing of amount *space* between particular paragraphs using the commands

```
\vspace{space}
\vspace*{space}
```

The ***-form will add the extra space even when a new page occurs, or when the command appears at the top of a new page. The standard form ignores the extra vertical spacing in these situations.

If these commands are given within a paragraph, the extra space is inserted after the current line, which is right and left justified as usual.

The *space* parameter may even be negative, in order to move the following text higher up the page than where it would normally be printed.

The command `\vfill` is an abbreviation for `\vspace{\fill}` (see Section 2.4.2). This is the equivalent of `\hfill` for vertical spacing, inserting enough blank vertical space to make the top and bottom of the text match up exactly with the upper and lower margins. The comments on multiple occurrences of `\hfill` also apply to `\vfill`. If this command is given at the beginning of a page, it is ignored, just like the standard form of `\vspace{\fill}`. If a rubber space is to be put at the top of a page, the ***-form `\vspace*{\fill}` must be used.

Further commands for increasing the spacing between paragraphs are

```
\bigskip \medskip \smallskip
```

which add vertical spacing depending on the font size declared in the document class.

2.7.4 Page breaking

Breaking text into pages occurs automatically in \TeX and \LaTeX , just as for line breaking. Here again, it may be necessary to interfere with the program's notion of where a break should take place.

Normal pages

The commands

```
\pagebreak[num]
\nopagebreak[num]
```

are the equivalents of `\linebreak` and `\nolinebreak` for page breaking. If `\pagebreak` appears between two paragraphs, a new page will be forced at that point. If it comes within a paragraph, the new page will be implemented after the current line is completed. This line will be right and left justified as usual.

The command `\nopagebreak` has the opposite effect: between paragraphs, it prevents a page break from occurring there, and within a paragraph, it stops a page break that might take place at the end of the current line.

Optional numbers between 0 and 4 express the degree of encouragement or discouragement for a page break. The analogy with the command `\linebreak` goes further: just as the line before the break is left and right justified with extra interword spacing, in the same way the page before the break is expanded with interline spacing to make it top and bottom justified.

The proper command to end a page in the middle, fill it with blank spacing, and go on to a new page is

```
\newpage
```

which is equivalent to `\newline` with regard to page breaking.

Pages with figures and tables

If the text contains tables, pictures, or reserved space for figures, these are inserted at the location of the corresponding command, provided that there is enough room for them on the current page. If there is not enough space, the text continues and the figure or table is stored to be put on a following page.

The command

`\clearpage`

ends the current page like `\newpage` and in addition outputs all the pending figures and tables on one or more extra pages (Chapter 7).

Two-column pages

If the document class option `twocolumn` has been chosen, or the command `\twocolumn` is in effect, then the two commands `\pagebreak` and `\newpage` end the current *column* and begin a new one, treating columns as pages. On the other hand, `\clearpage` and `\cleardoublepage` (see below) terminate the current page, inserting an empty right column if necessary.

Two-sided pages

An additional page-breaking command is available when the document class option `twoside` has been selected:

`\cleardoublepage`

which functions exactly the same as `\clearpage` (the current page is terminated, all pending figures and tables are output) but in addition, the next text will be put on to an *odd*-numbered page. If necessary, an empty page with an even number is printed to achieve this.

Controlling page breaks

\LaTeX provides the possibility of increasing the height of the current page slightly with commands

```
\enlargethispage{size}
\enlargethispage*{size}
```

which add the length *size* to `\textheight` for this one page only. Sometimes the difference of a few points is all that is necessary to avoid a bad page break. The ***-form of the command also shrinks any interline spacing as needed to maximize the amount of text on the page.

2.8 Word division

When a line is to be right and left justified, it often turns out that the break cannot be made between whole words without either shoving the text too close together or inserting huge gaps between the words. It is then necessary to split a word. This fundamental task is performed by \TeX , the underlying basis of \LaTeX , by means of a word-dividing algorithm

that works (almost) perfectly for English text, which is more than can be said for most authors. Nevertheless, even it makes mistakes at times which need to be corrected by human intervention.

If normal \TeX / \LaTeX is used for other languages, or if foreign words appear in English text, incorrect hyphenations are very likely to appear. (See Section 2.8.4 and Chapter 11 for more about \LaTeX with other languages.) In these cases too, something must be done to override \TeX 's hyphenation rules, as described below.

2.8.1 Manual hyphenation

The simplest way to correct a wrongly divided word is to include a `\-` command at the right place within the word. The word *manuscript*, for example, will not be hyphenated at all, so if it causes problems with breaking a line, write it as `man\ -u\ -script`. This tells \TeX to divide the word as necessary either as *man-uscript* or as *manu-script*, and to ignore its normal rules.

The `\-` command merely makes hyphenation possible at the indicated locations; it does not force it. If the author absolutely insists in dividing a word at a certain point, say between the *u* and *s* in *manuscript*, he or she can type `manu-\linebreak script` to achieve this. However, this brute force method is not recommended, because the line break will always occur here even if the text is later changed.

For English text, the spelling of a word remains the same when it is hyphenated, something that is not true in other languages. In traditional German spelling, for example, if *ck* is split, it becomes *k-k*. \TeX allows such behavior with the general hyphenation command

```
\discretionary{before}{after}{without}
```

where *before* and *after* are the letters (with hyphen) that come on either side of the break if division takes place, and *without* is the normal text with no hyphenation. Thus Boris Becker's name should be typed as

```
Boris Be\discretionary{k-}{k}{ck}er
```

something that one only wants to do in exceptional situations. Incidentally, the `\-` command is shorthand for `\discretionary{-}{-}{-}`.

Note: In today's new German spelling, *ck* is never split. This reformed spelling is still controversial however.

2.8.2 Hyphenation list

Words that are incorrectly hyphenated and that appear frequently within the document can be put into a *list of exceptions* in the preamble, to avoid laboriously inserting `\-` every time:

```
\hyphenation{list}
```

The *list* consists of a set of words, separated by blanks or new lines, with the allowed division points indicated by hyphens. For example,

```
\hyphenation{man-u-script com-pu-ter gym-na-sium
             coun-try-man re-sus-ci-tate ... }
```

The list may contain only words with the normal letters *a-z*, with no special characters or accents. However, if the `inputenc` package is loaded, then the directly typed letters are also be included in the automatic hyphenation.

2.8.3 Suppressing hyphenation

Another means of avoiding bad word divisions is to turn hyphenation off, at least for a paragraph or two. Actually the command

```
\begin{sloppypar} paragraph text \end{sloppypar}
```

does not prevent word division, but does permit larger interword spacings without giving a warning message. This means that practically all lines are broken between words. It is also possible to put the command `\sloppy` in the preamble or in the current environment to reduce the number of word divisions in the whole document or within the environment scope. This is recommended when the line width is rather narrow.

When the command `\sloppy` is in effect, it is possible to undo it temporarily and to turn hyphenation back on with the command `\fussy`.

2.8.4 Word division with multilingual text



Multiple hyphenation lists may be included in the \TeX format, making it possible to switch hyphenation schemes within one document, using the \TeX command `\language`. This command may be used as part of language-specific adaptations to translate certain explicit English words in the output (such as ‘Contents’), to simplify accents or punctuation, and to alter the definition of the date command `\today`. This topic is treated in more detail in Chapter 11.

3

Document Layout and Organization

3.1 Document class

The first command in the preamble of a \LaTeX file determines the global processing format for the entire document. Its syntax is:

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

where some value of *class* must be given, while [*options*] may be omitted if default values are acceptable.

The standard values of *class*, of which one and only one may be given, are: *book*, *report*, *article*, or *letter*. (The properties of the *letter* class are explained in Chapter 16.) The basic differences between these classes lie not only in the page layouts, but also in the organization. An article may contain *parts*, *sections*, *subsections*, and so on, while a report can also have *chapters*. A book also has chapters, but treats even and odd pages differently; also, it prints running heads on each page with the chapter and section titles.

Other classes besides the standard ones exist, as contributions for specific journals, or for book projects. These will have their own set of *options* and additional commands, which should be described in separate documentation or instructions. However, since they are normally modifications of one of the standard classes, most of the following options apply to them too.

3.1.1 Standard class options

The *options* available allow various modifications to be made to the formatting. They can be grouped as follows.

Selecting font size

The basic font size is selected with one of the options

10pt 11pt 12pt

This is the size of the font in which the normal text in the document will be set. The default is 10pt, which means that this is the value assumed if no size option is specified. All other font size declarations are relative to this standard size, so that the section titles, footnotes, and so on will all change size automatically if a different basic font size is selected.

Specifying paper size

LaTeX calculates the text line width and lines per page according to the selected font size and paper mode. It also sets the margins so that the text is centered both horizontally and vertically. In order to do this, it needs to know which paper format is being used. This is specified by one of the following options:

<code>letterpaper</code> (11 × 8.5 in)	<code>a4paper</code> (29.7 × 21 cm)
<code>legalpaper</code> (14 × 8.5 in)	<code>a5paper</code> (21 × 14.8 cm)
<code>executivepaper</code> (10.5 × 7.25 in)	<code>b5paper</code> (25 × 17.6 cm)

The default is `letterpaper`, American letter size paper, 11 × 8.5 in.

Normally, the paper format is such that the longer dimension is the vertical one, the so-called *portrait* mode. With the option

`landscape`

the shorter dimension becomes the vertical one, the *landscape* mode. (One still has to ensure that the output is printed as landscape; see for example page 232.)

Page formats

The text on the page may be formatted into one or two columns with the options

`onecolumn` `twocolumn`

The default is `onecolumn`. In the case of the `twocolumn` option, the separation between the columns as well as the width of any rule between them may be specified by `\columnsep` and `\columnseprule`, described below.

The even- and odd-numbered pages may be printed differently according to the options

`oneside` `twoside`

With `oneside`, all pages are printed the same; however, with `twoside`, the running heads are such that the page number appears on the right on odd

pages and on the left on even pages. *It does not force the printer to output double-sided.* The idea is that when these are later printed back-to-back, the page numbers are always on the outside where they are more easily noticed. This is the default for the `book` class. For `article` and `report`, the default is `oneside`.

With the `book` class, chapters normally start on a right-hand, odd-numbered page. The options

`openright` `openany`

control this feature: with `openany` a chapter always starts on the next page, but with `openright`, the default, a blank page may be inserted if necessary.

Normally the title of a book or `report` will go on a separate page, while for an `article`, it is placed on the same page as the first text. With the options

`notitlepage` `titlepage`

this standard behavior may be overruled. See Sections 3.3.1 and 3.3.2.

Further options

The remaining standard options are:

`leqno` Equation numbers in displayed formulas will appear on the left instead of the normal right side (Section 5.1).

`fleqn` Displayed formulas will be set flush left instead of centered (Section 5.1). The amount of indentation may be set with the parameter `\mathindent` described below.

`openbib`
The format of bibliographies may be changed so that segments are set on new lines. By default, the texts for each entry are run together.

`draft` If the \LaTeX line-breaking mechanism does not function properly and text must stick out into the right margin, then this is marked with a thick black bar, to make it noticeable.

`final` The opposite of `draft`, and the default. Lines of text that are too wide are not marked in any way.

If multiple options are to be given, they are separated by commas, as for example, `\documentclass[11pt,twoside,fleqn]{article}`. The order of the options is unimportant. If two conflicting options are specified, say `oneside` and `twoside`, it is not obvious which one will be effective. That depends entirely on the definitions in the class file itself, so it would be best to avoid such situations.

Parameters associated with some options

Some options make use of parameters that have been given certain default values:

`\mathindent`

specifies the indentation from the left margin for the equation numbers when `fleqn` is selected (Section 5.1);

`\columnsep`

specifies the space between the two columns for the `twocolumn` option (see Figure H.2 on page 603);

`\columnseprule`

determines the width of the vertical line between the two columns for the `twocolumn` option. The default is zero width, that is, no vertical rule (see Figure H.2).

The standard values of these parameters may be changed with the \LaTeX command `\setlength`. For example, to change `\mathindent` to 2.5 cm, give

```
\setlength{\mathindent}{2.5cm}
```

These parameters may be assigned values either in the preamble or at any place in the document. Parameters in the preamble apply to the entire document, whereas those within the text are in effect until the next change or until the end of the environment in which they were made (Section 2.3). In the latter case, the previous values become effective once more.

Exercise 3.1: Take your text file from Exercise 2.2 and change the initial command `\documentclass{article}` first to `\documentclass[11pt]{article}` and then to `\documentclass[12pt]{article}` and print the results of each \LaTeX processing. Compare the line breaking of these outputs with that of Exercise 2.2.

Note: if there are some improper word divisions, you call tell \LaTeX where the correct division should occur with the command `\-`, for example, `man\-\u\-\script`. (This is one of the few words that the \TeX English word divider does not handle properly.) Additional means of modifying word division are given in Section 2.8. If there are warnings of the sort `Overfull \hbox . . .` during the \LaTeX processing, \TeX was not able to break the lines cleanly. In the output, these lines will extend beyond the right margin. The usual cause is that \TeX was not able to divide some word, either because it is indivisible or because \TeX 's word division routines were not adequate. Here again a suggested hyphenation in the text can solve the problem. Other solutions will be given shortly.

Exercise 3.2: Now employ `\documentclass[twocolumn]{article}` in your text file. If you now receive a number of warnings with `Underfull \hbox . . .`, then these lines will indeed be left and right justified but will have too much empty

space between the words. Check the output yourself to see whether the word spacing is acceptable. If not, try giving some hyphenation suggestions in the first words of the next line.

Note: if you use the classes `book` or `report` instead of `article` in the preceding exercises, you will notice no difference in the outputs. These classes affect the subsequent structural elements of the document. Basically, you should use `article` for short articles (say 10–20 pages) and `report` for longer reports that are to be organized into chapters. The chapters always begin on a new page. The class `book` is available for producing books.

3.1.2 Loading packages

In Section 1.5.3 we explained how L^AT_EX can be extended by *packages* which are either part of the core installation or contributed by engaged users. How to write your own packages is described in Appendix D.

A package is nothing more than a set of L^AT_EX (or T_EX) commands stored in a file with the extension `.sty`, although there are some special commands that may only appear within them. To invoke a package, simply call

```
\usepackage{package}
```

in the preamble, where *package* is the root name of the file. More than one package may be loaded with one call to `\usepackage`. For example, two packages provided with standard L^AT_EX are stored in files `makeidx.sty` (Section 9.4.3) and `ifthen.sty` (Section 8.3.5). They may be read in together with

```
\usepackage{makeidx,ifthen}
```

A package may have options associated with it, which may be selected in the same way as for document classes: by including the option names within square braces. The general syntax is thus:

```
\usepackage[opt1,opt2...]{package1,package2,...}
```

where all the listed options will be applied to all the selected packages. If any of the packages does not understand one of the options, a warning message is output to the monitor.

3.1.3 Global and local options

!

One interesting feature about options specified with the `\documentclass` command is that they also apply to any packages that follow. This means that if several packages all take the same option, it is only necessary to declare it once in `\documentclass`. For example, one might design a package to modify `article` for generating a local house style that might do different things for single or double column text; this package could make use of the class options `onecolumn` and `twocolumn` to achieve this. Or it could elaborate on the draft

option to produce double line spacing, as for a manuscript. Alternatively, several packages might have language-dependent features that could be activated with options like `french` or `german`; it is sufficient to list such options only in `\documentclass` to apply them to all packages. Such options are called *global*, for they are passed on to all subsequent packages automatically.

Global options need not be limited to the standard class options listed in Section 3.1.1. A warning message is printed only if neither the class nor any of the packages understand one or more of them. By contrast, any options specified with `\usepackage` will be applied only to those packages listed in that one command; and it is applied to all of them. A warning is printed if one or more of those packages does not recognize any one of these *local* options.

3.1.4 Class and package versions



Class and package files normally have an internal version specification in the form of their release date, as *yyyy/mm/dd*. If you wish to make use of some feature that you know was added on a certain date, you include that date in square brackets after the class or package name. An example of this is shown in Section 3.2.4 on page 46.

The version date may also be added to the `\documentclass` command to ensure that the right version of the class file is being employed. The reason for doing this is to ensure that the source files are processed properly, say on other systems.

3.2 Page style

The basic page format is determined by the *page style*. With one exception, this command is normally given in the preamble. Its form is:

```
\pagestyle{style}
```

The mandatory argument *style* takes on one of the following values:

`plain` The page head is empty, the foot contains the centered page number. This is the default for the `article` and `report` classes when no `\pagestyle` is given in the preamble.

`empty` Both head and footlines are empty; no page numbers are printed.

`headings`

The head contains the page number as well as title information (chapter and section headings); the foot is empty. This is the default for book class.

`myheadings`

The same as `headings` except that the page titles in the head are not chosen automatically but rather are given explicitly by the commands `\markright` or `\markboth` (see below).

The command

```
\thispagestyle{style}
```

functions exactly as `\pagestyle` except that it affects only the current page. For example, the page numbering may be suppressed for just the current page with the command `\thispagestyle{empty}`. It is only the *printing* of the page number that is suppressed; the next page will be numbered just as though the command had never been given.

3.2.1 Heading declarations

For the page styles `headings` and `myheadings`, the information appearing in the headline may be given with the declarations

```
\markright{right_head}
\markboth{left_head}{right_head}
```

The declaration `\markboth` is used with the document class option `twoside`, with even-numbered pages considered to be on the *left* and odd-numbered pages on the *right*. Furthermore, the page number is printed on the left side of the head for a left page and on the right side for a right page.

For one-sided output, all pages are considered to be right-handed. In this case, the declaration `\markright` is appropriate. It may also be used with two-sided output to overwrite the *right.head* given in `\markboth`.

With the page style `headings`, the standard titles in the page headline are the chapter, section, or subsection headings, depending on the document and page style, according to the following scheme:

Style		Left Page	Right Page
book, report	one-sided	—	<i>Chapter</i>
	two-sided	<i>Chapter</i>	<i>Section</i>
article	one-sided	—	<i>Section</i>
	two-sided	<i>Section</i>	<i>Subsection</i>

If there are more than one `\section` or `\subsection` on a page, it is the heading of the last one that appears in the page head.

3.2.2 Customized head and footlines

Package: `fancyhdr` The standard page styles described in Section 3.2 select how the head and footlines are to appear, and what information they contain. This is a very limited choice, and the `fancyhdr` package by Piet van Oostrum offers the user considerable more flexibility.

This package makes available an additional page style named `fancy` which the user can easily redefine. Head and footlines consist each of

three parts, left, center, right, each of which can be individually defined with

```
\lhead{Left head} \chead{Center head} \rhead{Right head}
\lfoot{Left foot} \cfoot{Center foot} \rfoot{Right foot}
```

where the various texts may be explicit, or a command like `\thepage` to print the current page number. Both head and footlines may be decorated with a rule, the widths of which are set by commands `\headrulewidth` and `\footrulewidth`. By default, the fancy head and footlines are much the same as for the `headings` page style, but the head rule is set to 0.4 pt and the foot rule set to 0 (no rule). The rules may be redefined with, for example,

```
\renewcommand{\footrulewidth}{0.4pt}
```

to turn the foot rule on.

The above defining commands are in fact specific examples of the more general commands `\fancyhead` and `\fancyfoot`, where

```
\lhead{..} is \fancyhead[L]{..}
\cfoot{..} is \fancyfoot[C]{..}
```

and so on, with L C R standing for 'left', 'center', 'right'.

For two-sided output with the `twoside` option, one normally wants the left and right parts to alternate with page number. The easiest way to do this is with

```
\fancyhead[LE,RO]{Text 1} \fancyhead[LO,RE]{Text 2}
```

to put the same *Text 1* in the left part of even pages, and right part of odd pages, and *Text 2* for the other way round. With `\fancyhead{}`, all head line parts are set to blanks, something that should be done before resetting them explicitly. Similarly `\fancyfoot{}` sets all foot entries to blank.

The default (two-sided) definitions for the fancy page style are

```
\fancyhead[EL,OR]{\texts1\rightmark}
\fancyhead[ER,OL]{\texts1\leftmark}
```

where `\rightmark` and `\leftmark` contain the automatic texts for the `headings` page style generated by the `\chapter`, `\section`, `\subsection` commands (Section 3.3.3), while `\texts1` (Section 4.1.4) sets its argument in a slanted typeface. The user may also make use of these to redefine the head line with automatic texts.

There is also the most general `\fancyhf` command taking optional arguments [H] and [F] to apply to head or footlines. Thus `\fancyhf[HL]{..}` is the same as `\fancyhead[L]{..}`. Clearly, `\fancyhf{}` resets everything.

In many classes, the first page of a chapter, or the very first page of the document, is switched to `plain` automatically. If the user wants to change this, he or she must redefine that page style. The `fancyhdr` package simplifies this task with

```
\fancypagestyle{plain}{definitions}
```

where *definitions* consist of `\fancyhead`, `\fancyfoot`, and/or rule redefinitions that are to apply to the revised `plain` style. In fact, any existing page style can be redefined in this way.

3.2.3 Page numbering

The declaration that specifies the style of the page numbering has the form

```
\pagenumbering{num_style}
```

The allowed values of *num_style* are:

<code>arabic</code>	for normal (Arabic) numerals,
<code>roman</code>	for lower case Roman numerals,
<code>Roman</code>	for upper case Roman numerals,
<code>alph</code>	for lower case letters,
<code>Alph</code>	for upper case letters.

The standard value is `arabic`. This declaration resets the page counter to 1. In order to paginate the foreword of a document with Roman numerals and the rest with Arabic numbers beginning with page 1 for chapter 1, one must declare `\pagenumbering{roman}` at the start of the foreword and then reset the page numbering with `\pagenumbering{arabic}` immediately after the first `\chapter` command. (See Section 3.3.5 for the preferred method.)

Pages may be numbered starting with a value different from 1 by giving the command

```
\setcounter{page}{page_num}
```

where *page_num* is the number to appear on the current page.

Exercise 3.3: Expand your exercise text file so that it fills more than one page of output and include the following preamble:

```
\documentclass{article}
\pagestyle{myheadings} \markright{Exercises}
\pagenumbering{Roman}
\begin{document}
```

3.2.4 Paragraph formatting

The following parameters affect the appearance of a paragraph and may be given new values with `\setlength` as explained in Section 8.2:

`\parskip`

The distance between paragraphs, expressed in units of `ex` so that it will automatically change with character font size. This should be a *rubber* length.

`\parindent`

The amount of indentation for the first line of a paragraph.

`\baselinestretch`

This is a number that magnifies the normal distance between *baselines*, the line on which the letters sit. This number is initially 1, for standard line spacing. It may be changed to another number with

```
\renewcommand{\baselinestretch}{factor}
```

where *factor* is any decimal number, such as 1.5 for a 50% increase. This then applies to all font sizes. If this command is given outside the preamble, it does not come into effect until another font size has been selected (Section 4.1.2).

These parameters may be set either in the preamble or anywhere in the text of the document. In the latter case, the changes remain in effect until the next change or until the end of the environment in which they were made (Section 2.3).

To suppress indentation for one paragraph, or to force it where it would otherwise not occur, place

```
\noindent or \indent
```

at the beginning of the paragraph to be affected.

Package: `indentfirst` Normally, the first paragraph of a section is not indented, not even with `\indent`. However, by including the package `indentfirst` one ensures that all paragraphs are indented.

Package: `parskip` By default, \LaTeX indicates paragraphs by indenting the first line. An alternative is without indentation but with extra spacing between paragraphs. One could redefine `\parindent` and `\parskip` accordingly, or one could employ one of the oldest and simplest packages dating back to \LaTeX 2.09 days: `parskip`, written by H. Partl. For consistency, this package also makes some changes in the parameters for lists (Section 4.3). One loads this package with

```
\usepackage{parskip}
```

There is a recent update to the `parskip` package by Robin Fairbairns that includes the option `parfill`, given as

```
\usepackage[parfill]{parskip}
```

that avoids ugly-looking rectangular paragraphs by ensuring that there is always space at the end of the last line. This update is dated April 9, 2001, so to be sure that this package version is loaded, add this date as

```
\usepackage[parfill]{parskip}[2001/04/09]
```

as explained in Section 3.1.4. A warning will be issued on processing if the actual version of `parskip` is earlier than this. There will also be warning about the unknown option `parfill`.

Exercise 3.4: Add the following to the preamble of your exercise file:

```
\usepackage{parskip}
\renewcommand{\baselinestretch}{1.2}
```

After processing this exercise, repeat it with another value for the parameter `\baselinestretch`, say 1.5, in order to get a feeling for how it works. Remove these lines from the exercise file afterwards.

3.2.5 Page format

Each page consists of a *head*, the *body* containing the actual text, and a *foot*. The selection of the page style determines what information is to be found in the head and footlines.

LaTeX uses default values for the distances between the head, body, and foot, for the upper and left margins, and for the text line width and heights of the head, body, and foot. These formatting lengths are illustrated in Figure 3.1 on the next page. They may be changed by declaring new values for them, preferably in the preamble, with the command `\setlength` (Section 8.2). For example, give

```
\setlength{\textwidth}{12.5cm}
```

to make the text line width to be 12.5 cm.

There is also a parameter `\linewidth` equal to the text line width in whatever environment one is currently in. This must never be changed, but is used when one needs to know this width.

More detailed diagrams of the page formats for one- and two-column outputs are shown at the end of Appendix H in Figures H.1 and H.2.

Package:
layout

You can examine your own page layout with the `layout` package from the tools collection. Simply issue the command `\layout` and a diagram similar to that in Figure 3.1 will be drawn at that point, together with a list of the current values of the layout parameters. Naturally, you would not do this in the middle of the final version of a document, but only as diagnostic check.

`\oddsidemargin`
 left margin for odd pages,
`\evensidemargin`
 left margin for even pages,
`\topmargin`
 upper margin to top of head,
`\headheight`
 height of head,
`\headsep`
 distance from the bottom of
 headline to top of body,
`\topskip`
 distance from top of body to
 baseline of first line of text,
`\textheight`, `\textwidth`
 height and width of main text,
`\footskip`
 distance from bottom of body
 to bottom of foot,
`\paperwidth`, `\paperheight`
 total width and height of paper
 as given by paper size option,
 including all margins.

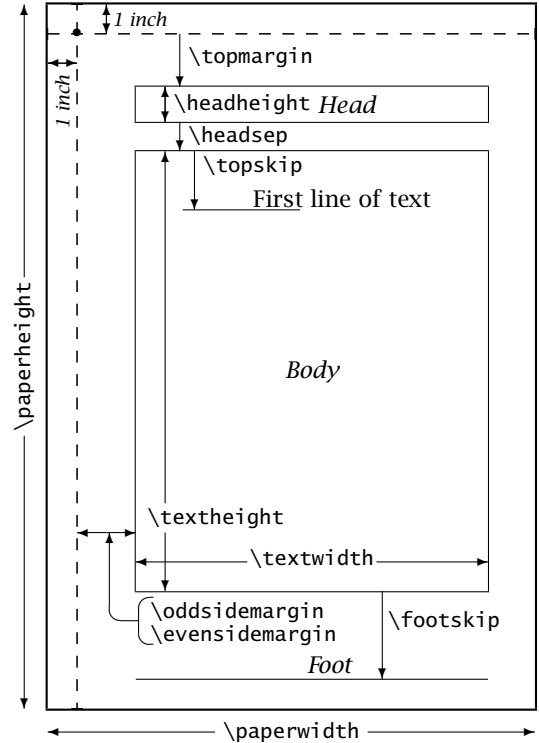


Figure 3.1: Page layout parameters

!

In order to calculate the page layout precisely, one must realize that \LaTeX measures all distances from a point one inch from the top of the paper and one inch from the left edge. Thus the total left margin is `\oddsidemargin` plus one inch. The \LaTeX parameters `\paperwidth` and `\paperheight`, which include this extra inch, are given their values by the paper size option in the `\documentclass` command; they are used internally to calculate the margins so that the text is centered. The user may also take advantage of them for calculations.

!

With document class `book` or with the option `twoside`, the bottom edge of the body will always appear at exactly the same position on every page. In the other classes or options, it will vary slightly. In the first two cases, the constant bottom edge is produced by the internal command `\flushbottom`, whereas the varying bottom is produced by the command `\raggedbottom`. The user may apply these declarations to change the behavior of the bottom edge at any time, independent of document class and options.

Exercise 3.5: You can change the page format of your text by altering the above parameters. Add the following to the preamble of your text:

```
\setlength{\textwidth}{13cm} \setlength{\textheight}{20.5cm}
```

The upper and left margins of your output will now seem too small. Select new values for `\oddsidemargin` and `\topmargin` to correct this. Note: do not

forget the 1 inch margin at the left and top from which additional margins are measured. You must take this into account when you select `\oddsidemargin` and `\topmargin`.

Exercise 3.6: Expand your text so that the output requires more than two full pages with the reduced page format. Add `\flushbottom` to the preamble and check that the last line of all pages is at exactly the same location.

Exercise 3.7: Remove the command `\flushbottom` and select the document class `\documentclass[twoside]{article}`. Now the last lines are at the same location without the `\flushbottom` command. On the other hand, the left margin of the odd pages probably does not agree with the right margin of the even pages. Adjust the value of `\evensidemargin` to correct this.

3.2.6 Simplified page formatting

Package: Getting the page layout to be exactly the way you want it can be very tedious. Just centering the text on the page involves a complex set of settings that are not at all intuitive. The `geometry` package by Hideo Umeki offers considerable assistance.

With this package, one can easily give values for some of the layout parameters, and the rest will be set automatically, taking into account the total paper size. For example, to set `\textwidth` to 15 cm and `\textheight` to 25 cm on A4 paper, one gives

```
\usepackage{geometry}
\geometry{a4paper,textwidth=15cm,textheight=25cm}
```

which will also automatically set `\oddsidemargin` and `\topmargin` so that the text is centered horizontally and vertically, including the head and footlines. Or, one can set all the margins to be 1 inch on US letter paper with

```
\geometry{letterpaper,margin=1in}
```

Rather than using the `\geometry` command, one may also place the parameters as options to `\usepackage`, for example as

```
\usepackage[a4paper,left=3cm,right=2cm]{geometry}
```

to set the left and right margins to definite values, and `\textwidth` to what is left over.

In general, all the parameters in Figure 3.1 may be specified by `geometry` by giving their names (without the backslash character). However, the package is far more powerful than that. Here we describe the essential features of version 2.3 from 2000/06/28.

- The paper size is either inherited from the `\documentclass` option, given as a predefined option like `a4paper`, given explicitly as

`paperwidth=pwidth` and `paperheight=pheight`, or as `papersize={pwidth,pheight}`.

- By default, the other layout parameters are set so that `\textwidth` is 80% of `\paperwidth` and `\textheight + \headheight + \headsep + \footskip` is 90% of `\paperheight`, centered horizontally and vertically.
- The text width and height may be set explicitly with `width=width` and `height=height`, or with `body={width,height}`. The margins are then set to center. Here *height* means total text height including head and footlines.
- Margins may be explicitly given with `left=lmarg` and `right=rmarg`, or with `hmargin={lmarg,rmarg}`. Similarly with `top=tmarg` and `bottom=bmarg`, or `vmargin={tmarg,bmarg}`. If only one value of a pair is given, the other is set to that same value, unless the corresponding text height or width has been given explicitly. All margins may be set to a common value with `margin=marg`.

Unlike L^AT_EX standard `\oddsidemargin` and `\topmargin`, `geometry`'s margins are measured from the edge of the paper, and not from a point 1 inch removed.

- With `nohead`, `nofoot`, `noheadfoot`, one tells `geometry` not to include the corresponding head or footline in the height calculation. Thus with `noheadfoot`, the total height is identical to `\textheight`.
- With `includemp`, the marginal note parameters `\marginparwidth` and `\marginparsep` (Section 4.10.5) are included in the total width calculation, which is then less than `\textwidth`. With `reversemp`, the marginal notes appear in the left margin.
- The text width and height may be set to a fraction of the paper size with `hscale=h` and `vscale=v`, or `scale={h,v}`. With `scale=s`, both *h* and *v* are set to *s*. For example, `\geometry{scale=0.8}` sets width and height to 80% of `\paperwidth` and `\paperheight` respectively.
- For two-sided output, add the option `twoside`. In this case, the values of the left and right margins will switch for even page numbers. In addition, a quantity of 20 pt is added to and subtracted from the left margin of odd and even pages, respectively. This value may be changed with `twosideshift=shift`, which also sets the `twoside` option automatically.
- With the `verbose` option, the calculated values of all the layout parameters are printed to the monitor and to the transcript file.

As you see, the `geometry` package is an enormous aid to setting the page layout, working fairly intuitively, automatically setting values for the unspecified parameters in a way that is normally what one would want anyway. There are many more aspects explained in the accompanying documentation, but the above synopsis should cover most requirements.

3.2.7 Single and double column pages

The document class option `twocolumn` sets the entire document in two columns per page. The default is one column per page. Individual pages may be output in one or two columns with the declarations:

`\twocolumn[header text]`

Terminates the current page, starting a new one with *two columns* per page. The optional *header text* is written at the top of the page in one column with the width of the whole page.

`\onecolumn`

Terminates the current two-column page and continues with one column per page.

!

The option `twocolumn` automatically changes certain page style parameters, such as indentation, compared with the one-column format. This does not occur with the command `\twocolumn`. These additional changes must be made with the corresponding `\setlength` declarations if they are desired. If the bulk of the document is in two-column format, the class option is to be preferred.

!

An additional page style parameter is `\columnwidth`, the width of one column of text. For single column text, this is the same as `\textwidth`, but when `twocolumn` has been selected, \LaTeX calculates it from the values of `\textwidth` and `\columnsep`. The author should never change this parameter, but he or she may make use of it, for example to draw a rule the width of a column of text.

!

The length `\linewidth` is even more general, always containing the text line width in the current environment, `minipage`, `parbox`. Within a single column, it is the same as `\columnwidth`. It too may never be changed.

3.2.8 Multicolumn text

Package:
`multicol`

The commands `\twocolumn` and `\onecolumn` always start a new page, and when two-column text is terminated, the two columns are of unequal length. These problems are solved with the `multicol` package in the `tools` collection, written by Frank Mittelbach, which also allows up to 10 columns of text. Once this package has been loaded, one can switch the number of columns in the middle of a page with

```
\begin{multicols}{num_cols}[header text][pre.space]
  Text set in num_cols columns
\end{multicols}
```

where the optional *header text* is written across all the columns before switching to multicolumns.

Some automatic control for page breaking before and after switching to multicolumns is offered by the two lengths `\premulticols` and `\postmulticols`: if the remaining space on the current page is less than `\premulticols`, a new page is started before switching to multicolumns. Similarly, if at the end of the environment, there is less than `\postmulticols` on the page, a page break is inserted before continuing. The standard values of these lengths may be altered by the user with `\setlength`, or in the case of `\premulticols` may be overridden by the second optional argument *pre.space*.

The lengths `\columnsep` and `\columnseprule` that apply to two-column texts are also in effect for the `multicols` environment, to set the widths of the gap between columns and a possible separating rule, respectively.

There is also a starred version `\begin{multicols*}{num.cols}... \end{multicols*}` for which the columns on the last page are not balanced, with all the remaining space put into the final column.

3.3 Parts of the document

Every document is subdivided into chapters, sections, subsections, and so on. There can be an appendix at the end and at the beginning a title page, table of contents, an abstract, etc. \LaTeX has a number of markup commands available to indicate these structures. In addition, sequential numbering and sub-numbering of headings take place automatically. Even a table of contents may be produced with a single command.

The effects of some sectioning commands depend on the selected document class and not all commands are available in every class.

3.3.1 Title page

A title page can be produced either unformatted with the environment

```
\begin{titlepage} Title page text \end{titlepage}
```

or with the commands

```
\title{Title text}
\author{Author names and addresses}
\date{Date text}
\maketitle
```

in the preprogrammed \LaTeX style.

In the standard \LaTeX layout for the title page, all entries are centered on the lines in which they appear. If the title is too long, it will be broken


```

\title{%
  How to Write DVI Drivers}

\author{%
  Helmut Kopka\thanks{Tel.
    [+49] 5556--401--451}\
  Max--Planck--Institut\
  f\"ur Aeronomie
\and
  Phillip G. Hardy
  \thanks{Tel.
    [+1] 319--824--7134}\
  University\of Iowa}

\maketitle

```

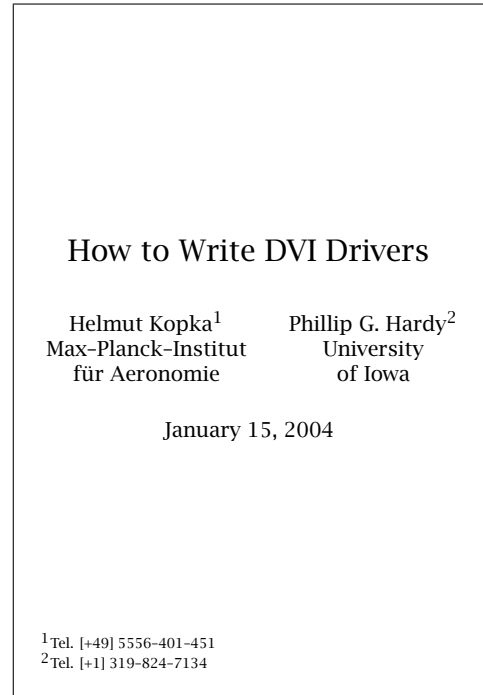


Figure 3.2: Sample title page and the text that produced it

up automatically. The author may select the break points himself with the `\\` command, that is, by giving `\title{...\\...\\...}`.

If there are several authors, their names may be separated with `\and` from one another, such as `\author{G. Smith \and J. Jones}`. These names will be printed next to each other in one line. The sequence

```

\author{Author1\\Institute1\\Address1
\and Author2\\Institute2\\Address2}

```

separately centers the entries, one per line, in each of the sets *Author1*, *Institute1*, *Address1* and *Author2*, *Institute2*, *Address2* and places the two blocks of centered entries beside each other on the title page.

Instead of printing the author names next to each other, one may position them on top of one another by replacing `\and` with the `\\` command. In this case, the vertical spacing may be adjusted with an optional length specification [*space*] following the `\\`.

If the command `\date` is omitted, the current date is printed automatically below the author entries on the title page. On the other hand, the command `\date{Date text}` puts the text *Date text* in place of the current date. Any desired text may be inserted here, including line break commands `\\` for more than one line of centered text.

The command

```
\thanks{Footnote text}
```

may be given at any point in the *title*, *author*, or *date text*. This puts a marker at that point where the command appears and writes *footnote text* as a footnote on the title page.

The title page is created using the entries in `\title`, `\author`, `\date`, and `\thanks` when the command

```
\maketitle
```

is issued. The title page itself does not possess a page number and the first page of the following document is number 1. (For `book`, the page numbering is controlled by the special commands in Section 3.3.5.) A separate title page is only produced for document classes `book` and `report`. For `article`, the command `\maketitle` creates a title heading on the first page using the centered entries from the `\title`, `\author`, and, if present, `\date` and `\thanks` declarations. If the document class option `titlepage` has been given, the title appears on a separate page even for the `article` class.

An example of a title page in the standard L^AT_EX format is shown in Figure 3.2 on the previous page. Note that the current date appears automatically since the command `\date` is missing in the definition of the title page. This command may be used to put any desired text in place of the date.

For the unformatted title page produced with the `titlepage` environment, the commands `\title` and `\author` are left out and the entire title page is designed according to the author's specifications within the environment. To this end he or she may make use of all the structuring commands described in Chapter 4. In this case the printing of the title page is implemented at the end of the `titlepage` environment, so the command `\maketitle` is also left out.

Exercise 3.8: Remove the declarations for changing the page format in Exercises 3.5–3.7. Add to your exercise text a title heading with the title 'Exercises', your name as author, and your address, together with a date entry in the form 'place, date'. To do this, write the following commands after `\begin{document}`:

```
\title{Exercises} \author{Your name\Your address}
\date{Your town, \today} \maketitle
```

Make sure that you have selected document class `article`. After printing the document, change the document class command to

```
\documentclass[titlepage]{article}
```

to put the title information on to a title page instead of a title heading. Deactivate these commands by putting the comment character `%` at the beginning of each of the lines. In this way you avoid getting a title page in the following exercises but you can easily reactivate the commands simply by removing the `%` characters.

3.3.2 Abstract

The abstract is produced with the command

```
\begin{abstract} Text for the abstract \end{abstract}
```

In document class `report`, the abstract appears on a separate page without a page number; in `article`, it comes after the title heading on the first page, unless the document class option `titlepage` has been selected, in which case it is also printed on a separate page. An abstract is not possible in document class `book`.

3.3.3 Sections

The following commands are available for producing automatic, sequential sectioning:

```
\part          \chapter      \subsection    \paragraph
               \section     \subsubsection \subparagraph
```

With the exception of `\part`, these commands form a sectioning hierarchy. In document classes `book` and `report`, the highest sectioning level is `\chapter`. The chapters are divided into sections using the `\section` command, which are further subdivided by means of `\subsection`, and so on. In document class `article`, the hierarchy begins with `\section` since `\chapter` is not available.

The syntax of all these commands is

```
\sec_command[short title]{title} or
\sec_command*{title}
```

In the first case, the section is given the next number in the sequence, which is then printed together with a heading using the text *title*. The text *short title* becomes the entry in the table of contents (Section 3.4) and the page head (provided that page style `headings` has been selected). If the optional *short title* is omitted, it is set equal to *title*; this is the normal situation unless *title* is too long to serve for the other entries.

In the second (*-form) case, no section number is printed and no entry in the table of contents is made (however, see Section 3.4.3).

The size of the title heading and the depth of the numbering depend on the position of the sectioning command within the hierarchy. For document class `article`, the `\section` command generates a single number (say 7), the `\subsection` command a double number with a period between the two parts (say 7.3), and so on.

In document classes `book` and `report`, the chapter headings are given a single number with the `\chapter` command, the `\section` command creates the double number, and so on. Furthermore, the command `\chapter` always starts a new page and prints **Chapter n** over the chapter title, where

`n` is the current chapter number. At this point in the present book, we are in *Chapter 3, Section 3.3, Subsection 3.3.3*.

For each sectioning command there is an internal counter that is incremented by one every time that command is called, and reset to zero on every call to the next higher sectioning command. These counters are not altered by the ***-forms, a fact that can lead to difficulties if standard and ***-forms of the commands are mixed such that the ***-forms are higher in the hierarchy than the standard forms. There are no problems, however, if the ***-forms are always lower than the standard forms. The sequence

```
\section ... \subsection ... \subsubsection* ...
```

numbers the headings for `\section` and `\subsection` while leaving the headings for `\subsubsection` without any numbering.

The sectioning command `\part` is a special case and does not affect the numbering of the other commands.

The automatic numbering of sections means that the numbers might not necessarily be known at the time of writing. The author may be writing them out of their final order, or might later introduce new sections or even remove some. If he or she wants to refer to a section number in the text, some mechanism other than typing the number explicitly will be needed. The L^AT_EX cross-reference system, described in detail in Section 9.2.1, accomplishes this task with the two basic commands

```
\label{name}    \ref{name}
```

the first of which assigns a keyword *name* to the section number, while the second may be used as reference in the text for printing that number. The keyword *name* may be any combination of letters, numbers, or symbols. For example, in this book the command `\label{sec:xref}` has been typed in at the start of Section 9.2.1, so that this sentence contains the input text at the start of Section `\ref{sec:xref}`.

A second referencing command is `\pageref` for printing the page number where the corresponding `\label` is defined.

The referencing commands may be used in many other situations for labeling items that are numbered automatically, such as figures, tables, equations.

!

Every sectioning command is assigned a level number such that `\section` is always level 1, `\subsection` level 2, ... `\subparagraph` level 5. In document class `article`, `\part` is level 0 while in `book` and `report` classes, `\part` is level -1 and `\chapter` becomes level 0. Section numbering is carried out down to the level given by the number `secnumdepth`. This limit is set to 2 for `book` and `report`, and to 3 for `article`. This means that for `book` and `report`, the section numbering extends only to the level of `\subsection` and for `article` to `\subsubsection`.

In order to extend (or reduce) the level of the section numbering, it is necessary to change the value of `secnumdepth`. This is done with the command

```
\setcounter{secnumdepth}{num}
```

(The command `\setcounter` is explained in Section 8.1.) In `article`, `num` may take on values from 0 to 5, and in `book` and `report` from -1 to 5.

It is possible to change the initial value of a sectioning command within a document with the command

```
\setcounter{sec_name}{num}
```

where `sec_name` is the name of the sectioning command without the preceding `\` character. This procedure may be useful when individual sections are to be processed by \LaTeX as single files. For example,

```
\setcounter{chapter}{2}
```

sets the `\chapter` counter to 2. The counter will be incremented on the next call to `\chapter` which then produces **Chapter 3**.

3.3.4 Appendix

An appendix is introduced with the declaration

```
\appendix
```

It has the effect of resetting the section counter for `article` and the chapter counter for `book` and `report` and changing the form of the numbering for these sectioning commands from numerals to capital letters A, B, Furthermore, the word ‘Chapter’ is replaced by ‘Appendix’ so that subsequent chapter headings are preceded by ‘Appendix A’, ‘Appendix B’, etc. The numbering of lower sectioning commands contains the letter in place of the chapter number, for example A.2.1.

3.3.5 Book structure

To simplify the structuring of a book, the commands

```
\frontmatter
  preface, table of contents
\mainmatter
  main body of text
\backmatter
  bibliography, index, colophon
```

are provided in the book class. The `\frontmatter` command switches page numbering to Roman numerals and suppresses the numbering of chapters; `\mainmatter` resets the page numbering to 1 with Arabic numbers and reactivates the chapter numbering; this is once again turned off with `\backmatter`.

Exercise 3.9: *Insert at the beginning of your exercise text the command `\section{Title A}` and at some appropriate place near the middle `\section{Title B}`. Select some suitable text for Title A and Title B. Insert at appropriate places*

some `\subsection` commands with reasonable subtitles. Remove the commands included from Exercise 3.3:

```
\pagestyle{myheadings} \markright{Exercises}
\pagenumbering{Roman}
```

and print the results.

Exercise 3.10: Include the additional command `\chapter{Chapter title}` with your own appropriate *Chapter title* before your first `\section` command. Change the document class command to `\documentclass[twoside]{report}` and call the page style command `\pagestyle{headings}` in the preamble. Note the twofold effect of the sectioning commands in the headings and in the page headlines. Compare the results with the table in Section 3.2.1.

Exercise 3.11: Change the chapter command to

```
\chapter[Short form]{Chapter title}
```

by putting an abbreviated version of *Chapter title* for *Short form*. Now the page head contains the shortened title where the full chapter title previously appeared.

3.4 Table of contents

3.4.1 Automatic entries

LaTeX can prepare and print a table of contents automatically for the whole document. It will contain the section numbers and corresponding headings as given in the standard form of the sectioning commands, together with the page numbers on which they begin. The sectioning depth to which entries are made in the table of contents can be set in the preamble with the command

```
\setcounter{tocdepth}{num}
```

The value *num* has exactly the same meaning and effect as it does for the counter `secnumdepth` described above, by which the maximum level of automatic subsectioning is fixed. By default, the depth to which entries are included in the table of contents is the same as the standard level to which automatic sectioning is done: that is, to level `\subsection` for `book` and `report` and to level `\subsubsection` for `article`.

3.4.2 Printing the table of contents

The table of contents is generated and printed with the command

```
\tableofcontents
```

given at the location where the table of contents is to appear, which is normally after the title page and abstract.

This leads to a paradox, for the information in the table of contents is to be printed near the beginning of the document, information that cannot be known until the end. \LaTeX solves this problem as follows: the first time the document is processed, no table of contents can be included but instead \LaTeX opens a new file with the same name as the source file but with the extension `.toc`; the entries for the table of contents are written to this file during the rest of the processing.

The next time \LaTeX is run on this document, the `\tableofcontents` command causes the `.toc` file to be read and the table of contents is printed. As the processing continues, the `.toc` file is updated in case there have been major changes since the previous run. This means that the table of contents that is printed is always the one corresponding to the previous version of the document. For this reason, it may be necessary to run \LaTeX more than once on the final version.

3.4.3 Additional entries



The `*`-form sectioning commands are not entered automatically in the table of contents. To insert them, or any other additional entry, the commands

```
\addcontentsline{toc}{sec_name}{entry text}
\addtocontents{toc}{entry_text}
```

may be used.

With the first command, the entries will conform to the format of the table of contents, whereby `section` headings are indented more than those for `chapter` but less than those for `subsection`. This is determined by the value of the argument `sec_name`, which is the same as one of the sectioning commands without the `\` character (for example, `section`). The `entry_text` is inserted in the table of contents along with the page number. This command is most useful to enter unnumbered section headings into the table of contents. For example,

```
\section*{Author addresses}
\addcontentsline{toc}{section}{Author addresses}
```

The `\addtocontents` command puts any desired command or text into the `.toc` file. This could be a formatting command, say `\newpage`, which takes effect when the table of contents is printed.

3.4.4 Other lists



In addition to the table of contents, lists of figures and tables can also be generated and printed automatically by \LaTeX . The commands to produce these lists are

```
\listoffigures  reads and/or produces file .lof
\listoftables   reads and/or produces file .lot
```

The entries in these lists are made automatically by the `\caption` command in the `figure` and `table` environments (see Section 7.4). Additional entries are made with the same commands as for the table of contents, the general form of which is

```
\addcontentsline{file}{format}{entry}
\addtocontents{file}{entry}
```

where *file* stands for one of the three types `toc` (*table of contents*), `lof` (*list of figures*), or `lot` (*list of tables*). The argument *format* is one of the sectioning commands for the table of contents, as described above, or `figure` for the list of figures, or `table` for the list of tables. The argument *entry* stands for the text that is to be inserted into the appropriate file.

Exercise 3.12: *In your exercise file, insert after the deactivated title page commands*

```
\pagenumbering{roman}
\tableofcontents \newpage
\pagenumbering{arabic}
```

Process your exercise file twice with L^AT_EX and print out the second results. Deactivate the above commands with % before doing the next run.

4

Displayed Text

There are a variety of ways to display or emphasize the text: changing font style or font size, centering, indentation, marking the paragraphs, and so on. \LaTeX supplies us with commands for the most common forms of display.

Many parts of this chapter violate the concept of logical markup, especially those dealing with selection of fonts. The author should not attempt to decorate the document with arbitrary switches of font size and style, but should pack his or her source text into a structure that indicates its purpose. The exercises in this book are an example of this. Rather than starting each one with the word ‘Exercise’ in bold face followed by an explicit number, and then shifting to a slanted font, we defined an `exercise` environment to do all that automatically. This not only ensures consistency, it also allows a change of style to be easily implemented, simply by redefining the environment. This is where the typographical font commands come into play. They should not appear in the main text at all, but rather in the preamble as part of the definitions of environments and commands.

On the other hand, many of the topics in this chapter really do involve logical markup, such as the `verse`, `quote`, and `quotation` environments, lists, bibliographies, theorems, and tables.

4.1 Changing font

In typography, a set of letters, numbers, and characters of a certain size and appearance is called a *font*. The standard font in \LaTeX for the main body of text is an *upright, Roman* one of *medium* weight, in the size specified in the `\documentclass` statement at the start. The three possible basic sizes are 10, 11, and 12 pt, depending on the size options `10pt` (default), `11pt`, and `12pt`. (Recall, there are 72.27 points per inch or about 28.45 pt per cm.) The parenthesis characters () extend the full height and depth of the font size.

The differences in the visual appearance of the three standard sizes are greater than would be expected from the ratios of the numbers:

This is an example of the 10 pt font. ()

And this is the 11 pt font for comparison. ()

And finally this is a sample of 12 pt font. ()

4.1.1 Emphasis

The usual way to emphasize text in a typewritten manuscript is by underlining. The typesetter will transform underlined text into *italics* for the printed version. Switching from standard to *emphasized* text is carried out in L^AT_EX with the command `\emph` or the declaration `\em`.

The `\em` declaration functions just as the other font declarations described below: the change of font remains in effect until negated by another appropriate declaration (which can be `\em` itself), or until the end of the current *environment* (Section 2.2). An environment may also be created with a pair of curly braces `{...}`. The command `\emph`, on the other hand, operates only on the text in the following argument. This is easiest way to *emphasize* short pieces of text, as for example:

This is the easiest way to `\emph{emphasize}` short ...

The `\em` declaration is more appropriate for longer text that is enclosed in an environment, *named or nameless*.

...enclosed in an environment, `{\em named or nameless.}`

Note carefully the difference between the *declaration* that remains in effect until the local environment is ended with the closing curly brace, and the command that operates on an argument enclosed in curly braces. Another more subtle difference is that the command `\emph` automatically inserts extra spacing at the end if necessary, the so-called *italic correction*, to improve the appearance at the interface between sloping and upright fonts.

Both the declaration and the command switch to an emphasizing font. That means, if the current font is upright it switches to *italics*, whereas if the text is already slanted, an upright font is selected.

Nested emphasis is possible and is simple to understand:

The `\emph{first}`, `second`, and `\emph{third font switch}`
 The `{\em first, {\em second, and {\em third font switch}}`

both produce ‘The *first*, second, and *third font switch*’.

4.1.2 Choice of font size

The following declarations are available in L^AT_EX for changing the font size:

<code>\tiny</code>	smallest	<code>\Large</code>	larger
<code>\scriptsize</code>	very small	<code>\LARGE</code>	even larger
<code>\footnotesize</code>	smaller	<code>\huge</code>	still larger
<code>\small</code>	small	<code>\Huge</code>	largest
<code>\normalsize</code>	normal		
<code>\large</code>	large		

all of which are relative to the standard size selected in the document class option. In this book, the standard size is 10 pt, which is then the size selected with `\normalsize`.

The font size declarations behave as all other declarations: they make an immediate change that remains in effect until counteracted by another size declaration, or until the current environment comes to an end. If issued within curly braces `{. .}`, the effect of the declaration extends only to the closing brace, as in a nameless environment:

```
normal {\large large \Large larger} normal again
normal large larger normal again
```

!

Changing the font size with one of the above commands also automatically changes the interline spacing. For every font size, there is a corresponding *natural* line spacing `\baselineskip`. This may be altered at any time. If the natural line spacing is 12 pt, the command `\setlength{\baselineskip}{15pt}` will increase it to 15 pt.

The value of `\baselineskip` that is effective at the end of the paragraph is used to make up the whole paragraph. This means that if there are several changes to `\baselineskip` within a paragraph, only the last value given will be taken into account.

With every change in font size, `\baselineskip` is reset to its natural value for that size. Any previous setting with `\setlength` will be nullified.

In order to create a change in the line spacing that is valid for all font sizes, one must make use of the factor `\baselinestretch`, which has a normal value of 1. The true interline spacing is really

$$\text{\baselinestretch} \times \text{\baselineskip}$$

which maintains the same relative spacing for all font sizes. The user may change this spacing at any time with:

```
\renewcommand{\baselinestretch}{factor}
```

where *factor* is any decimal number. A value of 1.5 increases the interline spacing (baseline to baseline) by 50% over its natural size for all font sizes.

The new value of `\baselinestretch` does not take effect until the next change in font size. In order to implement a new value in the current font size, it is necessary to switch to another size and back again immediately. If the present font size is `\normalsize`, the sequence

```
\small\normalsize
```

will do the trick. Any size command may be used in place of `\small`.

4.1.3 Font attributes

The size of a font is only one of several *attributes* that may be used to describe it. With the New Font Selection Scheme (NFSS), which was introduced as part of L^AT_EX 2_ε, it is possible to select fonts strictly by these attributes, as described in Appendix A. However, for normal usage, there are some declarations and corresponding commands to simplify this procedure.

For the Computer Modern fonts provided with T_EX and L^AT_EX, the following attributes and values exist:

Family: for the general overall style. Traditional typographical families have names like *Baskerville*, *Bodoni*, *Times Roman*, *Helvetica*, and so on. The standard L^AT_EX installation provides three families with declarations

```
\rmfamily to switch (back) to a Roman font;
\ttfamily to switch to a typewriter font;
\sffamily to select a sans serif font.
```

Shape: for the form of the font. The shape declarations available with the standard installation are

```
\upshape to switch (back) to an upright font;
\itshape to select an italic shape;
\slshape to choose a font that is slanted;
\scshape to switch to CAPS AND SMALL CAPS.
```

Series: for the width and/or weight (boldness) of the font. The declarations possible are

```
\mdseries to switch (back) to medium weight;
\bfseries to select a bold face font.
```

These do not exhaust all the possible attribute settings, but they do cover the most standard ones, especially for the Computer Modern fonts. For other fonts, especially PostScript ones, additional attribute values exist. See Section A.1 for more details.

These declarations are used just like any others, normally enclosed in a pair of curly braces {...}, such as {\scshape Romeo and Juliet} producing ROMEO AND JULIET. For longer sections of text, an environment is preferable:

```
\begin{font_style} ... text in new font ... \end{font_style}
```

This keeps better track of the beginning and end of the switch-over. For *font_style*, any of the above font commands may be used, leaving off the initial \ character.

Since changing any one attribute leaves the others as they were, all possible combinations may be obtained. (However, this does not mean

that a font exists for each possible combination; if not, a substitution will be made.) If we select first a bold series with `\bfseries`, and then a slanted shape with `\slshape`, we obtain a bold, slanted font.

```
normal and {\bfseries bold and
           {\slshape slanted} and back} again.
```

produces: normal and **bold and *slanted and back*** again.

Finally, the declaration `\normalfont` resets all the attributes (except size) back to their defaults: Roman, upright, medium weight. It is often useful to issue this command just to be sure of the font in effect.

4.1.4 Font commands

For each of the font declarations listed above, there is a corresponding *font command* that sets its argument in a font with the specified attribute.

```
Family:   \textrm{text}      \texttt{text}  \textsf{text}
Shape:    \textup{text}     \textit{text}  \textsl{text}
          \textsc{text}
Series:   \textmd{text}     \textbf{text}
Default:  \textnormal{text}
Emphasis: \emph{text}
```

Note that the `\emph` command is included here, corresponding to the declaration `\em`. The argument of `\textnormal` is set in the standard font selected with `\normalfont`.

The use of such commands to change the font for short pieces of text, or single words, is much more logical than placing a declaration inside an implied environment. The previous example now becomes

```
normal and \textbf{bold and \textsl{slanted}
              and back} again.
```

to make: normal and **bold and *slanted and back*** again.

As for the `\emph` command, these font commands automatically add any necessary *italic correction* between upright and slanted/italic fonts.

The old two-letter \TeX declarations such as `\bf` and `\tt`, which were part of \LaTeX 2.09, are still available but are now considered obsolete and should be avoided. They are listed for reference in Appendix F.

4.1.5 Additional fonts



It is likely that your computing center or your \TeX installation has even more fonts and sizes than those listed above. If so, they may be made available for use within a \LaTeX document either by referring to them by name, or by their attributes, if they have been set up for NFSS.

To load a new font explicitly by name, the command

```
\newfont{\fnt}{name scaled factor} or
\newfont{\fnt}{name at size}
```

is given, which assigns the font to the new command named `\fnt`. In the first case, *factor* is a number 1000 times the scaling factor that is to be used to magnify or reduce the font from its basic or design size. In the second case, the font is scaled to be of the *size* specified. To install a slanted, sans serif font of size 20.74 pt, as `\sss`, we load `cmssi17` at 20.74pt with

```
\newfont{\sss}{cmssi17 at 20.74pt}
```

Now the declaration `\sss` switches directly to this font but without altering the baseline separation.

Alternatively, the new font declaration can be made by attributes with (see Section A.3.2)

```
\DeclareFixedFont{\sss}{OT1}{cmss}{m}{sl}{20.74}
```

Indeed, if one wants to use the current encoding and `\sffamily` without knowing what they are, or without worrying so precisely what size must be stated, it is also possible to give

```
\DeclareFixedFont{\sss}{\encodingdefault}{\sfdefault}
{m}{sl}{20}
```

(The defaults are explained in Section A.3.1.)

4.1.6 Character sets and symbols



The individual character sets are each stored in their own files. The names of the 75 standard T_EX fonts are listed in Section G.2.2, where many of them are also printed out.

Each symbol within a character set is addressed by means of a number between 0 and 127 (or 255). The command

```
\symbol{num}
```

will produce that symbol with the internal identification number *num* in the current font. The symbol *i* in the present font has the internal number 62 and can be printed with the command `\symbol{62}`. The identification number may also be given as an *octal* (prefix `'`) or *hexadecimal* (prefix `"`) number. Thus the symbol commands `\symbol{28}`, `\symbol{'34}`, and `\symbol{"1C}` are all identical, producing `ø`.

The `\symbol` command may also be used to generate symbols for which no other command has been defined: for example, `{\ttfamily\symbol{'40}\symbol{'42}\symbol{'134}}` produces `_ " \` in typewriter font.

Section G.2.2 presents the assignments of the identification numbers with the characters for the different symbol families.

4.2 Centering and indenting

4.2.1 Centered text

The environment

```
\begin{center} line 1 \\ line 2 \\ ... line n \end{center}
```

centers the sections of text that are separated by the `\\` command. (An optional additional line spacing may be inserted with `\\[len]`.) If the text is too long for one line, it is split over several lines using uniform word spacing, filling the whole line width as best it can, except for the last line. Word division does not occur.

Within an environment, the command `\centering` may be used to center the following text, again with `\\` as the line divider. The effect of this declaration lasts until the end of that environment.

A single line may be centered by typing its text as the argument of the \TeX command `\centerline{text}`.

4.2.2 One-sided justification

The environments

```
\begin{flushleft} line 1 \\ line 2 \\ ... line 2 \end{flushleft}
\begin{flushright} line 1 \\ line 2 \\ ... line 2 \end{flushright}
```

produce text that is left (`flushleft`) or right (`flushright`) justified. If a section of text does not fit on to one line, it is spread over several with fixed word spacing, the same as for the `center` environment. Again, word division does not occur.

The same results may be produced within an environment with the declarations

```
\raggedright replacing the flushleft environment, and
\raggedleft  replacing the flushright environment.
```

4.2.3 Two-sided indentation

A section of text may be displayed by indenting it by an equal amount on both sides, with the environments

```
\begin{quote}      text  \end{quote}
\begin{quotation}  text  \end{quotation}
```

Additional vertical spacing is inserted above and below the displayed text to separate it visually from the normal text.

The text to be displayed may be of any length; it can be part of a sentence, a whole paragraph, or several paragraphs.

Paragraphs are separated as usual with an empty line, although no empty lines are needed at the beginning and end of the displayed text since additional vertical spacing is inserted here anyway.

The difference between the above two forms is thus:

In the `quotation` environment, paragraphs are marked by extra indentation of the first line, whereas in the `quote` environment, they are indicated with more vertical spacing between them.

The present text is produced within the `quotation` environment, while the sample above was done with the `quote` environment.

The `quotation` environment is only really meaningful when the regular text makes use of first-line indentation to show off new paragraphs.

4.2.4 Verse indentations

For indenting rhymes, poetry, verses, etc. on both sides, the environment

```
\begin{verse} poem \end{verse}
```

is more appropriate.

Stanzas are separated by blank lines while the individual lines of the stanza are divided by the `\\` command.

If a line is too long for the reduced text width, it will be left and right justified and continued on the next line, which is indented even further.

The above indenting schemes may be nested inside one another. Within a `quote` environment there may be another `quote`, `quotation`, or `verse` environment. Each time, additional indentations are created on both sides of the text and vertical spacing is added above and below; these quantities however decrease as the depth of nesting increases. A maximum of six such nestings is allowed.

Exercise 4.1: Put some appropriate sections of text in your exercise file into the `quote` and `quotation` environments, that is, enclose these sections within

```
\begin{quote} . . . . . \end{quote} or
\begin{quotation} . . . . . \end{quotation}
```

commands.

Exercise 4.2: Make up a new file with the name `poem.tex` and type your favorite poem in the `verse` environment. Select 12pt as the standard font size and italic as the typeface. Put the title of the poem before the `verse` environment in a larger bold typeface, such as `\Large\bfseries`. Include the name of the poet right justified.

Note: remember that you may include declarations to change the font style or size within an environment and that these remain in effect only until the end of that environment.

Exercise 4.3: Make up another file with the name `title.tex`. Do you recall the `titlepage` environment for producing a free-form title page? If not, refer to Section 3.3.1. Create a title page with this environment using font sizes and styles of your choice, centering all the entries.

Note: within the `titlepage` environment you may of course make use of the `center` environment, but it is also sufficient to give the `\centering` declaration instead, since this will remain in effect only until the end of the `titlepage` environment.

Choose the individual line spacings with the command `\[len]` using an appropriate value for the spacing `len`. Remember that vertical spacing before the first line of text must be entered with the `*`-form of the command `\vspace*[len]` (see Section 2.7.3).

Experiment with different font sizes and styles for the various parts of the title page, such as title, author's name, address, until you are satisfied with the results.

Compare your own title page with that of Exercise 3.8. If your creation appeals to you more, include it in your standard exercise file by replacing the commands `\title`, `\author`, `\date`, and `\maketitle` with the `titlepage` environment and your own entries.

4.3 Lists

There are three environments available for producing formatted lists:

```
\begin{itemize}      list text \end{itemize}
\begin{enumerate}   list text \end{enumerate}
\begin{description} list text \end{description}
```

In each of these environments, the *list text* is indented from the left margin and a label, or marker, is included. What type of label is used depends on the selected list environment. The command to produce the label is `\item`.

4.3.1 Sample `itemize`

- The individual entries are indicated with a black dot, a so-called *bullet*, as the label.

- The text in the entries may be of any length. The label appears at the beginning of the first line of text.
- Successive entries are separated from one another by additional vertical spacing.

The above text was produced as follows:

```
\begin{itemize}
\item The individual entries are indicated with a black dot, a
      so-called \emph{bullet}, as the label.
\item The text in the entries may be of any length. The label
      appears at the beginning of the first line of text.
\item Successive entries are separated from one another by
      additional vertical spacing.
\end{itemize}
```

4.3.2 Sample enumerate

1. The labels consist of sequential numbers.
2. The numbering starts at 1 with every call to the `enumerate` environment.

The above example was generated with the following text:

```
\begin{enumerate}
\item The labels consist of sequential numbers.
\item The numbering starts at 1 with every call to the
      \texttt{enumerate} environment.
\end{enumerate}
```

4.3.3 Sample description

purpose This environment is appropriate when a number of words or expressions are to be defined.

example A keyword is used as the label and the entry contains a clarification or explanation.

other uses It may also be used as an author list in a bibliography.

The above sample was created using the following:

```
\begin{description}
\item[purpose] This environment is appropriate when a number of
      words or expressions are to be defined.
\item[example] A keyword is used as the label and the entry
      contains a clarification or explanation.
\item[other uses] It may also be used as an author list in a
      bibliography.
\end{description}
```

The `\item[option]` command contains an optional argument that appears in bold face as the label.

4.3.4 Nested lists

The above lists may be included within one another, either mixed or of one type, to a depth of four levels. The type of label used depends on the depth of the nesting. The indentation is always relative to the left margin of the enclosing list. A fourfold nesting of the `itemize` environment appears as follows:

- The label for the first level is a black dot, a *bullet*.
 - That of the second level is a long dash.
 - * That of the third level is an asterisk.
 - And the label for the fourth level is a simple dot.
 - At the same time, the vertical spacing is decreased with increasing depth.
 - * Back to the third level.
 - Back to the second level.
- And here we are at the first level of `itemize` once again.

Similarly for the `enumerate` environment, where the style of the numbering changes with the nesting level:

1. The numbering at the first level is with Arabic numerals followed by a period.
 - (a) At the second level, it is with lower case letters in parentheses.
 - i. The third level is numbered with lower case Roman numerals with a period.
 - A. At the fourth level, capital letters are used.
 - B. The label style can be changed, as described in the next section.
 - ii. Back to the third level.
 - (b) Back to the second level.
2. And the first level of `enumerate` again.

An example of a nested list with mixed types:

- The `itemize` label at the first level is a bullet.
 1. The numbering is with Arabic numerals since this is the first level of the `enumerate` environment.

- This is the third level of the nesting, but the second `itemize` level.
 - (a) And this is the fourth level of the overall nesting, but only the second of the `enumerate` environment.
 - (b) Thus the numbering is with lower case letters in parentheses.
 - The label at this level is a long dash.
2. Every list should contain at least two points.
- Blank lines ahead of an `\item` command have no effect.

The above mixed list was produced with the following text:

```
\begin{itemize}
  \item The \texttt{itemize} label at the first level is a ...
  \begin{enumerate}
    \item The numbering is with Arabic numerals since this ...
    \begin{itemize}
      \item This is the third level of the nesting, but the ...
      \begin{enumerate}
        \item And this is the fourth level of the overall ...
        \item Thus the numbering is with lower case letters ...
      \end{enumerate}
    \end{itemize}
    \item The label at this level is a long dash.
  \end{itemize}
  \item Every list should contain at least two points.
\end{enumerate}

\item Blank lines ahead of an \verb+\item+ command ...
\end{itemize}
```

Exercise 4.4: Produce a nested list using the `itemize` and `enumerate` environments as in the above example, but with a different sequence of these commands.

Exercise 4.5: Prepare a list of conference participants with their place of residence using the `description` environment, where the name of the participant appears as the argument in the `\item` command.

Note: for all three types of lists, any text before the first `\item` command will yield an error message on processing.

4.3.5 Changing label style

The labels, or markers, used in the `itemize` and `enumerate` environments can be easily changed by means of the optional argument in the `\item` command. With `\item[+]` the label becomes +, and with `\item[2.1:]` it is 2.1:. The optional argument takes precedence over the standard

label. For the `enumerate` environment, this means that the corresponding counter is *not* automatically incremented and the user must do the numbering manually.

The optional label appears right justified within the area reserved for the label. The width of this area is the amount of indentation at that level less the separation between label and text; this means that the left edge of the label area is flush with the left margin of the enclosing level.

It is also possible to change the standard labels for all or part of the document. The labels are generated with the internal commands

```
\labelitemi , \labelitemii , \labelitemiii , \labelitemiv
\labelenumi , \labelenumii , \labelenumiii , \labelenumiv
```

The endings `i`, `ii`, `iii`, and `iv` refer to the four possible levels.

These commands may be altered with `\renewcommand`. For example, to change the label of the third level of the `itemize` environment from `*` to `+`, give

```
\renewcommand{\labelitemiii}{+}
```

Similarly the standard labels for the `enumerate` environment may be changed. However, here there is an additional complication that there is a counter for each `enumerate` level, named `enumi`, `enumii`, `enumiii`, and `enumiv`. As explained in Section 8.1.4, the value of a counter can be printed using one of the commands `\arabic`, `\roman`, `\Roman`, `\alph`, or `\Alph`, where the style of each command should be obvious from its name. That is, `\Roman{xyz}` prints the current value of the counter `xyz` in upper case Roman numerals, whereas `\alph{xyz}` prints it as a lower case letter (with `a` corresponding to 1 and `z` to 26).

These counters, together with the counter style commands, must be used in the redefinitions of the label commands. For example, to change the second-level label to Arabic numerals followed by `'.)'`, it is necessary to give

```
\renewcommand{\labelenumii}{\arabic{enumii}.)}
```

which redefines `\labelenumii` to the value of counter `enumii` printed in Arabic, plus the characters `'.)'`. In this way, all the numbering levels may be changed. It is even possible to include more than one counter:

```
\renewcommand{\labelenumii}{\Alph{enumi}.\arabic{enumii}}
```

which will produce for every call to `\item` at level two the value of the counter `enumi` as a capital letter followed by the value of counter `enumii` as a number: that is, in the form `A.1`, `A.2`, `...`, `B.1`, `B.2`, `...` and so on.

If the new standard labels are to apply to the whole document, the redefining commands should be included in the preamble. Otherwise, they are valid only within the environment in which they appear.

Exercise 4.6: Change the standard labels for the `itemize` environment into a long dash — (written ---) for the first level, to a medium dash - (--) for the second level, and to a hyphen - for the third level.

Exercise 4.7: Change the standard labels for the `enumerate` environment for the first level to (I), (II), . . . , and for the second level to the Roman numerals of the first level followed by the number for the second level in the form I-1; I-2; . . . , II-1; II-2;

Package:
enumer-
ate

An alternative method of customizing the enumeration labels is with the `enumerate` package in the `tools` collection (Section B.5.4). Once this package has been loaded, the `enumerate` environment accepts an optional argument specifying the text of the label. The characters A a I i 1 represent the number in alphabetical, Roman, Arabic styles. If these characters appear elsewhere in the label text, they must be in `{}`. For example,

```
\begin{enumerate}[{Case} A]
  \item Witness tells the truth
  \item Witness is lying
\end{enumerate}
```

⇒ Case A Witness tells the truth
Case B Witness is lying

4.4 Generalized lists

Lists such as those in the three environments `itemize`, `enumerate`, and `description` can be formed in a quite general way. The type of label and its width, the depth of indentation, spacings for paragraphs and labels, and so on, may be wholly or partially set by the user by means of the `list` environment:

```
\begin{list}{std.lbl}{list.decl} item.list \end{list}
```

Here *item.list* consists of the text for the listed entries, each of which begins with an `\item` command that generates the corresponding label.

The *std.lbl* contains the definition of the label to be produced by the `\item` command when the optional argument is missing (see below).

The list parameters described in Section 4.4.2 are set by *list.decl* to whatever new values the user wishes.

4.4.1 Standard label

The first argument in the `list` environment defines the *std.lbl*, that is, the label that is produced by the `\item` command when it appears without an argument. In the case of an unchanging label, such as for the `itemize` environment, this is simply the desired symbol. If this is to be a mathematical symbol, it must be given as $\$symbol.name\$,$ enclosed in $\$$ signs. For example, to select \Rightarrow as the label, *std.lbl* must be defined to be $\$\Rrightarrow\$.$

However, the label is often required to contain a sequential numeration. For this purpose, a counter must be created with the `\newcounter{name}` command, where *name* is its designation. This command must appear before the first application of the counter in a `list` environment. Suppose a counter named `marker` has been defined for this use, then the argument *std.lbl* could be any of the commands for printing counters described in Section 4.3.5: for example, `\arabic{marker}` produces a running Arabic number.

Even more complex labels can be made up in this way. If the sequential labels are to be A-I, A-II, . . . , *std.lbl* is set to `A--\Roman{marker}`.

Before a counter can function properly within the standard label, it must be associated with that list by including in the *list.decl* the command `\usecounter{counter}`, where *counter* is the name of the counter to be assigned (`marker` in the above example).

The standard label is actually generated by the command `\makelabel{label}`, which is called by the `\item` command. The user can redefine `\makelabel` with the aid of the `\renewcommand` in the list declaration:

```
\renewcommand{\makelabel}{new_definition}
```

If the standard label is defined in this manner, the corresponding entry in the `list` environment is left blank. This is because `\makelabel` is the more general command and overrides the other definition.



4.4.2 List style parameters

There are a number of style parameters used for formatting lists that are set by L^AT_EX to certain standard values. These values may be altered by the user in the *list.decl* for that particular list. The assignment is made in the usual way with the `\setlength` command. However, if the assignment is made outside the `list` environment, in most cases it will simply be ignored. This is because there are preset default values for each parameter at each level that can only be overridden by *list.decl*.

The style parameters are listed below and are also illustrated in Figure 4.1 on the next page, which is based on one taken from Lampion (1985, 1994).

`\topsep`

is the vertical spacing in addition to `\parskip` that is inserted between the list and the enclosing text above and below. Its default value is set at each list level and cannot be globally redefined outside the *list.decl*.

`\partopsep`

is the vertical spacing in addition to `\topsep + \parskip` that is inserted above and below the list when a blank line precedes the first or follows the last `\item` entry. It may be redefined globally, but only for the first and second levels.

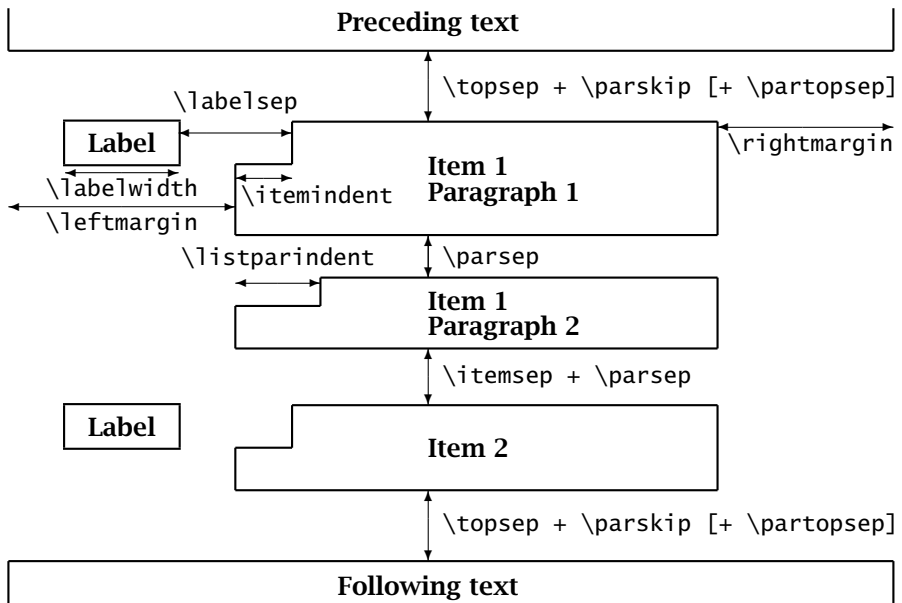


Figure 4.1: The list parameters

`\parsep`

is the vertical spacing between paragraphs of a single `\item`. Its default value is reset at each level, as for `\topsep`.

`\itemsep`

is the vertical spacing in addition to `\parsep` that is inserted between two `\item` entries. As for `\topsep` and `\parsep`, its default value is reset at each level and cannot be globally changed.

`\leftmargin`

is the distance from the left edge of the current environment to the left margin of the list text. There are default values for it at each level that may be globally redefined, as described in Section 4.4.6.

`\rightmargin`

is the distance from the right edge of the current environment to the right margin of the list text. Its standard value is 0 pt, which can only be altered in *list.decl*.

`\listparindent`

is the indentation depth of the first line of a paragraph within an `\item` with respect to the left margin of the list text. It is

normally set to 0 pt so that no indentation occurs. This can only be changed in *list.decl*.

`\labelwidth`

is the width of the box reserved for the label. The text of the label is printed right justified within this space. A new default value may be set globally which then applies to all list levels.

`\labelsep`

is the spacing between the label box and the list text. A new value may be assigned globally, but it is only effective at the first level.

`\itemindent`

is the distance by which the label and the first line of text in an `\item` are indented to the right. It is normally set to 0 pt and so has no effect. This value can only be redefined in *list.decl*.

When changing the vertical spacings from their standard values, it is recommended that a rubber length (Section 2.4.2) be used.

The label created by the `\item` command normally appears right justified within a box of width `\labelwidth`. It is possible to make it left justified, as in the following list of parameters, by putting `\hfill` at the end of the definition of the standard label or in the `\makeLabel` command.

4.4.3 Example of a user's list

List of Figures:

- Figure 1:** *Page format with head, body, and foot, showing the meaning of the various elements involved.*
- Figure 2:** *Format of a general list showing its elements.*
- Figure 3:** *A demonstration of some of the possibilities for drawing pictures with \LaTeX .*

This list was produced with the following input:

```
\newcounter{fig}
\begin{list}{\bfseries\upshape Figure \arabic{fig}:}
  {\usecounter{fig}
  \setlength{\labelwidth}{2cm}\setlength{\leftmargin}{2.6cm}
  \setlength{\labelsep}{0.5cm}\setlength{\rightmargin}{1cm}
  \setlength{\parsep}{0.5ex plus0.2ex minus0.1ex}
  \setlength{\itemsep}{0ex plus0.2ex} \s\shape}
  \item Page format with head, body, and foot, showing the
    meaning of the various elements involved.
  \item Format of a general list showing its elements.
  \item A demonstration of some of the possibilities for
    drawing pictures with  $\LaTeX$ .
\end{list}
```

The command `\newcounter{fig}` sets up the counter `fig`. The standard label is defined to be the word **Figure** in upright, bold face, followed by the running Arabic number, terminated by `:`. This label is printed for each `\item` command.

The list declaration contains `\usecounter{fig}` as its first command, which makes the counter `fig` operational within the list. The width of the label box (`\labelwidth`) is set to 2.0 cm, the left margin of the list text (`\leftmargin`) to 2.6 cm, the distance between the label and the text (`\labelsep`) to 0.5 cm, and the right edge of the list (`\rightmargin`) is set to be 1 cm from that of the enclosing text.

The vertical spacing between paragraphs within an item (`\parsep`) is 0.5 ex but can be stretched an extra 0.2 ex or shrunk by 0.1 ex. The additional spacing between items (`\itemsep`) is 0 ex, stretchable to 0.2 ex.

Standard values are used for all the other list parameters. The last command in the list declaration is `\slshape`, which sets the list text in a *slanted* typeface.

Note: If `\upshape` were not given in the label definition, the text of each `\item` would also be slanted, as **Figure 1:**

4.4.4 Lists as new environments

If a particular type of list is employed several times within a document, it can become tiresome typing the same `std.lbl` and `list_decl` into the `list` environment every time. \LaTeX offers the possibility of defining a given list as an environment under its own name. This is achieved by means of the `\newenvironment` command.

For example, the list in the above example can be stored so that it may be called at any time with the name `figlist`:

```
\newenvironment{figlist}{\begin{list}
  {\bfseries\upshape Figure \arabic{fig}:}
  {\usecounter{fig} ... {0ex plus0.2ex}\slshape}}
{\end{list}}
```

It can then be called with

```
\begin{figlist} item_list \end{figlist}
```

so that it behaves as a predefined list environment.

Exercise 4.8: Define a new environment with the name `sample` that produces a list in which every call to `\item` prints labels *Sample A*, *Sample B*, and so on. The labels are to be left justified within a box of width 20mm, and the distance between the label box and the item text is to be 2mm, with a total left margin of 22mm. The right edge of the text is to be moved in 5mm from that of the enclosing text. The extra vertical spacing between two items is to be 1ex plus 0.5ex minus 0.4ex in addition to the normal paragraph spacing. Secondary paragraphs within an

item are to be indented by 1em. The normal paragraph separation should be 0ex, expandable to 0.5ex.

!

L^AT_EX itself makes frequent use of the list environment to define a number of other structures. For example, the quote environment is defined as

```
\newenvironment{quote}{\begin{list}{}
  {setlength{\rightmargin}{\leftmargin}}
  \item[]}{\end{list}}
```

This environment is thus a list in which the value of `\rightmargin` is set to the current value of `\leftmargin` which has a default value of 2.5 em. The list itself consists of a single `\item` call with an *empty* label, a call that is automatically included in the definition of `quote` with the entry `\item[]`.

In the same way, L^AT_EX defines the `quotation` and `verse` environments internally as special `list` environments. The left margins and the vertical spacings around the structures are left as the standard values for the `list` environment, and are therefore changed only when the standard values themselves are altered.

Finally, as an example of a possible user-defined special list we offer

```
\newenvironment{lquote}{\begin{list}{}{} \item[]}{\end{list}}
```

which creates an `lquote` environment that does nothing more than indent its enclosed text by the amount `\leftmargin`, with the right edge flush with that of the normal text, since `\rightmargin` has the standard value of 0 pt.

4.4.5 Trivial lists

!

L^AT_EX also contains a `trivlist` environment, with syntax

```
\begin{trivlist} enclosed text \end{trivlist}
```

in which the arguments *stnd_lbl* and *list_decl* are omitted. This is the same as a `list` environment for which the label is empty, `\leftmargin`, `\labelwidth`, and `\itemindent` are all assigned the value 0 pt, while `\listparindent` is set equal to `\parindent` and `\parsep` to `\parskip`.

L^AT_EX uses this environment to create further structures. For example, the call to the `center` environment generates internally the sequence

```
\begin{trivlist} \centering \item[] enclosed text \end{trivlist}
```

The environments `flushleft` and `flushright` are similarly defined.

4.4.6 Nested lists

Lists can be nested within one another with the list environments `itemize`, `enumerate`, and `description`, to a maximum depth of six. At each level, the new left margin is indented by the amount `\leftmargin` relative to that of the next higher one.

!

As mentioned earlier, it is only possible to change the standard values of a limited number of the `list` parameters with declarations in the preamble. One exception is the indentations of the left margins for the different nesting levels.

These are set internally by the parameters `\leftmarginn`, where *n* stands for *i*, *ii*, *iii*, *iv*, *v*, or *vi*. These values can be changed by the user; for example, by declaring `\setlength{\leftmarginiv}{12mm}`, the left margin of the fourth-level list is shifted 12 mm from that of the third. These declarations must be made *outside* of the `list` environments and not in the `list_decl`.

At each level of list nesting, the internal macro `@listn` (*n* being *i* to *vi*) is called. This sets the value of `\leftmargin` equal to that of the corresponding `\leftmarginn`, unless `\leftmargin` is explicitly declared in the `list` environment. That is, there does not exist a single standard value for `\leftmargin` externally, but rather six different ones. The parameter `\leftmargin` has meaning only within a `list` environment.

4.5 Theorem-like declarations

In scientific literature one often has text structures like

Theorem 1 (Balzano–Weierstrass) *Every infinite set of bounded points possesses at least one maximum point.*

or

Axiom 4.1 *The natural numbers form a set *S* of distinct elements. For any two elements *a*, *b*, they are either identical, $a = b$, or different from one another, $a \neq b$.*

Similar structures frequently appear with names such as *Definition*, *Corollary*, *Declaration*, *Lemma*, instead of *Theorem* or *Axiom*. What they have in common is that a keyword and a running number are printed in **bold face** and the corresponding text in *italic*.

Of course, these could be generated by the user by explicitly giving the type styles and appropriate number, but if a new structure of that type is later inserted in the middle of the text, the user would have the tedious job of renumbering all the following occurrences. With the command

```
\newtheorem{struct_type}{struct_title}[in_counter]
```

LaTeX will keep track of the numbering automatically. Here *struct_type* is the user's arbitrary designation for the structure, while *struct_title* is the word that is printed in bold face followed by the running number (for example, **Theorem**). If the optional argument *in_counter* is missing, the numbering is carried out sequentially throughout the entire document. However, if the name of an existing counter, such as `chapter`, is given for *in_counter*, the numbering is reset every time that counter is augmented, and both are printed together, as in **Axiom 4.1** above.

The predefined structures are called with the command

```
\begin{struct_type}[extra_title] text \end{struct_type}
```

which also increments the necessary counter and generates the proper number. The above examples were produced with

```
\newtheorem{theorem}{Theorem} \newtheorem{axiom}{Axiom}[chapter]
. . . . .
\begin{theorem}[Balzano--Weierstrass] Every .... \end{theorem}
\begin{axiom} The natural numbers form ..... \end{axiom}
```

The optional *extra.title* also appears in bold face within parentheses () following the running number.

Occasionally a structure is not numbered on its own but together with another structure. This can be included in the definition with another optional argument

```
\newtheorem{struct.type}[num.like]{struct.name}
```

where *num.like* is the name of an existing theorem structure that shares the same counter. Thus by defining `\newtheorem{subthrm}{theorem}` {Sub-Theorem}, the two structures `theorem` and `subthrm` will be numbered as a single series: **Theorem 1, Sub-Theorem 2, Sub-Theorem 3, Theorem 4**, and so on.

For more powerful theorem tools, see the $\mathcal{A}\mathcal{M}\mathcal{S}$ `amsthm` package (Section 12.3.1) and the `theorem` package in the `tools` collection (Section B.5.4).

4.6 Tabulator stops

4.6.1 Basics

On a typewriter it is possible to set *tabulator stops* at various positions within a line; then by pressing the tab key the print head or carriage jumps to the next tab location.

A similar possibility exists in \LaTeX with the `tabbing` environment:

```
\begin{tabbing} lines \end{tabbing}
```

One can think of the set tab stops as being numbered from left to right. At the beginning of the `tabbing` environment, no tabs are set, except for the left border, which is called the *zeroth* tab stop. The stops can be set at any spot within a line with the command `\=`, and a line is terminated by the `\` command:

Here is the `\=first` tab stop, followed by `\= the second\`

sets the first tab stop after the blank following the word *the*, and the second immediately after the word *by*.

After the tab stops have been set in this way, one can jump to each of the stops in the subsequent lines, starting from the left margin, with the command `\>`. A new line is started with the usual `\` command.

Example:				<code>\begin{tabbing}</code>
				<code>Type\quad\= Quality\quad\=</code>
Type	Quality	Color	Price	<code>Color\quad\= Price\[\[0.8ex]</code>
Paper	med.	white	low	<code>Paper \> med. \> white \> low\</code>
Leather	good	brown	high	<code>Leather \> good \> brown \> high\</code>
Card	bad	gray	med.	<code>Card \> bad \> gray \> med.</code>
				<code>\end{tabbing}</code>

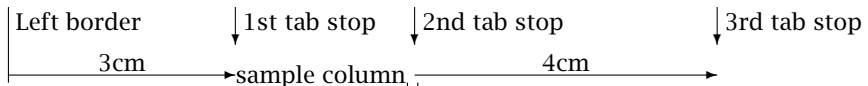
4.6.2 Sample line

It is often advantageous or even necessary to set the tab stops in a sample line that is not actually printed. It could contain, for example, the widest entries in the various columns that appear later, or the smallest intercolumn spacing between stops. The sample line may also contain `\hspace` commands to force the distance between stops to be a predetermined amount.

To suppress the printing of the sample line, it is ended with the command `\kill` instead of the `\` terminator.

```
\hspace*{3cm}\=sample column \=\hspace{4cm}\= \kill
```

In addition to the left border, the above statement sets three tab stops:



An `\hspace` command at the beginning of a sample line must be of the `*`-form, otherwise the inserted spacing will be deleted at the line margin.

4.6.3 Tab stops and the left margin

The left border of each line of the `tabbing` environment is at first identical with the left margin of the enclosing environment, and is designated the *zeroth* stop. By activating the ‘tab key’ `\>` at the start of a line, one sets the following text beginning at the first tab stop. However, the command `\+` has the same effect, putting the left border permanently at the first stop, for all subsequent lines. With `\+\+` at the beginning or end of a line, all the next lines will start two stops further along. There can be as many `\+` commands in all as there are tab stops set on the line.

The command `\-` has the opposite effect: it shifts the left border for the following lines one stop to the left. It is not possible to set this border to be to the left of the *zeroth* stop.

The effect of the `\+` commands may be overridden for a single line by putting `\<` at the start for each tab to be removed. This line then starts so many tabs to the left of the present border. With the next `\` command, the new line begins at the current left border determined by the total number of `\+` and `\-` commands.

4.6.4 Further tabbing commands

Tab stops can be reset or added in every line. The command `\=` will add a stop if there have been sufficient `\>` commands to have jumped to the last stop, otherwise it will reset the next stop.

For example:

Old column 1	Old column 2		Old column 1 <code>\=</code>	Old column 2 <code>\</code>
Left column	Middle col	Extra col	Left column <code>\></code>	Middle col
New col 1	New col 2	Old col 3	<code>\=</code>	Extra col <code>\</code>
Column 1	Column 2	Column 3	New col 1 <code>\=</code>	New col 2 <code>\></code>
			Old col 3 <code>\</code>	
			Column 1 <code>\></code>	Column 2 <code>\></code>
				Column 3
			<code>\end{tabbing}</code>	

Occasionally it is desirable to be able to reset the tab stops and then to reuse the original ones later. The command `\pushtabs` accomplishes this by storing the current tabs and removing them from the active line. All the tab stops can then be set once again. The stored stops can be reactivated with the command `\poptabs`. The `\pushtabs` command may be given as many times as needed, but there must be the same number of `\poptabs` commands within any one tabbing environment.

It is possible to position text on a tab stop with `left.text \ ' right.text`, where `left.text` goes just before the current tab (or left border) with a bit of spacing, while `right.text` starts exactly at the stop. The amount of spacing between the `left.text` and the tab stop is determined by the tabbing parameter `\tabbingsep`. This may be changed by the user with the `\setlength` command as usual.

Text may be right justified up against the right border of a line with the command `\' text`. There must not be any more `\>` or `\=` commands in the remainder of the line.

The commands `\=`, `\'`, and `\'` function as accent commands outside of the tabbing environment (Section 2.5.7). If these accents are actually needed within tabbing, they must be produced with `\a=`, `\a'`, and `\a'` instead. For example, to produce `ó`, `ò`, or `õ` inside a tabbing environment, one must give `\a'o`, `\a'o`, or `\a=o`. The command `\-` also has another meaning outside of the tabbing environment (suggested word division) but since lines are not broken automatically within this environment, there is no need for an alternative form.

Here is an example illustrating all the tabbing commands:

```

Apples:      consumed by: people \begin{tabbing}
              horses           Grapefruits: \= \kill
              and sheep       Apples: \> consumed by: \= people\+\+\
              reasonably juicy horses \\
Grapefruits: a delicacy      and \' sheep\-\
(see also: melons           reasonably juicy\-\
              pumpkins)     Grapefruits: \> a delicacy\\
Horses      feed on         apples \pushtabs
                                      (see also: \= melons\\
                                      \> pumpkins)\
                                      \poptabs
Horses \> feed on \> apples
\end{tabbing}

```

4.6.5 Remarks on tabbing

\TeX treats the `tabbing` environment like a normal paragraph, breaking a page if necessary between two lines within the environment. However, the commands `\newpage` and `\clearpage` are not allowed within it, and the command `\pagebreak` is simply ignored. If the user wishes to force a page break within the `tabbing` environment, there is a trick that he or she may employ: specify a very large interline spacing at the end of the line where the break should occur (for example, `\\[10cm]`). This forces the break and the spacing disappears at the start of the new page.

Each line of text is effectively within a `{ }` pair, so that any size or font declarations remain in force only for that one line. The text need not be put explicitly inside a pair of curly braces.

It is not possible to nest `tabbing` environments within one another.

Beware: the tab jump command `\>` always moves to the next logical tab stop. This could actually be a move backwards if the previous text is longer than the space available between the last two stops. This is in contrast to the way the tabulator works on a typewriter.

There is no automatic line breaking within the `tabbing` environment. Each line continues until terminated by a `\\` command. The text could extend beyond the right margin of the page. The user must take care that this does not happen.

The commands `\hfill`, `\hrulefill`, and `\dotfill` have no effect inside a `tabbing` environment, since no *stretching* takes place here.

Exercise 4.9: Generate the following table with the `tabbing` environment.

```

Project: Total Requirements = $900 000.00
         of which      2003 = $450 000.00
                       2004 = $350 000.00
                       2005 = $100 000.00
         2003 approved: $350 000.00  Deficiency: $100 000.00
         2004           $300 000.00           $150 000.00
         2005           $250 000.00  Surplus:   $150 000.00

```


tentative	2004 = \$100 000.00 for deficiency 2003	
	2005 = \$ 50 000.00	2004
	+ \$100 000.00	excess for 2003 in 2004
Commitments	2003 = \$100 000.00	
	2004 = \$150 000.00	signed: H. André

Hint: the first line in the tabbing environment should read

```
Project: \=Total Requirements\= = \$900\,000.00 \+\\
```

What is the effect of the \+ command at the end of this line? How do you arrange, using these tab stops, for the years 2003, 2004, and 2005 in the second to fourth lines all to be positioned before the second tab stop? Which command should be at the end of the second line just before the \\terminator?

Lines 1–4 and 8–12 all use the same set of tab stops, even though there are additional stops set in the eighth line. With \ \$1\=00\,000.00 one can align the entry \ \$\>50\,000.00 in the ninth line to match the decimal places of the lines above.

Lines 5–7 have their own tab stops. Use the save and recall feature to store the preset tab stops and to bring them back. The left border of lines 5–7 correspond to the first stop of the first group. What command is at the end of the fourth line to ensure that the left border is reset to one stop earlier? How is the left border of the second-to-last line reset?

The last line contains ‘signed: H. André’ right justified. With what tabbing command was this produced? Watch out for the accent é in this entry within the tabbing environment!

4.7 Boxes

A *box* is a piece of text that T_EX treats as a unit, like a single character. A *box* (along with the text within it) can be moved left, right, up, or down. Since the box is a unit, T_EX cannot break it up again, even it was originally made up of smaller individual boxes. It is, however, possible to put those smaller boxes together as one pleases when constructing the overall box.

This is exactly what T_EX does internally when it carries out the formatting: the individual characters are packed in *character* boxes, which are put together into *line* boxes horizontally with rubber lengths inserted between the words. The *line* boxes are stacked vertically into *paragraph* boxes, again with rubber lengths separating them. These then go into the *page body* box, which with the *head* and *foot* boxes constitutes the *page* box.

L^AT_EX offers the user a choice of three *box types*: LR boxes, paragraph boxes, and rule boxes. The LR (left–right) box contains material that is ordered horizontally from *left* to *right* in a single line. A paragraph box will have its contents made into vertically stacked lines. A rule box is a rectangle filled solidly with black, usually for drawing horizontal and vertical lines.

4.7.1 LR boxes

To create LR boxes containing single line text the commands

```
\mbox{text} and \makebox[width][pos]{text}
\fbox{text} and \framebox[width][pos]{text}
```

are available. The two commands at the left produce an LR box with a width exactly equal to that of the *text* given between the braces { }. The `\fbox` command is the same as `\mbox` except that the `text` is also framed.

With the two commands at the right, the width is predetermined by the optional length argument *width*. The other optional argument *pos* specifies how the text is positioned within the box. With no value given, the *text* is centered. Otherwise *pos* may be

```
l to left justify the text,
r to right justify it,
s to stretch it to fill up the full width.
```

Thus `\makebox[3.5cm]{centered text}` creates a box of width 3.5 cm in which the text is centered, as `centered text`, filled with white space, while with `\framebox[3.5cm][r]{right justified}` the text is right justified inside a framed box of width 3.5 cm: right justified. One may also give

```
\framebox[3.5cm][s]{stretched\dotfill text}
```

to fill up the box, as stretched.....text, in which case some rubber length (Section 2.4.2) or other filler (page 30) must be added where the stretching is to occur.

If the *text* has a natural width that is larger than that specified in *width*, it will stick out of the box on the left, right, or both sides, depending on the choice of *pos*. For example,

```
\framebox[2mm]{centered} produces centered
```

The above application may appear rather silly for `\framebox`, but it can indeed be very useful for `\makebox`. A width specification of 0 pt for `\makebox` can generate a centered, left, or right justified positioning of text in diagrams made with the `picture` environment (see Chapter 13 for examples). It may also be used to cause two pieces of text to overlap, as `\makebox[0pt][l]{/}S` prints a slash through an S, as §.

Note: Length specifications must always contain a dimensional unit, even when they are zero. Thus 0pt must be given for the width, not 0.

It is also possible to specify the *width* of an LR box relative to its natural dimensions (those produced by the simple `\mbox` command):

```
\width is the natural width of the box,
\height is the distance from baseline to top,
\depth is the distance from baseline to bottom,
\totalheight is \height plus \depth.
```

To make a framed box such that the width is six times the total height, containing centered text,

```
\framebox[6\totalheight]{Text}
```

Text

Note: These special length parameters only have meaning within the *width* specification of an LR box, or within the *height* specification of a paragraph box, as shown below. In any other context, they will produce an error message.

If a set piece of text is to appear in several places within the document, it can be stored by first giving the command

```
\newsavebox{\boxname}
```

to create a box with the name `\boxname`. This name must conform to \LaTeX command name syntax (letters only) with an initial `\`. The name must not conflict with any existing \LaTeX command names. After such a box has been initiated, the commands

```
\sbox{\boxname}{text} or
\savebox{\boxname}[width][pos]{text}
```

will store the contents *text* for future use. The optional arguments *width* and *pos* have the same meanings as for `\makebox` and `\framebox`. Now with the command

```
\usebox{\boxname}
```

the stored contents are inserted into the document text wherever desired, as a single unit.

The contents of an LR box may also be stored with the environment

```
\begin{lrbbox}{boxname}
text
\end{lrbbox}
```

This is equivalent to `\sbox{\boxname}{text}`. Its advantage is that it allows text within a user-defined environment (Section 8.4) to be stored for future use with `\usebox`.

4.7.2 Vertical shifting of LR boxes

The command

```
\raisebox{lift}[height][depth]{text}
```

produces an `\mbox` with contents *text*, raised above the current baseline by an amount *lift*. The optional arguments tell \LaTeX to treat the box as though its extension above the baseline were *height* and that below were *depth*. Without these arguments, the box has its natural size determined by *text* and *lift*. Note that *lift*, *height*, and *depth* are lengths (Section 2.4.1). If *lift* is negative, the box is lowered below the baseline.

For example:

Baseline `\raisebox{1ex}{high}` and `\raisebox{-1ex}{low}`
and back again

produces: Baseline ^{high} and _{low} and back again.

The values for *height* and *depth* can be totally different from the actual ones of the *text*. Their effect is to determine how far away the previous and next lines of text should be from the current line, based on the heights and depths of all the boxes (characters are also boxes) in the line. By raising a box but specifying *height* to be the regular character size, the raised box will overprint the line above, and similarly for *depth* when a box is lowered.

4.7.3 Parboxes and minipages

Whole paragraphs can be put into separate *vertical* boxes (or *parboxes* in the L^AT_EX jargon) with the command

```
\parbox[pos]{width}{text}
```

or with the environment

```
\begin{minipage}[pos]{width} text \end{minipage}
```

Both produce a vertical box of width *width*, in which the lines of text are stacked on top of each other as in normal paragraph mode.

The optional positioning argument *pos* can take on the values

- b to align the bottom edge of the box with the current baseline,
- t to align the top line of text with the current baseline.

Without any positioning argument, the parbox is centered vertically on the baseline of the external line of text.

The positioning argument is only meaningful when the `\parbox` command or the `minipage` environment occurs within a line of text, for otherwise the current line and its baseline have no meaning. If the parbox is immediately preceded by a blank line, it begins a new paragraph. In this case, the vertical positioning of the parbox is made with reference to the following elements of the paragraph. These could be further parboxes. If the paragraph consists of only a single parbox or minipage, the positioning argument is meaningless and has no effect.

Examples:

```
\parbox{3.5cm}{\sloppy This is a 3.5 cm wide parbox. It is  
vertically centered on the}  
\hfill CURRENT LINE \hfill  
\parbox{5.5cm}{Narrow pages are hard to format. They usually  
produce many warning messages on the monitor. The command  
\texttt{\symbol{92}sloppy} can stop this.}
```

This is a 3.5 cm wide parbox. It is vertically centered on the

Narrow pages are hard to format. They usually produce many warning messages on the monitor. The command `\sloppy` can stop this.

```
\begin{minipage}[b]{4.3cm}
  The minipage environment creates a vertical box like the parbox
  command. The bottom line of this minipage is aligned with the
\end{minipage}\hfill
\parbox{3.0cm}{middle of this narrow parbox, which in turn is
  aligned with}
\hfill
\begin{minipage}[t]{3.8cm}
  the top line of the right hand minipage. It is recommended that
  the user experiment with the positioning arguments to get used
  to their effects.
\end{minipage}
```

The minipage environment creates a vertical box like the parbox command. The bottom line of this minipage is aligned with the middle of this narrow parbox, which in turn is aligned with the top line of the right hand minipage. It is recommended that the user experiment with the positioning arguments to get used to their effects.

In Section 4.7.7 we demonstrate how parboxes can be vertically stacked in any desired manner relative to one another.

The `\parbox` command produces a vertical box containing the *text* just like the `minipage` environment. However, the latter is more general. The *text* in a `\parbox` may not contain any of the centering, list, or other environments described in Sections 4.2–4.5. These may, on the other hand, appear within a `minipage` environment. That is, a `minipage` can include centered or indented text, as well as lists and tabbings.

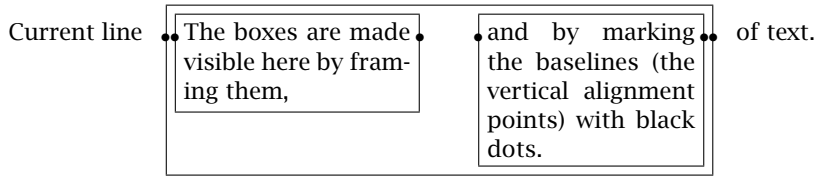
4.7.4 Problems with vertical placement

!

Vertical positioning of minipages and parboxes can often lead to unexpected results, which can be explained by showing more graphically how a box is treated by \LaTeX . Suppose we want to place two parboxes of different heights side by side, aligned on their first lines, and the two together set on the current line of text at the bottom. The ‘obvious’ way of doing this is

```
\begin{minipage}[b]{. .}
  \parbox[t]{. .}{. .} \hfill \parbox[t]{. .}{. .}
\end{minipage}
```

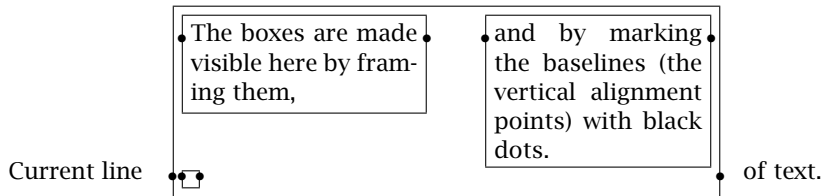
which does not work, for it produces instead the following results:



The reason for this is that each parbox or minipage is treated externally as a single character with its own height and depth above and below the baseline. As far as the outer minipage is concerned, it contains only two ‘characters’ on the same line, and that line is both the top and bottom one. Thus the bottom line of the outer minipage is indeed aligned with the line of text, but that bottom line is simultaneously the top line. The solution is to add a dummy second line to the outer box, as

```
\parbox[t]{.}{.} \hfill \parbox[t]{.}{.} \\ \mbox{}
```

The dummy line may not be entirely empty, hence the `\mbox{}`.



A similar problem occurs if two boxes are to be aligned with their bottom lines, and the pair aligned at the top with the current line of text. Here there are two possibilities to add a dummy *first* line.

```
\mbox{} \\ aligns with the very top, or
\mbox{} \\[-\baselineskip] aligns with the first text line.
```

An example of the first case is shown on page 176. Dummy lines are also needed for the solution of Exercise 4.10 on page 93.

4.7.5 Paragraph boxes of specific height

The complete syntax of the `\parbox` command and `minipage` environment includes two more optional arguments:

```
\parbox[pos][height][inner_pos]{width}{text}
\begin{minipage}[pos][height][inner_pos]{width}
  text
\end{minipage}
```

In both cases, *height* is a length specifying the height of the box; the parameters `\height`, `\width`, `\depth`, and `\totalheight` may be employed within the *height* argument in the same way as in the *width* argument of `\makebox` and `\framebox` (page 86).

The optional argument *inner_pos* states how the text is to be positioned *internally*, something that is only meaningful if *height* has been given. Its possible values are:

- t to push the text to the top of the box,
- b to shove it to the bottom,
- c to center it vertically,
- s to stretch it to fill up the whole box.

In the last case, rubber lengths (Section 2.4.2) should be present where the vertical stretching is to take place.

Note the difference between the external positioning argument *pos* and the internal one *inner_pos*: the former states how the box is to be aligned with the surrounding text, while the latter determines how the contents are placed within the box itself.

Example:

```
\begin{minipage}[t][2cm][t]{3cm}
  This is a minipage of height 2~cm with the text
  at the top.
\end{minipage}\hrulefill
\parbox[t][2cm][c]{3cm}{In this parbox, the text
  is centered on the same height.}\hrulefill
\begin{minipage}[t][2cm][b]{3cm}
  In this third paragraph box, the text is at the bottom.
\end{minipage}
```


This is a minipage _____ of height 2 cm with the text at the top.	In this parbox, the text is centered on the same height.	In this third para- graph box, the text is at the bottom.
--	--	---

The `\hrulefill` commands between the boxes show where the baselines are. All three boxes are the same size and differ only in their values of *inner_pos*.

4.7.6 Rule boxes

A rule box is a basically a filled-in black rectangle. The syntax for the general command is:

```
\rule[lift]{width}{height}
```

which produces a solid rectangle of width *width* and height *height*, raised above the baseline by an amount *lift*. Thus `\rule{8mm}{3mm}` generates . Without the optional argument *lift*, the rectangle is set on the baseline of the current line of text.

The parameters *lift*, *width*, and *height* are all lengths (Section 2.4.1). If *lift* has a negative value, the rectangle is set below the baseline.

It is also possible to have a rule box of zero width. This creates an invisible line with the given *height*. Such a construction is called a *strut* and is used to force a horizontal box to have a desired height or depth that is different from that of its contents. For this purpose, `\vspace` is inappropriate because it adds additional vertical space to that which is already there.

For example: `\fbox{Text}` produces Text. In order to print Text, one has to tell \TeX that the box contents extend above and below the baseline by the desired amounts. This was done with `\fbox{\rule[-2mm]{0cm}{6mm}Text}`. What this says is that the text to be framed consists of ‘an invisible bar beginning 2 mm below the baseline, 6 mm long, followed by the word *Text*’. The vertical bar indeed remains unseen, but it determines the upper and lower edges of the frame.

4.7.7 Nested boxes

The box commands described above may be nested to any desired level. Including an LR box within a parbox or a minipage causes no obvious conceptual difficulties. The opposite, a parbox within an LR box, is also possible, and is easy to visualize if one keeps in mind that every box is a unit, treated by \TeX as a single character of the corresponding size.

A parbox inside an `\fbox` command has the effect that the entire parbox is framed. The present structure was made with

```
\fbox{\fbox{\parbox{10cm}{A parbox...}}
```

This is a parbox of width 10 cm inside a framebox inside a second framebox, which thus produces the double framing effect.

Enclosing a parbox inside a `\raisebox` allows vertical displacements of any desired amount. The two boxes here both have positioning [b], but the one at the right has been produced with:

<code>\raisebox{1cm}{\begin{minipage}[b]{2.5cm}</code>	a b c d e f g h i
a b c d e ... x y z\	j k l m n o p q r
\underline{baseline}	s t u v w x y z
<code>\end{minipage} }</code>	<u>baseline</u>

which displaces it upwards by 1 cm. baseline

A very useful structure is one in which `minipage` environments are positioned relative to one another inside an enclosing `minipage`. The positioning argument of the outside `minipage` can be used to align its

contents as a unit with the neighboring text or boxes. An example of this is given in Exercise 4.10.

Finally, vertical boxes such as `\parbox` commands and `minipage` environments may be saved as the *text* in an `\sbox` or `\savebox` command, to be recalled later with `\usebox`, as described in Section 4.7.1.

4.7.8 Box style parameters



There are two style parameters for the frame boxes `\fbox` and `\framebox` that may be reset by the user:

`\fboxrule` determines the thickness of the frame lines,

`\fboxsep` sets the amount of spacing between the frame and enclosed text.

New values are assigned to these length parameters in the usual \LaTeX manner with the command `\setlength`: the line thickness for all the following `\framebox` and `\fbox` commands is set to 0.5 mm with `\setlength{\fboxrule}{0.5mm}`.

The scope of these settings also obeys the usual rule: if they are found in the preamble then they apply to the entire document; if they are within an environment then they are valid only until the end of that environment.

These parameters do *not* influence the `\framebox` command that is employed within the `picture` environment (Section 13.1.4) and which has different syntax and functionality from those of the normal `\framebox` command.

Exercise 4.10: *How can the following nested structure be generated? (Note: font size is `\footnotesize`)*

The first line of this 3.5 cm wide `minipage` or `parbox` is aligned with the first line of the neighboring `minipage` or `parbox`.

This 4.5 cm wide `minipage` or `parbox` is positioned so that its top line is at the same level as that of the box on the left, while its bottom line is even with that of the box on the right. The naive notion that this arrangement may be achieved with the positioning arguments set to `t`, `t`, and `b` is incorrect. Why? What would this selection really produce?

The true solution involves the nesting of two of the three structures in an enclosing `minipage`, which is then separately aligned with the third one.

Note: there are two variants for the solution, depending on whether the left and middle structures are first enclosed in a `minipage`, or the middle and right ones. Try to work out both solutions. Incidentally, the third `minipage` is 3 cm wide.

Note: the problems of correctly aligning two side-by-side boxes as a pair on a line of text (Section 4.7.4) arises here once more. It will be necessary to add a dummy line to get the vertical alignment correct.

Exercise 4.11: *Produce the framed structure shown below and store it with the command `\sbox{\warning}{structure}`. You will first have to create a box named `\warning` with the `\newsavebox{\warning}` command. Print this warning at various places in your exercise file by giving `\usebox{\warning}`.*

Vertical placement of minipages and parboxes can lead to surprising results which may be corrected by the use of dummy lines.

Note: the parbox width is 10 cm. There should be no difficulty producing the framed structure if one follows the previous example for the double framed box. Watch out when writing `\sbox{\warning}{structure}` that you have the correct number of closing braces at the end.

Next, change the values for the line thickness (`\fboxrule`) and frame spacing (`\fboxsep`) and print your results once more.

4.7.9 Further framed boxes

Package: The fancybox package, by Timothy van Zandt, allows additional framed boxes of various styles. These all make use of the length `\fboxsep` to set the distance between frame and text, the same as for `\fbox` and `\framebox`. Depending on the box type, additional new lengths are also applicable. They may be changed with `\setlength` to modify the box appearance. These new framed boxes are:

`\shadowbox{text}`

The width of the shadow is given by the length `\shadowsize`, default 4 pt. Multiline *text* must be placed in a `minipage` environment, the same as for `\fbox`.

`\doublebox{text}`

The width of the inner frame is 0.75\fboxrule , that of the outer frame 1.5\fboxrule , and the spacing between the frames is 1.5\fboxrule plus 0.5 pt.

`\ovalbox{text}`

The thickness of the frame is that of `\thinlines` (Section 13.1.4), the diameter of the corners is set with the command `\cornersize{frac}`, to *frac* times the smaller of the box width or height, or with `\cornersize*{size}` to the length *size*. The default is *frac*=.5.

`\Ovalbox{text}`

The frame thickness is set by `\thicklines`, but otherwise is the same as `\ovalbox`.

This package also allows all pages to be boxed as part of the page style. This is done by issuing `\fancy page{cmds1}{cmds2}`, where *cmds1* and *cmds2* are commands setting box parameters, terminated by one of the box commands `\fbox`, `\shadowbox`, and so on. The first set, *cmds1*, form a box with the head and footlines outside, while the second set draw a box including them. Normally one would only specify one set, leaving the other blank, such as:

```
\fancy page{\setlength{\fboxsep}{5pt}
           \setlength{\shadowsize}{3pt}\shadowbox{}}
```

for a shadow box on each page excluding head and footlines. There is also the command `\thisfancy page{cmds1}{cmds2}` to box just the current page.

4.8 Tables

With the *box* elements and *tabbing* environment from the previous sections it would be possible to produce all sorts of framed and unframed tables. However, \LaTeX offers the user far more convenient ways to build such complicated structures.

4.8.1 Constructing tables

The environments `tabular`, `tabular*`, and `array` are the basic tools with which tables and matrices can be constructed. The syntax for these environments is

```
\begin{array}[pos]{cols}          rows \end{array}
\begin{tabular}[pos]{cols}        rows \end{tabular}
\begin{tabular*}{width}[pos]{cols} rows \end{tabular*}
```

The `array` environment can only be applied in *mathematical mode* (see Chapter 5). It is described here only because its syntax and the meaning of its arguments are exactly the same as those of the `tabular` environment. All three environments actually create a minipage. The meaning of the arguments is as follows:

- pos* Vertical positioning argument (see also the explanation of this argument for `parboxes` in Section 4.7.3). It can take on the values
- t the top line of the table is aligned with the baseline of the current external line of text;
 - b the bottom line of the table is aligned with the external baseline; with no positioning argument given, the table is centered on the external baseline.

width This argument applies only to the `tabular*` environment and determines its overall width. In this case, the *cols* argument must contain the `@-expression` (see below) `@{\extracolsep{\fill}}` somewhere after the first entry. For the other two environments, the total width is fixed by the textual content.

cols The column formatting argument. There must be an entry for every column, as well as possible extra entries for the left and right borders of the table or for the intercolumn spacings.

The possible *column formatting symbols* are

l the column contents are *left* justified;

r the column contents are *right* justified;

c the column contents are *centered*;

`p{wth}` the text in this column is set into lines of width *wth*, and the top line is aligned with the other columns. In fact, the text is set in a parbox with the command `\parbox[t]{wth}{column text}`;

`*{num}{cols}` the *column format* contained in *cols* is reproduced *num* times, so that `*{5}{|c|}` is the same as `|c|c|c|c|c|`.

The available *formatting symbols* for the left and right borders and for the intercolumn spacing are

| draws a vertical line;

|| draws two vertical lines next to each other;

`@{text}` this entry is referred to as an *@-expression*, and inserts *text* in every line of the table between the two columns where it appears.

An *@-expression* removes the intercolumn spacing that is automatically put between each pair of columns. If white space is needed between the inserted text and the next column, this must be explicitly included with `\hspace{ }` within the *text* of the *@-expression*. If the intercolumn spacing between two particular columns is to be something other than the standard, this may be easily achieved by placing `@{\hspace{wth}}` between the appropriate columns in the formatting argument. This replaces the standard intercolumn spacing with the width *wth*.

An `\extracolsep{wth}` within an *@-expression* will put extra spacing of amount *wth* between all the following columns, until countermanded by another `\extracolsep` command. In contrast to the standard spacing, this additional spacing is not removed by later *@-expressions*. In the `tabular*` environment, there must be a command `@{\extracolsep{\fill}}` somewhere in the column format so that all the subsequent intercolumn spacings can stretch out to fill the predefined table width.

If the left or right borders of the table do not consist of a vertical line, spacing is added there of an amount equal to half the normal intercolumn spacing. If this spacing is not wanted, it may be suppressed by including an empty @-expression @{} at the beginning or end of the column format.

rows contain the actual entries in the table, each horizontal row being terminated with a `\` command. These rows consist of a sequence of column entries separated from each other by the `&` symbol. Thus each row in the table contains the same number of column entries as in the column definition *cols*. Some entries may be empty. The individual column entries are treated by L^AT_EX as though they were enclosed in braces { }, so that any changes in type style or size are restricted to that one column.

`\hline` This command may only appear before the first row or immediately after a `\` row termination. It draws a horizontal line the full width of the table below the row that was just ended, or at the top of the table if it comes at the beginning.

Two `\hline` commands together draw two horizontal lines with a little space between them.

`\cline{m-n}` This command draws a horizontal line from the left side of column *m* to the right side of column *n*. Like `\hline`, it may only be given just after a `\` row termination and there may be more than one after another. The command `\cline{1-3} \cline{5-7}` draws two horizontal lines from column 1 to 3 and from column 5 to 7, below the row that was just ended. In each case, the full column widths are underlined.

`\multicolumn{num}{col}{text}` This command combines the following *num* columns into a single column with their total width including intercolumn spacings. The argument *col* contains exactly one of the positioning symbols `l`, `r`, or `c`, with possible @-expressions and vertical lines `|`. A value of 1 may be given for *num* when the positioning argument is to be changed for that column in one particular row.

In this context, a ‘column’ starts with a positioning symbol `l`, `r`, or `c`, and includes everything up to but excluding the next one. The first column also includes everything before the first positioning symbol. Thus `|c@{}r|` contains three columns: the first is `|c@{}|`, the second `r`, and the third `|`.

The `\multicolumn` command may only come at the start of a row or right after a column separation symbol `&`.

`\vline` This command draws a vertical line with the height of the row at the location where it appears. In this way, vertical lines that do not extend the whole height of the table may be inserted within a column.

!

If a p-type column contains `\raggedright` or `\centering`, the `\\` forces a new line *within the column entry* and not the end of the whole row. If this occurs in the last column, then `\\` cannot be used to terminate the row; instead one must use `\tabularnewline` to end such a row.

Since a table is a vertical box of the same sort as `parbox` and `minipage`, it may be positioned horizontally with other boxes or text (see examples in Section 4.7.3). In particular, the table must be enclosed within

```
\begin{center} table \end{center}
```

in order to center it on the page.

4.8.2 Table style parameters

!

There are a number of style parameters used in generating tables which \LaTeX sets to standard values. These may be altered by the user, either globally within the preamble or locally inside an environment. They should not be changed within the `tabular` environment itself.

`\tabcolsep` is half the width of the spacing that is inserted between columns in the `tabular` and `tabular*` environments;

`\arraycolsep` is the corresponding half intercolumn spacing for the `array` environment;

`\arrayrulewidth` is the thickness of the vertical and horizontal lines within a table;

`\doublerulesep` is the separation between the lines of a double rule.

Changes in these parameters can be made with the `\setlength` command as usual. For example, to make the line thickness to be 0.5 mm, give `\setlength{\arrayrulewidth}{0.5mm}`. Furthermore, the parameter

`\arraystretch` can be used to change the distance between the rows of a table.

This is a multiplying factor, with a standard value of 1. A value of 1.5 means that the inter-row spacing is increased by 50%. A new value is set by redefining the parameter with the command

```
\renewcommand{\arraystretch}{factor}
```

4.8.3 Table examples

Creating tables is much easier in practice than it would seem from the above list of formatting possibilities. This is best illustrated with a few examples.

The simplest table consists of a row of columns in which the text entries are either centered or justified to one side. The column widths, the spacing between the columns, and thus the entire width of the table are automatically calculated.

Position	Club	Games	W	T	L	Goals	Points
1	Amesville Rockets	33	19	13	1	66:31	51:15
2	Borden Comets	33	18	9	6	65:37	45:21
3	Clarkson Chargers	33	17	7	9	70:44	41:25
4	Daysdon Bombers	33	14	10	9	66:50	38:28
5	Edgartown Devils	33	16	6	11	63:53	38:28
6	Freeburg Fighters	33	15	7	11	64:47	37:29
7	Gadsby Tigers	33	15	7	11	52:37	37:29
8	Harrisville Hotshots	33	12	11	10	62:58	35:31
9	Idleton Shovers	33	13	9	11	49:51	35:31
10	Jamestown Hornets	33	11	11	11	48:47	33:33
11	Kingston Cowboys	33	13	6	14	54:45	32:34
12	Lonsdale Stompers	33	12	8	13	50:57	32:34
13	Marsdon Heroes	33	9	13	11	50:42	31:35
14	Norburg Flames	33	10	8	15	50:68	28:38
15	Ollison Champions	33	8	9	16	42:49	25:41
16	Petersville Lancers	33	6	8	19	31:77	20:46
17	Quincy Giants	33	7	5	21	40:89	19:47
18	Ralston Regulars	33	3	11	19	37:74	17:49

The above table is made up of eight columns, the first of which is right justified, the second left justified, the third centered, the next three right justified again, and the last two centered. The column formatting argument in the `tabular` environment thus appears as

```
{r}lcccc}
```

The text to produce this table is

```
\begin{tabular}{r}lcccc}
Position & Club & Games & W & T & L & Goals & Points\\[0.5ex]
1 & Amesville Rockets & 33 & 19 & 13 & 1 & 66:31 & 51:15 \\
2 & Borden Comets & 33 & 18 & 9 & 6 & 65:37 & 45:21 \\
... & ..... & .. & .. & .. & .. & ... & ... \\
17 & Quincy Giants & 33 & 7 & 5 & 21 & 40:89 & 19:47 \\
18 & Ralston Regulars & 33 & 3 & 11 & 19 & 37:74 & 17:49 \\
\end{tabular}
```

In each row, the individual columns are separated from one another by the symbol `&` and the row itself is terminated with the `\\` command. The `[0.5ex]` at the end of the first row adds extra vertical spacing between the first two rows. The last row does not need the termination symbol since it is ended automatically by the `\end{tabular}` command.

The columns may be separated by vertical rules by including the symbol `|` in the column formatting argument. Changing the first line to

```
\begin{tabular}{r|l||c|rrr|c|c}
```

results in

Position	Club	Games	W	T	L	Goals	Points
1	Amesville Rockets	33	19	13	1	66:31	51:15
2	Borden Comets	33	18	9	6	65:37	45:21
⋮	⋮						⋮
17	Quincy Giants	33	7	5	21	40:89	19:47
18	Ralston Regulars	33	3	11	19	37:74	17:49

The same symbol | before the first or after the last column format generates a vertical line on the outside edge of the table. Two symbols || produce a double vertical line. Horizontal lines over the whole width of the table are created with the command \hline. They may only appear right after a row termination \\ or at the very beginning of the table. Two such commands \hline\hline draw a double horizontal line.

```
\begin{tabular}{|r|l||c|rrr|c|c|} \hline
Position & Club & Games & W & T & L & Goals & Points\\
\hline\hline
1 & Amesville Rockets & 33 & 19 & 13 & 1 & 66:31 & 51:15 \\
\hline
. . . . .
18 & Ralston Regulars & 33 & 3 & 11 & 19 & 37:74 & 17:49 \\
\hline
\end{tabular}
```

The table now appears as

Position	Club	Games	W	T	L	Goals	Points
1	Amesville Rockets	33	19	13	1	66:31	51:15
2	Borden Comets	33	18	9	6	65:37	45:21
⋮	⋮						⋮
17	Quincy Giants	33	7	5	21	40:89	19:47
18	Ralston Regulars	33	3	11	19	37:74	17:49

In this case, the row termination \\ must be given for the last row too because of the presence of \hline at the end of the table.

In this example, all rows contain the same entry in the third column, that is, 33. Such a common entry can be automatically inserted in the column format as an @-expression of the form @{text}, which places text between the neighboring columns. This could be accomplished for our example by changing the column format to

```
{r|l@{ 33 }rrrcc} or {|r|l||@{ 33 }|rrr|c|c|}
```

so that the text ' 33 ', blanks included, appears between the second and third columns in every row. This produces the same table with slightly different row entries: for example, the fourth row would now be given as


```
4 & Daysdon Bombers & 14 & 10 & 9 & 66:50 & 38:28 \\
```

!

The column format now consists of only seven column definitions, `r1rrrcc`. The previous third column `c` has been removed, and so each row contains one less column separation symbol `&`. The new third column, the number of games won, begins with the second `&` and is separated from the club name by the contents of `@{ 33 }`, which is entered automatically without any additional `&` symbol.

The last two columns give the relations between goals and points won and lost as a centered entry of the form $m:n$. The colons `:` are only coincidentally ordered exactly over one another since two-digit numbers appear in every case on both sides of the colon. If one entry had been `9:101`, the colon would have been shifted slightly to the left as the entire entry was centered.

A vertical alignment of the `:` independent of the number of digits can also be achieved using an `@-` expression of the form `r@{:}1` in the column format. This means that a colon is placed in every row between a right and a left justified column. The column formatting argument in the example now becomes

```
{r1@{ 33 }rrrr@{:}1r@{:}1} or
{|r|1||@{ 33 }|rrr|r@{:}1|r@{:}1|}
```

and the row entry is

```
4 & Daysdon Bombers & 14 & 10 & 9 & 66 & 50 & 38 & 28 \\
```

!

Each of the former `c` columns has been replaced by the two columns in `r@{:}1`. An `@-` expression inserts its text between the neighboring columns, removing the intercolumn spacing that would normally be there. Thus the `r` column is justified flush right with the `:` and the following `1` column flush left.

The same method can be employed when a column consists of numbers with decimal points and a varying number of digits.

The entries for the goal and point relationships are now made up of two columns positioned about the `:` symbol. This causes no problems for entering the number of goals won and lost or for the number of plus and minus points, since each entry has its own column. The column headings, however, are the words ‘Goals’ and ‘Points’, stretching over two columns each and without the colon. This is accomplished with the `\multicolumn` command, which merges selected columns in a particular row and redefines the column format. The first row of the unframed soccer table is then

```
Position& Club & W & T & L & \multicolumn{2}{c}{Goals}
& \multicolumn{2}{c}{Points}\\[0.5ex]
```

Here `\multicolumn{2}{c}{Goals}` means that the next two columns are to be combined into a centered column, containing the text ‘Goals’. For the framed table, the new formatting argument in the `\multicolumn` commands must be `{c|}` since the vertical line symbol `|` was also removed when the old columns were combined. In deciding what belongs to a given

column, use the rule that a column ‘owns’ everything up to but excluding the next r, l, or c.

The table of final results for our soccer league 2002/03 is to have the following title:

```
\begin{tabular}{|r|l||rrr|r@{:}l|r@{:}l||c|}\hline
 \multicolumn{10}{|c|}{\bfseries 1st Regional Soccer League ---
 Final Results 2002/03}\ \hline
 &\itshape Club &\itshape W &\itshape T &\itshape L &
 \multicolumn{2}{|c|}{\itshape Goals}
 &\multicolumn{2}{|c|}{\itshape Points}
 &\itshape Remarks \ \hline\hline
 . . . . .
```

1st Regional Soccer League — Final Results 2002/03							
	<i>Club</i>	<i>W</i>	<i>T</i>	<i>L</i>	<i>Goals</i>	<i>Points</i>	<i>Remarks</i>
1	Amesville Rockets	19	13	1	66:31	51:15	League Champs
2	Borden Comets	18	9	6	65:37	45:21	Trophy Winners
3	Clarkson Chargers	17	7	9	70:44	41:25	Candidates for National League
4	Daysdon Bombers	14	10	9	66:50	38:28	
5	Edgartown Devils	16	6	11	63:53	38:28	
6	Freeburg Fighters	15	7	11	64:47	37:29	
7	Gadsby Tigers	15	7	11	52:37	37:29	
8	Harrisville Hotshots	12	11	10	62:58	35:31	Medium Teams
9	Idleton Shovers	13	9	11	49:51	35:31	
10	Jamestown Hornets	11	11	11	48:47	33:33	
11	Kingston Cowboys	13	6	14	54:45	32:34	
12	Lonsdale Stompers	12	8	13	50:57	32:34	
13	Marsdon Heroes	9	13	11	50:42	31:35	
14	Norburg Flames	10	8	15	50:68	28:38	
15	Ollison Champions	8	9	16	42:49	25:41	
16	Petersville Lancers	6	8	19	31:77	20:46	Disbanding
17	Quincy Giants	7	5	21	40:89	19:47	Demoted
18	Ralston Regulars	3	11	19	37:74	17:49	

The horizontal lines for positions 3-5, 7-14, and 17 were made with the command `\cline{1-9}` while all the others used `\hline`:

```
11 & Kingston Cowboys & 13 & 6 & 14 & 54&45 & 32&34 &
Medium Teams \ \cline{1-9}
```



The last two rows of the table deserve a comment. The remark ‘Demoted’ is vertically placed in the middle of the two rows. This is accomplished by typing

```
18 & Ralston Regulars & 3 & 11 & 19 & 37&74 & 17&49
& \raisebox{1.5ex}[0pt]{Demoted}\ \hline
```

The `\raisebox` command lifts the text ‘Demoted’ by 1.5 ex. If the optional argument `[Opt]` had been left out, this lifting of the box would have increased the total height of the last row by 1.5 ex. This would have resulted in correspondingly more vertical spacing between the horizontal line of row 17 and the text of row 18. This additional spacing is suppressed by the optional argument `height = [Opt]`. (See Section 4.7.2 for a description of the `\raisebox` command.)

Occasionally one wants to increase the vertical spacing between horizontal lines and enclosed text. The soccer table would look better if the heading were thus:

1st Regional Soccer League — Final Results 2002/03							
	<i>Club</i>	<i>W</i>	<i>T</i>	<i>L</i>	<i>Goals</i>	<i>Points</i>	<i>Remarks</i>

This is done by inserting an invisible vertical rule, a *strut* (Section 4.7.6), into the heading text:

```
\multicolumn{10}{|c|}{\rule[-3mm]{0mm}{8mm}\bfseries 1st
Regional Soccer League --- Final Results 2002/03}\ \hline
```

The included rule has a width of 0 mm, which makes it invisible, extends 3 mm below the baseline, and is 8 mm high. It thus stretches 5 mm (8 – 3) above the baseline. It effectively pushes the horizontal lines away from the baseline in both directions. If a row consists of more than one column, it is sufficient to include a *strut* in only one of them since the size of the whole row is determined by the largest column.

Exercise 4.12: Produce your own table for the final results of your favorite team sport in the same manner as for the soccer results above. Watch out that the colons ‘:’ are properly aligned for the goals and points relationships.

Exercise 4.13: Generate the following timetable.

Day	6.15–7.15 pm		7.20–8.20 pm		8.30–9.30 pm	
	Subj.	Teacher Room	Subj.	Teacher Room	Subj.	Teacher Room
Mon.	UNIX	Dr. Smith Comp. Ctr	Fortran	Ms. Clarke Hall A	Math.	Mr. Mills Hall A
Tues.	LaTeX	Miss Baker Conf. Room	Fortran	Ms. Clarke Conf. Room	Math.	Mr. Mills Hall A
Wed.	UNIX	Dr. Smith Comp. Ctr	C	Dr. Jones Hall B	ComSci.	Dr. Jones Hall B
Fri.	LaTeX	Miss Baker Conf. Room	C++	Ms. Clarke Conf. Room	canceled	

The entries ‘Day’ and ‘Subj.’ are raised in the same way as ‘Demoted’ was in the soccer table. To simplify its application, one can introduce a user-defined command with

```
\newcommand{\rb}[1]{\raisebox{1.5ex}[0pt]{#1}} (see Section 8.3.2)
```

so that `\rb{entry}` behaves the same as `\raisebox{1.5ex}[0pt]{entry}`. This can be used, for example, as `\rb{ Mon. }` or `\rb{UNIX}` to elevate the entries by the necessary amount.

In all the above examples, the entries in the individual columns are each a single line. Some tables contain certain columns with several lines of text that are somewhat separated from the rest of the row:

Model	Description	Price
FBD 360	Desktop: XP3600+ Processor, 512 MB DDR-RAM, 80 GB hard disk, 16x DVD drive, 32x CDRW drive, 64 MB TV output, Windows XP, 15" monitor	999.00
FBD 480	Desktop DeLuxe: same as FBD 360 but with XP4800+ Processor, 48x CDRW drive, 17" monitor	1399.00
FBT 240	Laptop: XP2400+, 512 MB RAM, 40 GB hard disk, 56 kb modem, 32x speed DVD/CD-RW drive, 2x USB, 15" display, Windows XP, Infrared interface	1299.00

The above table is made up of three columns, the first left justified, the third right justified. The middle column contains several lines of text with a line width of 7.5 cm. This is generated with the column formatting symbol `p{width}`. The whole column formatting argument in this example is `{lp{7.5cm}r}`.

```
\begin{tabular}{lp{7.5cm}r}
\bfseries Model & Description & \bfseries Price \\
FBD 360 & \small{\bfseries Desktop}: XP3600+ Processor,
512~MB DDR-RAM, 80~GB hard disk, 16x DVD drive,
32x CDRW drive, 64~MB TV~output,
Windows~XP, 15'' monitor & 999.00 \\
. . . . .
15'' display, Windows~XP, Infrared interface & 1299.00 \\
\end{tabular}
```

The text for the middle column is simply typed in, being broken up into lines of width 8.0 cm automatically. The column is separated from the others with the `&` symbol in the usual way.

Warning: The line termination command `\\` is ambiguous within a `p` column, for it can either start a whole new row, or if `\raggedright` or `\centering` have been given, it ends a line of text within that column entry. In this case, if this is the last column in the row, the only way to

terminate the row is with `\tabularnewline` which always starts a new row.

Exercise 4.14: Produce the following table.

Course and Date	Brief Description	Prerequisites
Introduction to LSEDIT March 14 - 16	Logging on — explanation of the VMS file system — explanation and intensive application of the VMS editor LSEDIT — user modifications	none
Introduction to L ^A T _E X March 21 - 25	Word processors and formatting programs — text and commands — environments — document and page styles — displayed text — math equations — simple user-defined structures	LSEDIT

The final example describes a blank form produced as a framed table. The difficulty here is to set the heights and widths of the empty boxes, since these are normally determined automatically by the text entries. The example shows how this may be accomplished with the help of *struts* and `\hspace` commands.

Budget Plan 2003-2004			
Project	Nr. <input type="text"/>	Name <input type="text"/>	
Year	2003		2004
	€	US \$	€
2005			€
2005	€	US \$	€
Investment Costs			
Operating Costs			
Industrial Contracts			
Signature			Authorization

```


\newsavebox{\k}\newsavebox{\kkk}
\sbox{\k}{\framebox[4mm]{\rule{0mm}{3mm}}}
\sbox{\kkk}{\usebox{\k}\usebox{\k}\usebox{\k}}
\begin{tabular} { | l | c | c | c | } \hline
\multicolumn{4}{|c|}{\rule[-0.3cm]{0mm}{0.8cm}}\bfseries
Budget Plan 2003--2004}\
\hline\hline
\rule[-0.4cm]{0mm}{1cm}Project
& \multicolumn{3}{|l|}{Nr. \usebox{\kkk}\hspace{0.5cm}}
\vline\hspace{0.5cm}Name\usebox{\kkk}\usebox{\kkk}\usebox{\kkk}
\usebox{\kk}\}\ \hline

```

```

\multicolumn{1}{|r|}{Year} & 2003 & 2004 & 2005 \\
\cline{2-4}
& \euro\ \vline\ US \$ & \euro\ \vline\ US \$
  & \euro\ \vline\ US \$ \\ \hline
Investment & \hspace{2.5cm}& \hspace{2.5cm}& \hspace{2.5cm} \\
Costs & & & \\ \hline
Operating & & & \\
Costs & & & \\ \hline
Industrial& & & \\
Contracts & & & \\ \hline
\multicolumn{4}{|l|}{\rule[-1.0cm]{0mm}{1.3cm}Signature
  \hspace{5cm}\vline~Authorization} \\ \hline
\end{tabular}

```

The first three lines are only indirectly related to the table construction. They arrange for three empty boxes  to be drawn when the command `\usebox{\kkk}` is given (see Section 4.7.1).

Except for the command `\hspace{2.5cm}` to set the column widths of the last three columns and the command `\vline` to draw a vertical line within a column, this example contains nothing new that was not in the previous examples. It is only necessary to give a brief explanation of the last row in the table:

The command `\multicolumn{4}{|l|}` merges all four table columns into one, in which the text is set flush with the left margin. This text consists first of a strut `\rule[-12mm]{0mm}{15mm}` that says the height of the last row begins 12 mm below the baseline and is a total of 15 mm high. Then, beginning at the left margin, comes the word *Signature*, followed 5 cm later by `\vline`, a vertical line. The word *Authorization* is separated from the vertical line by a blank space (~).

The above examples clearly illustrate how the column widths and row heights are automatically determined for tables. These sizes, however, may be influenced by *struts* and `\hspace` commands. In addition, the commands described in Section 4.8.2 permit the *intercolumn* and *interrow* spacings as well as *line thickness* to be altered. For example,

```
\setlength{\tabcolsep}{5mm}
```

inserts 5 mm of spacing before and after every column; that is, it produces an intercolumn spacing of 10 mm. Section 4.8.2 gives more information about the use of these *table style* parameters.

4.8.4 Extension packages for tables

As powerful as the `tabular` environment is, it does have limitations. For this reason, there are a number of tools packages (Section B.5.4) that add additional features for constructing tables.

Package: The array package extends the normal functionality of the `tabular` and `array` environments by adding several column formatting arguments, and by allowing the user to be able to define his or her own such arguments.

`m{wth}` produces a column of width *wth* which is aligned vertically in the middle. (The standard `p{wth}` aligns the text with the top line.)

`b{wth}` is like `p` and `m` but aligns the text on the bottom line.

`>{decl}` inserts *decl* before the next column; thus `>{\bfseries}` sets the entire column in bold face without having to type `\bfseries` in each row.

`<{decl}` inserts *decl* after the last column; to have a centered column in math mode, give `>{ c }`.

`!{decl}` inserts *decl* between two columns without removing the normal intercolumn spacing, as for `@{decl}`.

With `\newcolumntype{type}{decl}` one can define new column specifiers for multiple applications. For example, to have `C` defined as a centered math column, give

```
\newcolumntype{C}{>{ $c$ }
```

The height of all rows can be increased by setting `\extrarowheight` to some value with `\setlength`; this is useful to prevent horizontal lines from being too close to the text below them.

With `\firsthline` and `\lasthline`, horizontal lines can be issued before the first and after the last rows respectively without interfering with the vertical alignment of the table.

Package: The `dcolumn` package loads the array package and defines a column specifier `D` to align a column of numbers on a decimal point. Its syntax is

```
D{in_char}{out_char}{number}
```

where *in_char* is the input character for the decimal point (say `.`), *out_char* is the character that is output (say `\cdot`), and *number* is the maximum number of decimal places. If *number* is negative, the column is centered on the decimal point, otherwise it is right justified. Later versions allow *number* to specify the number of digits on both sides of the decimal point, for example as 3.2.

Package: The `tabularx` package loads the array package and defines an environment `tabularx` which makes a table of a desired total width, like `tabular*`, but in which the columns expand, not the intercolumn spacings. The column specifier `X` is used to indicate the expandable columns, and is equivalent to `p{wth}` where *wth* is adjusted to the necessary size. For example,

```
\begin{tabularx}{10cm}{c X 1 X} ... \end{tabularx}
```

produces a table of width 10 cm with columns 2 and 4 expandable.

Package: `delarray` The `delarray` package loads the `array` package and redefines the `array` environment so that it may be enclosed in braces that are automatically adjusted in size, as with the `\left` and `\right` commands of Section 5.4.1. The braces surround the column specifier. For example,

$$\begin{array}[cc] a & b \\ c & d \end{array} \Rightarrow \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

Package: `longtable` The `longtable` package produces tables extending over several pages. It does not require the `array` package, but does recognize its extra features if loaded. The `longtable` environment takes the same column formatting argument as `tabular` and `array`, but has additional row entries at the start to determine:

- those rows that appear at the start of the table, terminated by `\endfirsthead`; this often includes the main `\caption`;
- those at the top of every continuation page, terminated by `\endhead`; these normally include an additional `\caption` and the column headers;
- those at the bottom of each page, terminated by `\endfoot`;
- and those rows at the end of the table, terminated by `\endlastfoot`.

An example of a long table is:

```
\begin{longtable}[l|c|r]
\caption[Short title]{Demonstration of a long table} \\
\hline
Left & Center & Right \\
\hline \endfirsthead
\caption[ ]{\emph{continued}} \\
\hline
Left & Center & Right \\
\hline \endhead
\hline
\multicolumn{3}{r}{\emph{continued on next page}}
\endfoot
\hline \endlastfoot
Twenty-two & fifty & A hundred and eighty \\
22 & 50 & 180 \\
. . . . .
\end{longtable}
```

The `\caption` command normally may only appear within `table` and `figure` environments (Section 7.4) but may also be used within `longtable` which never goes into a `table` environment; in a continued row, `\caption` must have an empty optional argument `[]` to prevent multiple entries in the list of tables.

A `\newpage` command forces a new page within the long table.

Up to four L^AT_EX runs may be needed to get the column widths right.

Primary Energy Consumption

Energy Source	1975	1980	1986
Total Consumption (in million tons of BCU ^a)	347.7	390.2	385.0
of which (percentages)			
petroleum	52.1	47.6	43.2
bituminous coal	19.1	19.8	20.0
brown coal	9.9	10.0	8.6
natural gas	14.2	16.5	15.1
nuclear energy	2.0	3.7	10.1
other ^b	2.7	2.3	3.0

^aBCU = Bituminous Coal Unit (1 ton BCU corresponds to the heating equivalent of 1 ton of bituminous coal = 8140 kwh)

^bWind, water, solar energy, etc.

Source: Energy Balance Study Group, Essen 1987.

4.8.5 Floating tables

In Chapter 7 we explain how figures and tables can be made to *float*, that is, to be moved to the top or bottom of a page, or to a separate page altogether. The reason for doing this is that the author does not know in advance where the page breaks will occur, and so does not know if there is enough room on the current page for such a large object. The float mechanism allows the material to be saved and then placed later at an appropriate location. It also allows for table and figure captions and automatic numbering.

Table material is made to float with the environment:

```
\begin{table} head.text table foot.text \end{table}
```

where *table* stands for the entire table as defined in a `tabular` environment, *head.text* for whatever text appears above the table, and *foot.text* for that below. Widths, spacing, and positioning of the texts relative to the table are all matters for the user to arrange.

Independently of the enclosed text, everything that appears between `\begin{table}` and `\end{table}` is normally placed at the start of the current page. If a table already occupies the top of the page, an attempt is made to place it at the page bottom, if there is enough space for it. Otherwise, it will be placed on the next page, where further tables may be accumulated. The surrounding text is printed as though the table were not there. For further details about floats in general, including automatic sequential numbering, see Chapter 7.

The table at the top of this page was generated within the text at this location with the following (excluding the footnotes, which are described later in Section 4.10.4):

```

\begin{table} {\bfseries Primary Energy Consumption}\\[1ex]
  \begin{tabular*}{118mm}{@{}l...rr@{}}
    . . . . .
  \end{tabular*}\[0.5ex]
  \emph{Source:} Energy Balance Study Group, . . .
\end{table}

```

There are a number of formatting parameters that may be used in connection with the `table` environment, which are described together with those for figures in Section 7.3.

Exercise 4.15: Complete the above text for the table on the previous page (without the footnotes). Pay attention to the following questions (check the explanations for the `@`-expressions in Section 4.8.1):

1. What is the effect of the `@{}` entries at the beginning and end of the formatting definition?
2. The `tabular*` environment generates a table with a given width, here 118 mm. What would be the effect of `@{extracolsep{fill}}` at the beginning of the formatting definition?
3. Where in the formatting definition should `@{extracolsep{fill}}` and the countermanding `@{\hspace{1em}}@{\extracolsep{1em}}` appear in order to format the table as it is printed here? How would the table appear if only `@{\extracolsep{1em}}` were given as countermand?

4.9 Printing literal text

Occasionally it is necessary to print text exactly as it is typed, with all special characters, blanks, and line breaks appearing literally, unformatted, and in a typewriter font. Lines of computer code or samples of \LaTeX input text are examples of such literal text. This is accomplished with the environments

```

\begin{verbatim}  text  \end{verbatim}
\begin{verbatim*} text  \end{verbatim*}

```

A new line is inserted before and after these environments.

With the `*`-form, blanks are printed with the symbol `_` to make them visible.

As an example, on page 115 some input text is printed to demonstrate the use of footnotes in forbidden modes. This was done with

```

\begin{verbatim}
  \addtocounter{footnote}{-1}\footnotetext{Small insects}
  \stepcounter{footnote}\footnotetext{Large mammals}
\end{verbatim}

```

Literal text may also be printed within a line using the commands `\verb` and `\verb*`, as for example

```

\verb=\emph{words of text}=    \emph{words of text}
\verb*=\emph{words of text}=  \emph{words_of_text}

```

where the first character after `\verb` or `\verb*` (here =) is the delimiter, such that all text up to the next occurrence of that character is printed literally. This character may not appear in the literal text, obviously.

In contrast to the behavior in the `verbatim` environment, the literal text must be all on one line in the input text, otherwise an error message is printed. This is to indicate that you just might have forgotten to repeat the delimiting character.

Important: *neither the `verbatim` environment nor the `\verb` command may be used in an argument of any other command!*

Exercise 4.16: Reproduce some input lines from this book as literal text.

4.9.1 Extension packages for literal text

Package: `alltt` The standard package `alltt` (Section B.5.3, page 392) provides an `alltt` environment that also prints its contents literally in a typewriter font, except that the characters `\ { }` retain their normal meaning. Thus \LaTeX commands can be included within the literal text. For example,

```

\begin{alltt}
Underlining \underline{typewriter}    Underlining typewriter
text is also possible.                text is also possible.
Note that dollar ($) and              Note that dollar ($) and
percent (%) signs are                  percent (%) signs are
treated \emph{literally}.              treated literally.
\end{alltt}

```

Package: `shortvrb` The standard package `shortvrb` (Section B.5.3, page 393) offers a shorthand for the `\verb` command. After issuing `\MakeShortVerb{\|}`, one can print short literal text with `|text|`. The counter command `\DeleteShortVerb{\|}` then restores the original meaning to `|`. Any character may be temporarily turned into a literal switch this way.

Package: `verbatim` One problem with the `verbatim` environment is that the entire literal text is input and stored before processing, something that can lead to memory overflows. The `verbatim` package in the `tools` collection (Section B.5.4, page 396) re-implements the environment to avoid this problem. A minor drawback is that *there must not be any other text on the same line as the `\end{verbatim}`*.

The `verbatim` package offers two other extra features. It provides a `comment` environment that simply ignores its contents, as though each line started with a `%` sign (Section 4.11). And it adds a command `\verbatiminput{filename}` to input the specified file as literal text. This is useful for listing actual computer programs rather than copying them into the \LaTeX file.

4.9.2 Email and Internet addresses

Package: `url` Email and Internet addresses present some special problems that are solved with the `url` package by Donald Arseneau. These addresses are best listed in a typewriter font, often contain special symbols, and should never be hyphenated, since the hyphen could be interpreted as part of the address. The obvious solution would be to use the `\verb` command, which fulfills all these conditions. However, if the address does not fit on the current line, it will stick out into the right margin. Using `\texttt` instead will allow the words in the address to be broken over two lines, but at the price of inserting an ambiguous hyphen.

Inserting the address with the `\url` command allows it to be broken at non-letters between words, without a hyphen. Moreover, its argument is treated literally, so all special characters are printed as given, just as with `\verb`. In fact, the argument of the `\url` command may either be enclosed in curly braces as usual, or delimited by some arbitrary character, just as with `\verb`.

An Internet address may be given as `\url{http://address.edu/home/page/}` or an email address might be given as `\url=fred.smith@general.services.gov=`

An Internet address is given as `http://address.edu/home/page/` or an email address might be given as `fred.smith@general.services.gov`

The `\url` command is to be preferred for another reason: it conforms to logical markup indicating the purpose of its argument. In fact, the `hyperref` package of Section 10.2.4 will even turn the argument into an active link, something it does not do for `\verb` arguments.

The printed appearance of the address can be controlled by specifying `\urlstyle{style}`, where *style* is one of `tt` (default), `rm`, `sf`, or `same`, for typewriter, Roman, sans serif, or unchanged font, respectively.

A fixed address can be predefined with, e.g.,

```
\urldef{\myurl}\url{myname@mydomain.uk}
```

Now `\myurl` is used to print `myname@mydomain.uk`.

There is also a `\path` command for giving directory/folder names, with the same syntax as `\url`. As logical markup, it has a different significance; for example, the `hyperref` package does not turn it into a link.

For further information on advanced uses of this package, see the comments at the end of the file `url.sty`.

4.10 Footnotes and marginal notes

4.10.1 Standard footnotes

Footnotes are generated with the command

```
\footnote{footnote_text}
```

which comes immediately after the word requiring an explanation in a footnote. The text *footnote_text* appears as a footnote in a smaller typeface at the bottom of the page. The first line of the footnote is indented and is given the same footnote marker as that inserted in the main text. The first footnote on a page is separated from the rest of the page text by means of a short horizontal line.

The standard footnote marker is a small, raised number¹, which is sequentially numbered. This footnote is produced with:

```
... raised number\footnote{The usual method of marking
footnotes in a typewritten ... same page.}, which is ...
```

The footnote numbering is incremented throughout the whole document for the `article` class, whereas it is reset to 1 for each new chapter in the `report` and `book` classes.

The `\footnote` command may only be given within the normal paragraph mode, and not within `math` or `LR` modes. In practice, this means it may not appear within an `LR` box (Section 4.7.1) or a `parbox` (Section 4.7.3). However, it may be used within a `minipage` environment, in which case the footnote text is printed beneath the `minipage` and not at the bottom of the actual page.²

The `\footnote` command must immediately follow the word that is to receive the note, without any intervening blanks or spacing. A footnote at the end of a sentence can be given after the period, as in the last example above:

```
... of the actual page.\footnote{With nested ... wrong place.}
```

4.10.2 Non-standard footnotes

If the user wishes the footnote numbering to be reset to 1 for each `\section` command with the `article` class, this may be achieved with

```
\setcounter{footnote}{0}
```

just before or after a `\section` command.

The internal footnote counter has the name `footnote`. Each call to `\footnote` increments this counter by one and prints the new value in Arabic numbering as the footnote marker. A different style of marker can be implemented with the command

```
\renewcommand{\thefootnote}{\numberstyle{footnote}}
```

¹The usual method of marking footnotes in a typewritten manuscript with *, **, etc., could also be done; however, since the page breaks are not known at the time of typing the text, there would be a problem of avoiding duplication of the symbols on the same page.

²With nested `minipages`, the footnote comes after the next `\end{minipage}` command, which could be at the wrong place.

where *number_style* is one of the counter print commands described in Section 4.3.5: `\arabic`, `\roman`, `\Roman`, `\alph`, or `\Alph`. However, for the counter `footnote`, there is an additional counter print command available, `\fnsymbol`, which prints the counter values 1–9 as one of nine symbols:

```
* † ‡ § ¶ || ** †† ‡‡
```

It is up to the user to see that the footnote counter is reset to zero sometime before the tenth `\footnote` call.

An optional argument may be added to the `\footnote` command

```
\footnote[num]{footnote_text}
```

where *num* is a positive integer that is used instead of the value of the footnote counter for the marker. In this case, the footnote counter is not incremented. For example**,

```
\renewcommand{\thefootnote}{\fnsymbol{footnote}}
For example\footnote[7]{The 7th symbol ... marker.},
\renewcommand{\thefootnote}{\arabic{footnote}}
```

where the last line is necessary to restore the footnote marker style to its standard form. Otherwise, all future footnotes would be marked with symbols and not with numbers.

4.10.3 Footnotes in forbidden modes

A footnote marker can be inserted in the text with the command

```
\footnotemark[num]
```

even where the `\footnote` command is normally not allowed, that is, in LR boxes, tables, and math mode. The marker is either the optional argument *num* or, if it is omitted, the incremented value of the footnote counter. The footnote itself is not generated. This must be done external to the forbidden mode with the command

```
\footnotetext[num]{footnote_text}
```

If the optional argument has been used for the footnote marker, the same *num* must be given as the option for the text command. Similarly, if no option was used for the marker, none may appear with the text. The footnote will be generated with the value of *num* or with that of the footnote counter.

This counter is incremented by a call to `\footnotemark` without an optional argument. The corresponding `\footnotetext` command, on the other hand, does not alter the counter.

**The 7th symbol appears as the footnote marker.

If there are a number of `\footnotemark` commands without optional arguments appearing before the next `\footnotetext` command, it is necessary to adjust the counter with the command

```
\addtocounter{footnote}{dif}
```

where *dif* is a negative number saying how many times the counter must be set back. Then before every `\footnotetext` command, the counter must be incremented by one. This can be done either with the command `\addtocounter`, with *dif*=1, or with the command

```
\stepcounter{footnote}
```

which adds 1 to the given counter.

For example: mosquitoes³ and elephants⁴

```
For example: \fbox{mosquitoes\footnotemark\ and
elephants\footnotemark}
```

generates the footnote markers ³ and ⁴. Now the counter has the value 4. In order for the first `\footnotetext` outside the framed box to operate with the correct counter value, it must first be decremented by one. The two footnote texts are made with

```
\addtocounter{footnote}{-1}\footnotetext{Small insects}
\stepcounter{footnote}\footnotetext{Large mammals}
```

immediately following the `\fbox{}` command. The footnote counter now has the same value as it did on leaving the `\fbox`.

4.10.4 Footnotes in minipages

As mentioned in Section 4.10.1, footnote commands are allowed inside the `minipage` environment. However, the footnote appears underneath the minipage, not below the main page.

Footnote commands within a `minipage`^a have a different marker style. The footnote comes after the next `\end{minipage}` command.^b Minipage footnotes have a counter separate from that of the main page, called `mpfootnote`, counting independently of footnote.

```
\begin{minipage}{6cm}
Footnote commands within
a minipage\footnote{The
marker is a raised
lower-case letter.} have
a different...
\end{minipage}
```

^aThe marker is a raised lower-case letter.

^bWatch out for nested minipages.



Footnotes within a `tabular` environment can normally only be generated with the commands described above: `\footnotemark` within the table and

³Small insects

⁴Large mammals

`\footnotetext` outside the environment. However, if the `tabular` environment is inside a `minipage`, normal `\footnote` commands may also be used inside the table. The footnote appears below the table where the `minipage` comes to an end.

Exercise 4.17: Produce a number of footnotes in your standard exercise file by inserting them where you think fit and by selecting some appropriate footnote text.

Exercise 4.18: Redefine the command `\thefootnote` so that the footnote markers become the symbols illustrated in Section 4.10.2. Add the redefinition to the preamble of your standard exercise file.

Exercise 4.19: Complete Exercise 4.15 so that the footnotes ^a and ^b appear as in the table on page 109.

4.10.5 Marginal notes

Notes in the page margin are produced with the command

```
\marginpar{note_text}
```

which puts the text *note_text* into the margin beginning at the level of the line where the command is given. The marginal note appearing here was generated with

```
margin- ... The marginal note \marginpar{This\\ is a\\ margin-\\a| note}
al note   appearing here ...
```

The text is normally enclosed in a parbox of width 1.9 cm (0.75 in). Such a narrow box causes great difficulties with line breaking, which is why the lines are manually broken with the `\\` command in the above example. Such a box is far more appropriate for marginal notes in the form of a single symbol, such as the arrow shown here.

⇒ Another common use for the marginal note is to draw attention to certain text passages by marking them with a vertical bar in the margin. This is often done to indicate changes in a text, for comparison with earlier versions after updated single sheets have been redistributed. The example marking this paragraph was made by including

```
\marginpar{\rule[-17.5mm]{1mm}{20mm}}
```

in the first line.

The width of the marginal note can be changed with a style parameter described in the next section. The user must watch out that the total page width does not become too big for the printer.

By default, marginal notes appear in the right-hand margin of the page, or in the outer margin when the `twoside` option has been selected. ‘Outer’ means the right margin for odd pages, and left for even ones. With the `twocolumn` option, they are placed in the outside margins: left for the left column and right for the right one.

This leads to a problem for marginal markings such as the arrow illustrated on the previous page. On this page, it must point in the opposite direction. In fact, its direction depends on which side of the page it is to appear, and that in turns depends on the page number or column. Since these are not known at the time of writing (and may even change with later revisions) it is necessary to have another solution. This is provided by the extended syntax of the `\marginpar` command

```
\marginpar[left_text]{right_text}
```

This form of the command contains two versions of the marginal text, *left_text* to go into the left margin, and *right_text* for the right margin, depending on which one is selected. Both the arrows on this and the previous page were generated with the same command

```
\marginpar[\hfill$\Longrightarrow$]{$\Longleftarrow$}
```

(The mathematical arrow commands are explained in Section 5.3.5.)

Without the `\hfill` command in the above `\marginpar` example, the arrow in the left margin appears as it does at the side of this paragraph, too far over to the left. The reason for this is that the `\marginpar` command sets its contents flush with the left edge of the narrow margin box, made visible here with a frame. This left edge is aligned with the main text only when the note is put on the right side; however, in the left margin, it is displaced from the main text. The `\hfill` command has the effect of setting the contents flush with the right edge of the margin box, which is then properly aligned with the main text.

A similar device was used to make the first marginal note in this section. The actual command given was

```
\marginpar[\flushright This\ is a\ margin-\a\ note]
{This\ is a\ margin-\a\ note}
```

Here `\flushright` (Section 4.2.2) is equivalent to putting an `\hfill` on each line.

The standard positioning of the marginal notes can be switched with the command `\reversemarginpar`. Once this command has been given, marginal notes will appear in the left margin, or in the ‘inner’ margin for the `twoside` option. The command `\normalmarginpar` restores normal behavior. These commands have no effect with the `twocolumn` option.

If the note appears at the bottom of a page, it will extend downwards below the last line of regular text. For this reason, and because of the difficulties with line breaking for narrow columns, marginal notes should be kept short, limited to a few words or a symbol.

4.10.6 Style parameters for footnotes and marginal notes

There are two footnote style parameters that may be changed as needed, either in the preamble or locally within an environment.

```
\footnotesep
```

The vertical spacing between two footnotes. This is a length that can be changed with the `\setlength` command.

`\footnoterule`

The command that draws a horizontal line between the page text and the footnotes. It should not add any net vertical spacing. It may be changed, for example, by

```
\renewcommand{\footnoterule}
{\rule{wth}{hght}\vspace{-hght}}
```

A value of 0 cm for the *hght* produces an invisible line of zero thickness.

The following style parameters may be changed to redefine how marginal notes appear:

`\marginparwidth`

determines the width of the margin box;

`\marginparsep`

sets the separation between the margin box and the main text;

`\marginparpush`

is the smallest vertical distance between two marginal notes.

These parameters are all lengths and are assigned new values as usual with the `\setlength` command.

4.11 Comments within text

All computer languages provide a means of inserting comments into the code. These are explanatory notes, documentation, history of development, or alternative text or code that has been temporarily deactivated. Comment lines are completely ignored during processing. They are only intended for human readers inspecting the source text.

In \LaTeX , the comment character is the percent sign `%`. When this character appears in the text, it and the rest of the line are ignored. If a comment is several lines long, each line must be prefixed with `%`.

As for other single character commands, the percent sign itself is printed with the command `\%`, as explained in Section 2.5.4.

The comment character `%` is also useful for experimenting with text or definitions of user commands or formatting parameters, to try alternatives without deleting the old versions. By ‘commenting out’ selective lines, one can play around with variations without losing them.

Large sections of text may be more effectively commented out with the `comment` environment from the `verbatim` package (page 111).

Finally, the `%` character has an important role to play in suppressing implied blanks at the end of a line. This is especially desirable in user definitions where unexpected blanks can creep in between otherwise invisible declarations with arguments. See Section 8.5.2.

Exercise 4.20: Comment out the changes from Exercise 4.18 in your preamble. These commands may be reactivated later by removing the `%` character.

Mathematical Formulas

Mathematics is the soul of $\text{T}_{\text{E}}\text{X}$. It was because the setting of mathematical formulas is so complicated in normal printing, not to mention on a typewriter, that Donald Knuth invented his text formatting system. On the other hand, the soul of $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ is logical markup. Nevertheless, all the power of $\text{T}_{\text{E}}\text{X}$'s math setting is also available in $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$, offering an unbeatable combination.

In this chapter, we confine ourselves to the elements of mathematical typesetting available in standard $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$. The simplifications and additional elements provided by $\mathcal{A}\mathcal{M}\mathcal{S}\text{-L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ are reserved for Chapter 12.

Mathematical formulas are produced by typing special descriptive text. This means that $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ must be informed that the *following text* is to be interpreted as a *mathematical formula*, and it must also be told when the *math text* has come to an end and normal text recommences. The processing of *math text* is carried out by switching to *math mode*. Mathematical environments serve this purpose.

5.1 Mathematical environments

Mathematical formulas may occur within a line of text, as $(a + b)^2 = a^2 + 2ab + b^2$, or separated from the main text as

$$\int_0^{\infty} f(x) dx \approx \sum_{i=1}^n w_i e^{x_i} f(x_i)$$

These two types are distinguished by referring to them as *text* and *displayed formulas* respectively.

Text formulas, or equations, are generated with the environment

```
\begin{math} formula_text \end{math}
```

Since text formulas are often very short, sometimes consisting of only a single character, a shorthand version is available as $\backslash(formula_text \backslash)$.

However, most authors prefer the very short form $\$formula_text\$$ which is actually the \TeX method. All three are essentially the same, and there is no reason not to use the $\$$ sign.

The contents of the formula, $formula_text$, consist of math constructs, which are described in the following sections.

Displayed formulas, or equations, are produced in the environments

```
\begin{displaymath} formula\_text \end{displaymath}
\begin{equation} formula\_text \end{equation}
```

The difference between these two is that the `equation` environment automatically adds a sequential equation number. The `displaymath` environment may be given with the shorthand forms `\[... \]` or `$$...$$`.

By default displayed formulas are centered horizontally with the equation number, if it is present, set flush with the right margin. By selecting the document class option `fleqn` (Section 3.1.1), the formulas are set left justified with an adjustable indentation. This option remains valid for the entire document whereas the amount of indentation may be changed at will with `\setlength{\mathindent}{indent}`, where *indent* is a length specification. Moreover, the document class option `leqno` sets the equation numbers flush with the left margin throughout the whole document.

Finally, multiline formulas can be created with the environments

```
\begin{eqnarray} formula\_text \end{eqnarray}
\begin{eqnarray*} formula\_text \end{eqnarray*}
```

where the standard form adds a sequential equation number for each line and the `*`-form is without equation numbers.

5.2 Main elements of math mode

5.2.1 Constants and variables

Numbers that appear within formulas are called *constants*, whereas *simple variables* are represented by single letters. The universal practice in mathematical typesetting is to put constants in Roman typeface and variables in *italics*. \TeX adheres to this rule automatically in math mode. Blanks are totally ignored and are included in the input text simply to improve the appearance for the writer. Spacing between constants, variables, and operators like $+$, $-$, $=$ are set automatically by \TeX . For example $\$z=2a+3y\$$, $\$ z = 2 a + 3 y \$$ both produce $z = 2a + 3y$.

Mathematical symbols that are available on the keyboard are

+ - = < > / : ! ' | [] ()

all of which may be used directly in formulas. The curly braces $\{ \}$ serve the purpose of logically combining parts of the formula and therefore

cannot act as printable characters. To include braces in a formula, the same commands $\{$ and $\}$ are used as in normal text.

$$M(s) < M(t) < |M| = m \quad \$M(s) < M(t) < |M| = m\$ \\ y'' = c\{f[y', y(x)] + g(x)\} \quad \$y'' = c\{f[y', y(x)] + g(x)\}\$$$

Preparation: Create a new \LaTeX file with the name *math.tex* containing at first only the commands $\documentclass\{article\}$, $\begin\{document\}$, and $\end\{document\}$.

Exercise 5.1: Produce the following text with your *math exercise file*: ‘The derivative of the indirect function $f[g(x)]$ is $\{f[g(x)]\}' = f'[g(x)]g'(x)$. For the second derivative of the product of $f(x)$ and $g(x)$ one has $[f(x)g(x)]'' = f''(x)g(x) + 2f'(x)g'(x) + f(x)g''(x)$.’

Note: higher derivatives are made with multiple ' symbols: $\$y'''\$$ yields y''' .

5.2.2 Exponents and indices

Mathematical formulas often contain exponents and indices, characters that are either raised or lowered relative to the main line of the formula, and printed in a smaller typeface. Although their mathematical meanings are different, superscripts and subscripts are typographically the same things as exponents and indices, respectively. It is even possible that exponents themselves have exponents or indices, and so on. These are produced by multiple applications of the raising and lowering operations.

\LaTeX and \TeX make it possible to create any combination of exponents and indices with the correct type size in a simple manner: the character command \hat sets the next character as an exponent (raised), while the character command $_$ sets it as an index (lowered).

$$x^2 \quad x^2 \quad a_n \quad a_n \quad x_i^n \quad x^n_i$$

When exponents and indices occur together, their order is unimportant. The last example above could also have been given as x_i^n .

If the exponent or index contains more than one character, the group of characters must be enclosed in braces $\{ \}$:

$$x^{2n} \quad x^{\{2n\}} \quad x_{2y} \quad x_{\{2y\}} \quad A_{i,j,k}^{-n!2} \quad A_{\{i,j,k\}}^{-n!2}$$

Multiple raisings and lowerings are generated by applying \hat and $_$ to the exponents and indices:

$$x^{y^2} \quad x^{\{y^2\}} \quad x^{y_1} \quad x^{\{y_1\}} \\ A_{j_{n,m}^2} \quad A^{\{x_i^2\}}_{\{j^{\{2n\}}_{\{n,m\}}\}}$$

Note: The raising and lowering commands \hat and $_$ are only permitted in math mode.

5.2.3 Fractions

Short fractions, especially within a text formula, are best represented using the slash character /, as in $\$(n+m)/2\$$ for $(n + m)/2$. For more complicated fractions, the command

$$\backslash\text{frac}\{numerator\}\{denominator\}$$

is employed to write the *numerator* on top of the *denominator* with a horizontal fraction line of the right width between them.

$$\frac{1}{x+y} \quad \backslash[\ \backslash\text{frac}\{1\}\{x+y\}\ \backslash]$$

$$\frac{a^2 - b^2}{a + b} = a - b \quad \backslash[\ \backslash\text{frac}\{a^2 - b^2\}\{a+b\} = a-b\ \backslash]$$

Fractions may be nested to any depth within one another.

$$\frac{\frac{a}{x-y} + \frac{b}{x+y}}{1 + \frac{a-b}{a+b}} \quad \backslash[\ \backslash\text{frac}\{\backslash\text{frac}\{a\}\{x-y\} + \backslash\text{frac}\{b\}\{x+y\}\}\{1 + \backslash\text{frac}\{a-b\}\{a+b\}\}\ \backslash]$$

L^AT_EX sets fractions within fractions in a smaller typeface. Section 5.5.2 describes how the automatic type sizes may be overridden if L^AT_EX's choice is unsuitable.

5.2.4 Roots

Roots are printed with the command

$$\backslash\text{sqrt}[n]\{arg\}$$

as in the example: $\$\text{sqrt}[3]\{8\} = 2\$$ produces $\sqrt[3]{8} = 2$. If the optional argument n is omitted, the square root is generated: $\$\text{sqrt}\{a\}$ yields \sqrt{a} .

The size and length of the root sign are automatically fitted to *arg*:
 $\$\text{sqrt}\{x^2 + y^2 + 2xy\} = x+y\$$ $\sqrt{x^2 + y^2 + 2xy} = x + y$, or

$$\sqrt[n]{\frac{x^n - y^n}{1 + u^{2n}}} \quad \backslash[\ \backslash\text{sqrt}[n]\{\backslash\text{frac}\{x^n - y^n\}\{1 + u^{2n}\}\}\ \backslash]$$

Roots may be nested inside one another to any depth:

$$\sqrt[3]{-q + \sqrt{q^2 + p^3}} \quad \backslash[\ \backslash\text{sqrt}[3]\{-q + \backslash\text{sqrt}\{q^2 + p^3\}\}\ \backslash]$$

5.2.5 Sums and integrals

Summation and integral signs are made with the two commands `\sum` and `\int`, which may appear in two different sizes depending on whether they occur in a text or displayed formula.

Sums and integrals very often possess upper and lower limits. These are printed with the exponent and index commands `^` and `_`. The positioning of the limits also depends on whether the formula is in text or displayed.

In a text formula `\sum_{i=1}^n` and `\int_a^b` produce $\sum_{i=1}^n$ and \int_a^b , whereas in a displayed formula they appear as at the left below:

$\sum_{i=1}^n \int_a^b$	<p>Some authors prefer the limits for the integral to be placed above and below the integral sign, the same as for summation. This is achieved with the command <code>\limits</code> immediately following the integral sign: <code>\int\limits_{x=0}^{x=1}</code></p>	$\int_{x=0}^{x=1}$
-------------------------	--	--------------------

The rest of the formula text coming before and after the sum and integral signs is correctly aligned with them.

$2 \sum_{i=1}^n a_i \int_a^b f_i(x) g_i(x) dx$	<code>[2\sum_{i=1}^n a_i \int_a^b f_i(x)g_i(x)\,\mathrm{d}x \]</code>
--	---



Two points must be made regarding integrals such as $\int y dx$ and $\int f(z) dz$. First, there should be a little extra spacing between the differential operators dx and dz and the integrands preceding them. This is achieved with the small spacing command `\,`, mentioned in Section 2.7.1, not with a blank which is ignored in math mode. Second, the differential operator should be written upright, not italic, as explained in Section 5.4.10. This is accomplished by setting it within a `\mathrm` command (Section 5.4.2). Thus `\int y\,\mathrm{d}x` and `\int f{z}\,\mathrm{d}z` produce the desired results shown above, whereas `\int y dx` and `\int f(z) dz` yield $\int y dx$ and $\int f(z) dz$.

5.2.6 Continuation dots—ellipsis

Formulas occasionally contain a row of dots \dots , meaning *and so on*. Simply typing a period three times in a row produces an undesirable result: \dots , that is, the dots are too close together. Therefore L^AT_EX provides several commands

<code>\ldots</code>	...	<i>low dots</i>	<code>\cdots</code>	...	<i>center dots</i>
<code>\vdots</code>	⋮	<i>vertical dots</i>	<code>\ddots</code>	⋱	<i>diagonal dots</i>

to space the dots correctly. The difference between the first two commands is best illustrated by the examples a_0, a_1, \dots, a_n and $a_0 + a_1 + \dots + a_n$, which are produced with `a_0, a_1, \ldots, a_n` for the first and `$a_0 + a_1 + \cdots + a_n$` for the second.

The command `\ldots` is also available in normal text mode, whereas the other three are only allowed in math mode. In text mode, the command `\dots` may be used in place of `\ldots` with the same effect.

Exercise 5.2: Generate the following output:

The reduced cubic equation $y^3 + 3py + 2q = 0$ has one real and two complex solutions when $D = q^2 + p^3 > 0$. These are given by Cardan's formula as

$$y_1 = u + v, \quad y_2 = -\frac{u+v}{2} + \frac{i}{2}\sqrt{3}(u-v), \quad y_3 = -\frac{u+v}{2} - \frac{i}{2}\sqrt{3}(u-v)$$

where

$$u = \sqrt[3]{-q + \sqrt{q^2 + p^3}}, \quad v = \sqrt[3]{-q - \sqrt{q^2 + p^3}}$$

Note: the spacings between the parts of the displayed equations are made with the spacing commands `\quad` and `\qqquad`.

Exercise 5.3: Select the option `f1eqn` in the document class command and include the specification `\setlength{\mathindent}{2cm}` in the preamble. Redo the three y equations above, each as a separate displayed formula, using the equation environment instead of `displaymath` or `\[...]` brackets.

Exercise 5.4: Create the following text:

Each of the measurements $x_1 < x_2 < \dots < x_r$ occurs p_1, p_2, \dots, p_r times. The mean value and standard deviation are then

$$\bar{x} = \frac{1}{n} \sum_{i=1}^r p_i x_i, \quad s = \sqrt{\frac{1}{n} \sum_{i=1}^r p_i (x_i - \bar{x})^2}$$

where $n = p_1 + p_2 + \dots + p_r$.

Exercise 5.5: Although this equation looks very complicated, it should not present any great difficulties:

$$\int \frac{\sqrt{(ax+b)^3}}{x} dx = \frac{2\sqrt{(ax+b)^3}}{3} + 2b\sqrt{ax+b} + b^2 \int \frac{dx}{x\sqrt{ax+b}}$$

The same applies to $\int_{-1}^8 (dx/\sqrt[3]{x}) = \frac{3}{2}(8^{2/3} + 1^{2/3}) = 15/2$.

5.3 Mathematical symbols

There is a very wide range of symbols used in mathematical text, of which only a few are directly available from the keyboard. \LaTeX provides many of the mathematical symbols that are commonly used. They are called with the symbol name prefixed with the `\` character. The names themselves are derived from their mathematical meanings.

5.3.1 Greek letters

Lower case letters

α	<code>\alpha</code>	θ	<code>\theta</code>	o	<code>o</code>	τ	<code>\tau</code>
β	<code>\beta</code>	ϑ	<code>\vartheta</code>	π	<code>\pi</code>	υ	<code>\upsilon</code>
γ	<code>\gamma</code>	ι	<code>\iota</code>	ϖ	<code>\varpi</code>	ϕ	<code>\phi</code>
δ	<code>\delta</code>	κ	<code>\kappa</code>	ρ	<code>\rho</code>	φ	<code>\varphi</code>
ϵ	<code>\epsilon</code>	λ	<code>\lambda</code>	ϱ	<code>\varrho</code>	χ	<code>\chi</code>
ε	<code>\varepsilon</code>	μ	<code>\mu</code>	σ	<code>\sigma</code>	ψ	<code>\psi</code>
ζ	<code>\zeta</code>	ν	<code>\nu</code>	ς	<code>\varsigma</code>	ω	<code>\omega</code>
η	<code>\eta</code>	ξ	<code>\xi</code>				

Upper case letters

Γ	<code>\Gamma</code>	Λ	<code>\Lambda</code>	Σ	<code>\Sigma</code>	Ψ	<code>\Psi</code>
Δ	<code>\Delta</code>	Ξ	<code>\Xi</code>	Υ	<code>\Upsilon</code>	Ω	<code>\Omega</code>
Θ	<code>\Theta</code>	Π	<code>\Pi</code>	Φ	<code>\Phi</code>		

The Greek letters are made simply by putting the command character `\` before the name of the letter. Upper case (capital) letters are distinguished by capitalizing the first letter of the name. Greek letters that do not appear in the above list are identical with some corresponding Latin letter. For example, upper case ρ is the same as Latin P and so needs no special symbol.

L^AT_EX normally sets the upper case Greek letters in Roman (upright) type within a mathematical formula. If they need to be in italics, this can be brought about with the *math alphabet command* `\mathnormal`: `\mathnormal{\Gamma\Pi\Phi}` appears as $\Gamma\Pi\Phi$.

Greek letters may only be used in math mode. If they are needed in normal text, the command must be enclosed in `$. . . $` signs.

5.3.2 Calligraphic letters

The following 26 *calligraphic* letters may also be used in math formulas:

$\mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{D}, \mathcal{E}, \mathcal{F}, \mathcal{G}, \mathcal{H}, \mathcal{I}, \mathcal{J}, \mathcal{K}, \mathcal{L}, \mathcal{M}, \mathcal{N}, \mathcal{O}, \mathcal{P}, \mathcal{Q}, \mathcal{R}, \mathcal{S}, \mathcal{T}, \mathcal{U}, \mathcal{V}, \mathcal{W}, \mathcal{X}, \mathcal{Y}, \mathcal{Z}$

These are called with the math alphabet command `\mathcal`:

`\mathcal{A}, \mathcal{B}, \mathcal{C}, \dots, \mathcal{Z}`

5.3.3 Binary operators

Two mathematical quantities combined with one another to make a new quantity are said to be joined by a *binary operation*. The symbols that are available for use as binary operators are

\pm	<code>\pm</code>	\cap	<code>\cap</code>	\circ	<code>\circ</code>	\bigcirc	<code>\bigcirc</code>
\mp	<code>\mp</code>	\cup	<code>\cup</code>	\bullet	<code>\bullet</code>	\square	<code>\Box</code>
\times	<code>\times</code>	\uplus	<code>\uplus</code>	\diamond	<code>\diamond</code>	\diamond	<code>\Diamond</code>
\div	<code>\div</code>	\sqcap	<code>\sqcap</code>	\triangleleft	<code>\lhd</code>	\triangle	<code>\bigtriangleup</code>
\cdot	<code>\cdot</code>	\sqcup	<code>\sqcup</code>	\triangleright	<code>\rhd</code>	∇	<code>\bigtriangledown</code>
$*$	<code>\ast</code>	\vee	<code>\vee</code>	\triangleleft	<code>\unlhd</code>	\triangleleft	<code>\triangleleft</code>
\star	<code>\star</code>	\wedge	<code>\wedge</code>	\triangleright	<code>\unrhd</code>	\triangleright	<code>\triangleright</code>
\dagger	<code>\dagger</code>	\oplus	<code>\oplus</code>	\oslash	<code>\oslash</code>	\setminus	<code>\setminus</code>
\ddagger	<code>\ddagger</code>	\ominus	<code>\ominus</code>	\odot	<code>\odot</code>	\wr	<code>\wr</code>
\amalg	<code>\amalg</code>	\otimes	<code>\otimes</code>				

Package: The underlined symbol names in the above and following tables are `latexsym` only available if one of the packages `latexsym` (Section B.5.3) or `amsfonts` (Section 12.4.4) has been loaded.

5.3.4 Relations and their negations

When two mathematical quantities are compared, they are connected by a *relation*. The different types of relational symbols for the various comparisons are

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

A number of the above symbols may be called by more than one name. For example, \leq may be produced with either `\le` or `\leq`.

The opposite, or negated, meaning of the relation is indicated in mathematics with a slash / through the symbol: $=$ and \neq mean *equals* and *not equals*. One may put a slash through any of the above symbols by prefixing its name with `\not`. Thus `\not\in` yields \notin . The same is true for the keyboard characters: `\not=`, `\not>`, and `\not<` produce \neq , \nless , and \ngtr . For `\not=` there is also the special command `\neq` producing \neq which is a symbol on its own and not the combined \neq .

The following symbols may be negated in this manner. Note that the last two, `\not\in` and `\notin`, are not exactly the same: \notin and \notin . The latter form is the preferred one.

\nless	<code>\not<</code>	\ngtr	<code>\not></code>	\neq	<code>\not=</code>
\nleq	<code>\not\le</code>	\ngeq	<code>\not\ge</code>	$\not\equiv$	<code>\not\equiv</code>
\nprec	<code>\not\prec</code>	\nsucc	<code>\not\succ</code>	$\not\sim$	<code>\not\sim</code>
\npreceq	<code>\not\preceq</code>	\nsucceq	<code>\not\succeq</code>	$\not\approx$	<code>\not\approx</code>
\nsubset	<code>\not\subset</code>	\nsupset	<code>\not\supset</code>	$\not\cong$	<code>\not\cong</code>
\nsubseteq	<code>\not\subseteq</code>	\nsupseteq	<code>\not\supseteq</code>	$\not\asymp$	<code>\not\asymp</code>
\nsubsetneq	<code>\not\subsetneq</code>	\nsupsetneq	<code>\not\supsetneq</code>		
\nsubseteqq	<code>\not\subseteqq</code>				
\notin	<code>\notin</code>				

5.3.5 Arrows and pointers

Mathematical manuscripts often contain arrow symbols, also called *pointers*. The following arrow symbols are available:

\leftarrow	<code>\leftarrow</code>	\longleftarrow	<code>\longleftarrow</code>	\uparrow	<code>\uparrow</code>
\Leftarrow	<code>\Leftarrow</code>	\Lleftarrow	<code>\Lleftarrow</code>	\Uparrow	<code>\Uparrow</code>
\rightarrow	<code>\rightarrow</code>	\longrightarrow	<code>\longrightarrow</code>	\downarrow	<code>\downarrow</code>
\Rightarrow	<code>\Rightarrow</code>	\Longrightarrow	<code>\Longrightarrow</code>	\Downarrow	<code>\Downarrow</code>
\leftrightarrow	<code>\leftrightarrow</code>	\longleftrightarrow	<code>\longleftrightarrow</code>	\updownarrow	<code>\updownarrow</code>
\Leftrightarrow	<code>\Leftrightarrow</code>	\Llongleftrightarrow	<code>\Llongleftrightarrow</code>	\Updownarrow	<code>\Updownarrow</code>
\mapsto	<code>\mapsto</code>	\longmapsto	<code>\longmapsto</code>	\nearrow	<code>\nearrow</code>
\hookrightarrow	<code>\hookrightarrow</code>	\hookleftarrow	<code>\hookleftarrow</code>	\searrow	<code>\searrow</code>
\leftharpoonup	<code>\leftharpoonup</code>	\rightharpoonup	<code>\rightharpoonup</code>	\swarrow	<code>\swarrow</code>
\leftharpoondown	<code>\leftharpoondown</code>	\rightharpoondown	<code>\rightharpoondown</code>	\nwarrow	<code>\nwarrow</code>
\Rightarrow	<code>\Rightarrow</code>	\leadsto	<code>\leadsto</code>		

Here again the symbols \rightarrow and \leftarrow may also be referred to under the names `\to` and `\gets`. Furthermore, the command `\Llongleftrightarrow` may be substituted by `\iff`, although the latter (\iff) has a little more spacing on either side than the former (\Lleftrightarrow).

5.3.6 Various other symbols

The above lists by no means exhaust the complete repertoire of mathematical symbols. However, the following are additional characters that standard L^AT_EX does make available. (Even more symbols are possible with the $\mathcal{A}\mathcal{M}\mathcal{S}$ symbol fonts and `amssymb` package, Section 12.4.4.)

\aleph	<code>\aleph</code>	\prime	<code>\prime</code>	\forall	<code>\forall</code>	\Box	<code>\Box</code>
\hbar	<code>\hbar</code>	\emptyset	<code>\emptyset</code>	\exists	<code>\exists</code>	\Diamond	<code>\Diamond</code>
\imath	<code>\imath</code>	∇	<code>\nabla</code>	\neg	<code>\neg</code>	\triangle	<code>\triangle</code>
\jmath	<code>\jmath</code>	\surd	<code>\surd</code>	\flat	<code>\flat</code>	\clubsuit	<code>\clubsuit</code>
ℓ	<code>\ell</code>	∂	<code>\partial</code>	\natural	<code>\natural</code>	\diamondsuit	<code>\diamondsuit</code>
\wp	<code>\wp</code>	\top	<code>\top</code>	\sharp	<code>\sharp</code>	\heartsuit	<code>\heartsuit</code>
\Re	<code>\Re</code>	\perp	<code>\perp</code>	\parallel	<code>\parallel</code>	\spadesuit	<code>\spadesuit</code>
\Im	<code>\Im</code>	\vdash	<code>\vdash</code>	\angle	<code>\angle</code>	\Join	<code>\Join</code>
\mho	<code>\mho</code>	\dashv	<code>\dashv</code>	\backslash	<code>\backslash</code>	∞	<code>\infty</code>

5.3.7 Symbols with two sizes

The following symbols are printed in different sizes depending on whether they appear in text or displayed formulas:

Σ	\sum	<code>\sum</code>	\cap	\bigcap	<code>\bigcap</code>	\odot	\bigodot	<code>\bigodot</code>
\int	\int	<code>\int</code>	\cup	\bigcup	<code>\bigcup</code>	\otimes	\bigotimes	<code>\bigotimes</code>
\oint	\oint	<code>\oint</code>	\sqcup	\bigsqcup	<code>\bigsqcup</code>	\oplus	\bigoplus	<code>\bigoplus</code>
\prod	\prod	<code>\prod</code>	\vee	\bigvee	<code>\bigvee</code>	\uplus	\biguplus	<code>\biguplus</code>
\coprod	\coprod	<code>\coprod</code>	\wedge	\bigwedge	<code>\bigwedge</code>			

The symbols `\int` and `\sum` have already been introduced in Section 5.2.5. There it was shown how these symbols may take on upper and lower limits; in the same way, all the above symbols may also be assigned upper and lower limits using the shifting commands `^` and `_`. The positioning of the limits varies for some symbols depending on whether they occur in text or displayed formulas. As indicated in Section 5.2.5, the command `\limits` forces the limits to be written above and below the symbol where they would otherwise be placed beside it. Similarly the complementary command `\nolimits` sets them beside the symbol when the standard positioning is above and below.

\int_0^∞	\int_0^∞	<code>\int_0^\infty</code>	<code>\int_0^\infty</code>	<code>\int_0^\infty</code>	<code>\int_0^\infty</code>
$\prod_{\nu=0}^n$	$\prod_{\nu=0}^n$	<code>\prod_{\nu=0}^n</code>	<code>\prod_{\nu=0}^n</code>	<code>\prod_{\nu=0}^n</code>	<code>\prod_{\nu=0}^n</code>

5.3.8 Function names

The universal standard for mathematical formulas is to set variable names in *italics* but the names of functions in Roman. If one were simply to write the function names *sin* or *log* in math mode, \LaTeX would interpret these as variables *s i n* and *l o g* and write them as *sin* and *log*. In order to tell \LaTeX that a function name is wanted, it is necessary to enter a command consisting of the backslash `\` plus the function name. The following names are recognized by \LaTeX :

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

Some of these functions may also appear with limits attached to them. This is easily achieved by means of the subscript command after the name of the function: `\lim_{x\to\infty}` yields $\lim_{x\rightarrow\infty}$ in text formulas and

$$\lim_{x\rightarrow\infty} \text{ in displayed formulas}$$

The following function names may accept a limit with the lowering (index) command `_`:

`\det` `\gcd` `\inf` `\lim` `\liminf` `\limsup` `\max` `\min`
`\Pr` `\sup`

Finally, there are the function commands `\bmod` and `\pmod{arg}`, both of which produce the function *mod* in one of two forms:

$$\begin{aligned} \$ a \backslash\bmod b \$ & \Rightarrow a \bmod b \\ \$ y \backslash\pmod{a+b} \$ & \Rightarrow y \pmod{a + b}. \end{aligned}$$

With $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ (Section 12.2.5) it is possible to define additional function names.

5.3.9 Mathematical accents

The following mathematical accents are available within math mode:

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

The letters *i* and *j* should be printed without their dots when they are given an accent. To accomplish this, type the symbols `\imath` and `\jmath` instead of the letters, as in

$$\vec{\imath} + \tilde{\jmath}: \quad \vec{i} + \tilde{j}$$

There are wider versions of `\hat` and `\tilde` available with the names `\widehat` and `\widetilde`. In this way, these accents may be placed over parts of a formula:

$$\begin{aligned} \widehat{1-x} = \widehat{-y} & \quad \$\widehat{1-x}=\widehat{-y} \$ \\ \widetilde{xyz} & \quad \$\widetilde{xyz} \$ \end{aligned}$$

Exercise 5.6: The union of two sets \mathcal{A} and \mathcal{B} is the set of all elements that are in at least one of the two sets, and is designated as $\mathcal{A} \cup \mathcal{B}$. This operation is commutative $\mathcal{A} \cup \mathcal{B} = \mathcal{B} \cup \mathcal{A}$ and associative $(\mathcal{A} \cup \mathcal{B}) \cup \mathcal{C} = \mathcal{A} \cup (\mathcal{B} \cup \mathcal{C})$. If $\mathcal{A} \subseteq \mathcal{B}$, then $\mathcal{A} \cup \mathcal{B} = \mathcal{B}$. It then follows that $\mathcal{A} \cup \mathcal{A} = \mathcal{A}$, $\mathcal{A} \cup \{\emptyset\} = \mathcal{A}$ and $J \cup \mathcal{A} = J$.

Exercise 5.7: Applying l'Hôpital's rule, one has

$$\lim_{x \rightarrow 0} \frac{\ln \sin \pi x}{\ln \sin x} = \lim_{x \rightarrow 0} \frac{\pi \frac{\cos \pi x}{\sin \pi x}}{\frac{\cos x}{\sin x}} = \lim_{x \rightarrow 0} \frac{\pi \tan x}{\tan \pi x} = \lim_{x \rightarrow 0} \frac{\pi / \cos^2 x}{\pi / \cos^2 \pi x} = \lim_{x \rightarrow 0} \frac{\cos^2 \pi x}{\cos^2 x} = 1$$

Exercise 5.8: The gamma function $\Gamma(x)$ is defined as

$$\Gamma(x) \equiv \lim_{n \rightarrow \infty} \prod_{v=0}^{n-1} \frac{n! n^{x-1}}{x+v} = \lim_{n \rightarrow \infty} \frac{n! n^{x-1}}{x(x+1)(x+2) \cdots (x+n-1)} \equiv \int_0^{\infty} e^{-t} t^{x-1} dt$$

The integral definition is valid only for $x > 0$ (2nd Euler integral).

Exercise 5.9: Remove the option `fleqn` from the document class command in Exercise 5.3 and redo the output.

Exercise 5.10:

$$\alpha \vec{x} = \vec{x} \alpha, \quad \alpha \beta \vec{x} = \beta \alpha \vec{x}, \quad (\alpha + \beta) \vec{x} = \alpha \vec{x} + \beta \vec{x}, \quad \alpha(\vec{x} + \vec{y}) = \alpha \vec{x} + \alpha \vec{y}.$$

$$\vec{x} \vec{y} = \vec{y} \vec{x} \text{ but } \vec{x} \times \vec{y} = -\vec{y} \times \vec{x}, \quad \vec{x} \vec{y} = 0 \text{ for } \vec{x} \perp \vec{y}, \quad \vec{x} \times \vec{y} = 0, \text{ for } \vec{x} \parallel \vec{y}.$$

Exercise 5.11: Reproduce Equations 5.1 and 5.2 from the next section.

5.4 Additional elements

The math elements described in the previous sections already permit the construction of very complex formulas, such as

$$\lim_{x \rightarrow 0} \frac{\sqrt{1+x} - 1}{x} = \lim_{x \rightarrow 0} \frac{(\sqrt{1+x} - 1)(\sqrt{1+x} + 1)}{x(\sqrt{1+x} + 1)} = \lim_{x \rightarrow 0} \frac{1}{\sqrt{1+x} + 1} = \frac{1}{2} \quad (5.1)$$

$$\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2} = 0 \quad \Rightarrow \quad U_M = \frac{1}{4\pi} \oint_{\Sigma} \frac{1}{r} \frac{\partial U}{\partial n} ds - \frac{1}{4\pi} \oint_{\Sigma} \frac{\partial}{\partial n} \left(\frac{1}{r} U \right) ds \quad (5.2)$$

$$I(z) = \sin\left(\frac{\pi}{2} z^2\right) \sum_{n=0}^{\infty} \frac{(-1)^n \pi^{2n}}{1 \cdot 3 \cdots (4n+1)} z^{4n+1} - \cos\left(\frac{\pi}{2} z^2\right) \sum_{n=0}^{\infty} \frac{(-1)^n \pi^{2n+1}}{1 \cdot 3 \cdots (4n+3)} z^{4n+3} \quad (5.3)$$

By reading the formulas from left to right there should be no difficulty in reconstructing the text that produced them. For example, the last equation is generated with

```
\begin{equation}
I(z) = \sin\left(\frac{\pi}{2} z^2\right) \sum_{n=0}^{\infty} \frac{(-1)^n \pi^{2n}}{1 \cdot 3 \cdots (4n+1)} z^{4n+1}
- \cos\left(\frac{\pi}{2} z^2\right) \sum_{n=0}^{\infty} \frac{(-1)^n \pi^{2n+1}}{1 \cdot 3 \cdots (4n+3)} z^{4n+3}
\end{equation}
```

The above examples were made using the `equation` environment instead of the `displaymath` environment or its abbreviated form `\[...]`, which has the effect of adding the equation numbers automatically. In the document classes `book` and `report`, equations are sequentially numbered within the chapter, the number being preceded by the chapter number and set within parentheses (`()`), as illustrated above. For document class

article, the equations are numbered sequentially throughout the entire document.

By default the equation number appears right justified and vertically centered with the equation. If there is not enough room for it on the same line, it is printed right justified below the equation. If the document class option `leqno` has been selected, the equation numbers are set left justified for the entire document.

The automatic numbering of equations means that the author may not know at the time of writing just what the equation number is. The \LaTeX cross-reference system described in Section 9.2.1 has already been explained for referring to section numbers (Section 3.3.3) and may also be used for equation numbers. By including a command `\label{name}` within the `equation` environment, one can print the unknown equation number in the text with the command `\ref{name}`, where *name* is a keyword consisting of any combination of letters, numbers, or symbols.

Examining Equation 5.3 more closely, one notices that the two parentheses pairs () in `cos()` and `sin()` could be somewhat larger. Furthermore, this equation just fills the line width, and if it were any longer, it would have to be broken at some appropriate spot and the parts positioned in a meaningful way relative to one another. None of the math elements described so far can accomplish these requirements.

Even something so simple as including some normal text within a formula has not yet been mentioned. The rest of this section addresses these problems.

Finally, there are times when one is not happy with the sizes that \TeX has chosen, as for example in the last integral of Equation 5.2 where $\partial \frac{1}{r}$ would be more desirable than $\partial \frac{1}{r}$. This and other formatting aids, such as adjusting horizontal spacing between parts of formulas, are dealt with in Section 5.5.

5.4.1 Automatic sizing of bracket symbols

Mathematics often contains bracketing symbols, usually in pairs that enclose part of the formula. When printed, these bracket symbols should be the same size as the included partial formula. \LaTeX provides a pair of commands

$$\backslash\left lbrack \quad sub_form \quad \backslash\right rbrack$$

to accomplish this. The command `\left` is placed immediately before the opening (left hand) bracket symbol *lbrack* while `\right` comes just before the closing (right hand) symbol *rbrack*.

$\left[\int + \int \right]_{x=0}^{x=1}$ The pair of brackets `[]` is adjusted to the size of the enclosed formula, as are the raised exponent and lowered index as well.

The commands `\left` and `\right` must appear as a pair. For every `\left` command there must be a corresponding `\right` command somewhere afterwards. The pairs may be nested. The first `\left` is paired with the last `\right`; the following `\left` with the second last `\right`, and so on. There must be the same number of `\right` as `\left` commands in a nesting.

The corresponding bracket symbols *lbrack* and *rbrack* may be perfectly arbitrary and do not need to be a logical pair.

$\vec{x} + \vec{y} + \vec{z} = \begin{pmatrix} a \\ b \end{pmatrix}$ This set of brackets is admittedly unusual but permissible.
 $\left[\vec{x} + \vec{y} + \vec{z} = \left(\dots \right) \right]$

Sometimes a formula contains only a single opening or closing bracket without a corresponding counterpart. However, the `\left... \right` commands must still be given as a pair, but with a period ‘.’ as an *invisible* bracket symbol.

$y = \begin{cases} -1 & : x < 0 \\ 0 & : x = 0 \\ +1 & : x > 0 \end{cases}$ `\left\{ y = \left\{ \begin{array}{l} -1 & : x < 0 \\ 0 & : x = 0 \\ +1 & : x > 0 \end{array} \right. \right.`

The `array` environment in the above example is described in Section 4.8.1 and produces a table in math mode.

The `\left... \right` commands may be applied to a total of 22 different symbols. These are

<code>((</code>	<code>))</code>	<code>\lfloor</code>	<code>\rfloor</code>
<code>[[</code>	<code>]]</code>	<code>\lceil</code>	<code>\rceil</code>
<code>{ \{</code>	<code>} \}</code>	<code>\langle</code>	<code>\rangle</code>
<code> </code>	<code>\ \ </code>	<code>\uparrow</code>	<code>\Uparrow</code>
<code>/ /</code>	<code>\ \backslash</code>	<code>\downarrow</code>	<code>\Downarrow</code>
		<code>\updownarrow</code>	<code>\Updownarrow</code>

For example, `\left|... \right|` produces two vertical bars adjusted in height to contain the enclosed formula text.

Exercise 5.12: In Equation 5.3, generate $\cos\left(\frac{\pi}{2}z^2\right)$ and $\sin\left(\frac{\pi}{2}z^2\right)$ instead of $\cos\left(\frac{\pi}{2}z^2\right)$ and $\sin\left(\frac{\pi}{2}z^2\right)$.

5.4.2 Ordinary text within a formula

It is often necessary to include some *normal* text within a formula, for example single words such as *and*, *or*, *if*, and so on. In this case one must switch to LR mode (Section 4.7.1) while staying in math mode. This is carried out with the command `\mbox{normal text}` given inside the formula, together with horizontal spacing commands such as `\quad` or `\hspace`. For example:

$$X_n = X_k \quad \text{if and only if} \quad Y_n = Y_k \quad \text{and} \quad Z_n = Z_k$$

$$\left[X_n = X_k \quad \text{\quad\quad\quad} \text{\mbox{if and only if}} \quad \text{\quad\quad\quad} Y_n = Y_k \quad \text{\quad\quad\quad} \text{\quad\quad\quad} \text{\mbox{and}} \quad \text{\quad\quad\quad} Z_n = Z_k \quad \right]$$

In order to set a longer piece of text beside a displayed formula, as in some of the above examples, it is more appropriate to put both the formula and the text in their own parboxes or minipages, placed side by side with the proper vertical positioning.

On the other hand, if letters from text fonts are required as mathematical symbols, they should be entered with the *math alphabet commands*:

$$\begin{array}{lll} \mathrm{\mathrm} & \mathrm{\mathtt} & \mathrm{\mathbf} \\ \mathrm{\mathsf} & \mathrm{\mathit} & \mathrm{\mathcal} \end{array}$$

We have already met `\mathcal` in Section 5.3.2 on calligraphic letters. All these commands function the same way: they set their argument in the corresponding font.

$$\mathbf{B}^0(x) \quad T_j^i \quad \mathsf{\mathcal{B}}^0(x) \quad \mathsf{\mathcal{T}}^i_j$$

The command `\mathnormal` in Section 5.3.1 also belongs to this group. The difference between it and `\mathit` is that it sets its argument in the regular *math* italic font, while the latter uses the normal *text* italic. The letters are the same, but the spacing is different.

$$\mathnormal{\mathit{differ}} \quad \neq \quad \mathit{\mathit{differ}}$$

All the math alphabet commands set their text in math mode, which means that spaces are ignored as usual. This is not the case for text placed in an `\mbox`.

5.4.3 Matrices and arrays

$$\begin{array}{cccc} a_{11} & a_{12} & \cdots & a_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{array}$$

Structures like the one at the left are the basis for matrices, determinants, system of equations, and so on. They will all be referred to here as *arrays*.

Arrays are produced by means of the array environment, whose syntax and construction are described in Section 4.8.1 on tables. The array environment generates a table in math mode, that is, the column entries are interpreted as formula text. For example:

$$\begin{array}{l}
 a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1 \\
 a_{22}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2 \\
 \dots\dots\dots \\
 a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = b_n
 \end{array}$$

```

\left[ \begin{array}{*{3}{c@{\:}\:}\c@{\;}\c@{\;}\c@{\;}\c@{\;}}
  a_{11}x_1 & a_{12}x_2 & \cdots & a_{1n}x_n & b_1 \\
  a_{22}x_1 & a_{22}x_2 & \cdots & a_{2n}x_n & b_2 \\
  \multicolumn{5}{c}{\dotfill} \\
  a_{n1}x_1 & a_{n2}x_2 & \cdots & a_{nn}x_n & b_n
\end{array} \right]

```



As a reminder of the table construction elements (Section 4.8.1): `@{t}` inserts the contents of `t` between the adjacent columns. In the above example, this is `\:+` and `\;+`. The commands `\:` and `\;` have not yet been introduced but they produce small horizontal spacing in math mode (Section 5.5.1). `*{3}{c@{\:}\:}` is an abbreviation for three repetitions of the column definition `c@{\:}\:`. `c` defines the column to be one of centered text. `\multicolumn{5}{c}` says that the next five columns are to be merged and replaced by one with centered text. The command `\dotfill` fills the column with dots.

It is possible to nest array environments:

```

\left( \left| \begin{array}{cc}
  x_{11} & x_{12} \\
  x_{21} & x_{22}
\end{array} \right| \right) \left[ \begin{array}{c}
  \left( \begin{array}{cc}
    x_{11} & x_{12} \\
    x_{21} & x_{22}
  \end{array} \right) \\
  y \\
  z
\end{array} \right]

```

The outermost array consists of one column with centered text (c). The first entry in this column is also an array, with two centered columns. This array is surrounded left and right by vertical lines with adjusted sizes.

The array environment is structurally the same as a vertical box. This means that it is treated as a single character within the surrounding environment, so that it may be coupled with other symbols and construction elements.

$$\sum_{p_1 < p_2 < \cdots < p_{n-k}}^{(1,2,\dots,n)} \Delta \frac{p_1 p_2 \cdots p_{n-k}}{p_1 p_2 \cdots p_{n-k}} \sum_{q_1 < q_2 < \cdots < q_k} \left| \begin{array}{cccc}
 a_{q_1 q_1} & a_{q_1 q_2} & \cdots & a_{q_1 q_k} \\
 a_{q_2 q_1} & a_{q_2 q_2} & \cdots & a_{q_2 q_k} \\
 \dots\dots\dots & \dots\dots\dots & \dots\dots\dots & \dots\dots\dots \\
 a_{q_k q_1} & a_{q_k q_2} & \cdots & a_{q_k q_k}
 \end{array} \right|$$

```
\[ \sum_{p_1 < p_2 < \dots < p_{n-k}}^{\{1, 2, \dots, n\}}
\Delta_{\{\begin{array}{l}
p_1 p_2 \dots p_{n-k} \\
\end{array}\}}
\sum_{\{q_1 < q_2 < \dots < q_k\}} \left| \begin{array}{l}
a_{\{q_1 q_1\}} & a_{\{q_1 q_2\}} & \dots & a_{\{q_1 q_k\}} \\
a_{\{q_2 q_1\}} & a_{\{q_2 q_2\}} & \dots & a_{\{q_2 q_k\}} \\
\multicolumn{4}{c}{\dots} \\
a_{\{q_k q_1\}} & a_{\{q_k q_2\}} & \dots & a_{\{q_k q_k\}}
\end{array} \right| \]
```

In this example, an array environment is used as an index on the Δ . However, the indices appear too large with respect to the rest of the formula. Section 5.4.6 presents a better solution for array indices.

As for all table environments, an optional vertical positioning parameter `b` or `t` may be included with the array environment. The syntax and results are described in Sections 4.7.3 and 4.8.1. This argument is included only if the array is to be positioned vertically relative to its top or bottom line rather than its center.

```
\[ x - \begin{array}{c}
a_1 \\
\vdots \\
a_n
\end{array} - u - v \quad \begin{array}{c}
10 \\
12 \\
-120
\end{array}
\begin{array}{c}
x - \\
a_n
\end{array} \begin{array}{c}
u - v \\
u + v
\end{array} \begin{array}{c}
10 \\
12 \\
-120
\end{array} \]
```

We suggest that the user try to deduce how the various arrays are structured with the help of the generating text on the right.

Exercise 5.13: The solution for the system of equations

$$F(x, y) = 0 \quad \text{and} \quad \begin{vmatrix} F''_{xx} & F''_{xy} & F'_x \\ F''_{yx} & F''_{yy} & F'_y \\ F'_x & F'_y & 0 \end{vmatrix} = 0$$

yields the coordinates for the possible inflection points of $F(x, y) = 0$.
Note: the above displayed formula consists of two sub-formulas, between which the word ‘and’ plus extra spacing of amount `\quad` are inserted. Instead of enclosing the array environment within size-adjusted vertical lines with `\left|... \right|`, one may use a formatting argument `{|...|}` (Section 4.8.1) to produce the vertical lines. Such a structure is called a determinant in mathematics.

Exercise 5.14: The shortest distance between two straight lines represented by the equations

$$\frac{x - x_1}{l_1} = \frac{y - y_1}{m_1} = \frac{z - z_1}{n_1} \quad \text{and} \quad \frac{x - x_2}{l_2} = \frac{y - y_2}{m_2} = \frac{z - z_2}{n_2}$$

is given by the expression

$$\pm \frac{\begin{vmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \end{vmatrix}}{\sqrt{\begin{vmatrix} l_1 & m_1 \\ l_2 & m_2 \end{vmatrix}^2 + \begin{vmatrix} m_1 & n_1 \\ m_2 & n_2 \end{vmatrix}^2 + \begin{vmatrix} n_1 & l_1 \\ n_2 & l_2 \end{vmatrix}^2}}$$

If the numerator is zero, the two lines meet somewhere.

Note: we do not recommend using `{|cc|}` in the formatting argument of the three determinants in the denominator under the root sign. Here the `\left|... \right|` pair should be applied. Try out both possibilities for yourself and compare the results.

Exercise 5.15: *Laurent expansion:* using $c_n = \frac{1}{2\pi i} \oint (\zeta - a)^{-n-1} f(\zeta) d\zeta$, for every function $f(z)$ the following representation is valid ($n = 0, \pm 1, \pm 2, \dots$)

$$f(x) = \sum_{n=-\infty}^{+\infty} c_n (z - a)^n = \begin{cases} c_0 + c_1(z - a) + c_2(z - a)^2 + \dots + c_n(z - a)^n + \dots \\ \quad \quad \quad + c_{-1}(z - a)^{-1} + c_{-2}(z - a)^{-2} + \dots \\ \quad \quad \quad \quad \quad \quad + c_{-n}(z - a)^{-n} + \dots \end{cases}$$

Tip: the right-hand side of the equation can be created with an array environment consisting of only one column. What is its formatting argument?

5.4.4 Lines above and below formulas

The commands

`\overline{sub-form}` and `\underline{sub-form}`

can be used to draw lines over or under a formula or sub-formula. They may be nested to any level:

$$\overline{\overline{\overline{a^2 + xy + z}}} \quad \backslash[\quad \overline{\overline{\overline{a^2 + \underline{\underline{\underline{xy}}}}}} \quad \backslash]$$

The command `\underline` may also be employed in normal text mode to underline text, whereas `\overline` is allowed only in math mode.

Exactly analogous to these are the two commands

`\overbrace{sub-form}` and `\underbrace{sub-form}`

which put horizontal curly braces above or below the sub-formula.

$$\overbrace{a + b + c}^d \quad \overbrace{a + \underbrace{b+c}^d} + d$$

In displayed formulas, these commands may have exponents or indices attached to them. The (raised) exponent is set above the *overbrace* while the (lowered) index is placed below the *underbrace*.

$$\underbrace{a + \overbrace{b + \cdots + y}^{123} + z}_{\alpha\beta\gamma} \quad \backslash [\quad \underbrace{a + \overbrace{b + \cdots + y}^{\{123\}} + z}_{\{\alpha\beta\gamma\}} \quad \backslash]$$

Exercise 5.16: The total number of permutations of n elements taken m at a time (symbol P_n^m) is

$$P_n^m = \prod_{i=0}^{m-1} (n-i) = \underbrace{n(n-1)(n-2)\dots(n-m+1)}_{\text{total of } m \text{ factors}} = \frac{n!}{(n-m)!}$$

5.4.5 Stacked symbols

The command

$$\backslash\text{stackrel}\{upper_sym\}\{lower_sym\}$$

places the symbol *upper_sym* centered on top of *lower_sym*, whereby the symbol on top is set in a smaller typeface.

$$\vec{x} \stackrel{\text{def}}{=} (x_1, \dots, x_n) \quad \$ \backslash\text{vec}\{x\} \backslash\text{stackrel}\{\mathrm{def}\}\{=\} (x_1, \dots, x_n) \\ A \stackrel{\alpha'}{\longrightarrow} B \stackrel{\beta'}{\longrightarrow} C \quad \$ A \backslash\text{stackrel}\{\alpha'\}\{\longrightarrow\} B \dots \$$$

By making use of math font size commands (Section 5.5.2) it is possible to construct new symbols with this command. For example, some authors prefer to have the \leq symbol appear as $\stackrel{<}{\leq}$ instead of \leq . This is achieved by combining $<$ and $=$ with $\backslash\text{stackrel}\{\text{<}\}\{=\}$. If the command < were omitted, the symbol would be printed as $\stackrel{<}{\leq}$.

5.4.6 Additional T_EX commands for math

The T_EX math commands atop and choose are useful additions to the set of commands and may be applied within any L^AT_EX document. (In fact, all T_EX math commands except eqalign , eqalignno , and leqalignno may be used in a L^AT_EX manuscript.) Their syntax is

$$\{top\} \backslash\text{atop} \{bottom\} \\ \{top\} \backslash\text{choose} \{bottom\}$$

Both commands produce a structure that looks like a fraction without the dividing line. With the choose command, this structure is also enclosed within round brackets (in mathematics this is called a *binomial coefficient*).

$$\binom{n+1}{k} = \binom{n}{k} + \binom{n}{k-1} \quad \backslash [\quad \{n+1\} \backslash\text{choose} \{k\} = \{n\} \backslash\text{choose} \{k\} + \{n\} \backslash\text{choose} \{k-1\} \quad \backslash]$$

$$\prod_{j \geq 0} \left(\sum_{k \geq 0} a_{jk} z^k \right) = \sum_{n \geq 0} z^n \left(\sum_{\substack{k_0, k_1, \dots \geq 0 \\ k_0 + k_1 + \dots = n}} a_{0k_0} a_{1k_1} \dots \right)$$

`\[\prod_{j \ge 0} \left(\sum_{k \ge 0} a_{jk} z^k \right) = \sum_{n \ge 0} z^n \left(\sum_{\substack{k_0, k_1, \dots \ge 0 \\ k_0 + k_1 + \dots = n}} a_{0k_0} a_{1k_1} \dots \right) \]`

Similar structures can be generated with the \LaTeX environments

`\begin{array}{c} upper_line \\ lower_line \end{array} (atop)`
`\left(\begin{array}{c} upper \\ lower \end{array}\right) (choose)`

The difference between these array structures and those of the \TeX commands is that the former are always printed in the size and style of normal text formulas, whereas the latter will have varying sizes depending on where they appear within the formula.

For comparison

$\Delta \begin{array}{c} p_1 p_2 \cdots p_{n-k} \\ p_1 p_2 \cdots p_{n-k} \end{array}$	The index array is produced using <code>\atop</code>
$\Delta \begin{array}{c} p_1 p_2 \cdots p_{n-k} \\ p_1 p_2 \cdots p_{n-k} \end{array}$	The index array is produced using <code>\array</code>

The above \TeX commands may also be employed to produce small matrices within text formulas, such as $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ or $\begin{pmatrix} a & b & c \\ l & m & n \end{pmatrix}$. Here the first matrix was typed in with

`\{1\,0\choose0\,1\}`

and the second with

`\left(\{a\atop l\}{b\atop m}{c\atop n}\right)`

!

The syntax of these Plain \TeX commands is radically different from that normally used by \LaTeX . See page 189 for a way to correct this.

5.4.7 Multiline equations

A multiline equation is one that is developed over several lines in which the relation symbols (for example, = or \leq) in each line are all vertically aligned with each other. For this purpose, the environments

`\begin{eqnarray} line.1 \dots \ line.n \end{eqnarray}`
`\begin{eqnarray*} line.1 \dots \ line.n \end{eqnarray*}`

are used to set several lines of formulas or equations in displayed math mode. The individual lines of the equation or formula are separated from one another by `\`. Each entry line has the form

left_formula & *mid_formula* & *right_formula* \\

When printed, all the *left_formulas* appear right justified in a left column, the *right_formulas* left justified in a right column, and the *mid_formulas* centered in between. The column separation character & designates the various parts of the formula. Normally the *mid_formula* is a single math character, the relation operator mentioned above. The individual lines thus have the same behavior as they would in a `\begin{array}{rcl}... \end{array}` environment.

!

The difference between the `array` and `eqnarray` environments is that in the latter the lines are set as displayed formulas. This means that for those symbols listed in Section 5.3.7 the larger form will be selected, and that the numerator and denominator of fractions will be in normal size. On the other hand, for the `array` environment the column entries will be set as text formulas, the smaller form of these symbols will be chosen and the parts of the fraction will appear in a smaller type size.

The standard form of the `eqnarray` environment adds an automatic sequential equation number, which is missing in the `*-form`. To suppress the equation number for a single line in the standard form, add the command `\nonumber` just before the line termination `\\`.

The equation numbers may be referred to in the text with the command `\ref{name}` once the keyword *name* has been assigned to the equation number with the `\label{name}` command somewhere in the line of the equation. See Section 9.2.1 for more details.

Examples:

$$\begin{aligned} (x+y)(x-y) &= x^2 - xy + xy - y^2 \\ &= x^2 - y^2 \end{aligned} \tag{5.4}$$

$$(x+y)^2 = x^2 + 2xy + y^2 \tag{5.5}$$

```
\begin{eqnarray}
(x+y)(x-y) & & = & & x^2 - xy + xy - y^2 \ \nonumber \\
& & & & = & & x^2 - y^2 \\
(x+y)^2 & & = & & x^2 + 2xy + y^2 \\
\end{eqnarray}
```

$$\begin{aligned} x_n u_1 + \cdots + x_{n+t-1} u_t &= x_n u_1 + (ax_n + c)u_2 + \cdots \\ &+ \left(a^{t-1} x_n + c(a^{t-2} + \cdots + 1) \right) u_t \\ &= (u_1 + au_2 + \cdots + a^{t-1} u_t) x_n + h(u_1, \dots, u_t) \end{aligned}$$

```
\begin{eqnarray*}
x_{nu_1} + \cdots + x_{n+t-1} u_t & & = & & x_{nu_1} + (ax_n + c)u_2 + \\
& & & & \cdots \\
& & + & & \left( a^{t-1} x_n + c(a^{t-2} + \cdots + 1) \right) u_t \\
& & = & & (u_1 + au_2 + \cdots + a^{t-1} u_t) x_n + h(u_1, \dots, u_t) \\
\end{eqnarray*}
```

The second example requires some explanation. In the second line there is a `\left(...\right)` pair for the automatic sizing of the `()`. Such a pair may only appear within a single line; that is, it may *not* be broken by the `\` line terminator! If automatic bracket sizing is to occur in a multiline equation, it may only be found within a single line.

If bracket pairs must appear on different lines, one can try using the construction `\left(...\right.\ \ \left....\right)`. In the first line, the `\left(` is paired with the *invisible* bracket `\right.`, while the second begins with the invisible `\left.` which is paired with the closing `\right)`. However, this will only work satisfactorily if both parts of the equation have roughly the same height so that the two automatic sizings yield much the same results. Section 5.5.3 describes how to select bracket sizes manually in the event that the automatic method fails.

The `+` sign at the beginning of the second line also requires a remark. The signs `+` and `-` have two meanings in mathematics: between two math quantities they act as a coupling (*binary operator*), but coming before a math symbol they serve as a sign designation (positive or negative). \LaTeX stresses this difference by inserting different spacing in the two cases (for example, compare `+b` with `a + b`).

$y = a + b + c + d$	If a long formula is broken into several lines and one of them begins with <code>+</code> or <code>-</code> , \LaTeX regards it as a sign designation and moves it closer to the next character.
$+ e + f + g$	
$+ h + i + j$	

The solution is to introduce an *invisible* character of *zero* width at the beginning of such a line. This may be the empty structure `{}`. Compare the effects of `&& +e+f+g` and `&&{}+h+i+j` in the above equation.

Since the extra spacing is always inserted between `+` and an opening parenthesis `(`, it was not necessary to give the `{}` at the beginning of the second line of the `eqnarray*` example on the previous page.

Occasionally it is better to break long multiline equations as follows:

$w + x + y + z =$	that is, the second and subsequent lines are not aligned with the equals sign but are left justified with a certain indentation from the beginning of the first line.
$a + b + c + d + e + f +$	
$g + h + i + j + k + l$	

<code>\begin{eqnarray*}</code>	The command <code>\lefteqn{w+x+y+z =}</code> <code>\</code> in the first line has the effect that the contents of the argument are indeed printed out, but that \LaTeX considers them to have <i>zero</i> width. The left-hand column then contains only intercolumn spacing, which produces the indentation for the rest of the lines.
<code>\lefteqn{w+x+y+z = } \</code>	
<code>& & a+b+c+d+e+f+ \</code>	
<code>& & g+h+i+j+k+l</code>	
<code>\end{eqnarray*}</code>	

produces the indentation for the rest of the lines.

The indentation depth may be altered by inserting `\hspace{depth}` between the `\lefteqn{...}` and the `\` line termination. A positive value for *depth* increases the indentation, a negative value decreases it.

Exercise 5.17: The following equations are to be broken as shown:

$$\begin{aligned} \arcsin x &= -\arcsin(-x) = \frac{\pi}{2} - \arccos x = \left[\arccos \sqrt{1-x^2} \right] \\ &= \arctan \frac{x}{\sqrt{1-x^2}} = \left[\operatorname{arccot} \frac{\sqrt{1-x^2}}{x} \right] \end{aligned} \quad (5.6)$$

$$\begin{aligned} f(x+h, y+k) &= f(x, y) + \left\{ \frac{\partial f(x, y)}{\partial x} h + \frac{\partial f(x, y)}{\partial y} k \right\} \\ &+ \frac{1}{2} \left\{ \frac{\partial^2 f(x, y)}{\partial x^2} h^2 + 2 \frac{\partial^2 f(x, y)}{\partial x \partial y} kh + \frac{\partial^2 f(x, y)}{\partial y^2} k^2 \right\} \\ &+ \frac{1}{6} \{ \dots \} + \dots + \frac{1}{n!} \{ \dots \} + R_n \end{aligned} \quad (5.7)$$

Note on possible error messages:

Long formulas with many sets of logical brackets, especially deeply nested ones, will almost always contain errors at first. The cause is often brackets that have been incorrectly ordered or overlooked.

If \LaTeX produces error messages during formula processing, which the beginner is not able to interpret correctly (error messages are described in detail in Appendix C), he or she should check the bracket pairing very carefully in the formula text. Some text editors can do the search for the matching bracket, which greatly simplifies the task.

If the error is not found in this way, one can try pressing the return key at the error message in order to proceed with the processing. The resulting printout can indicate where things may have gone wrong.

Exercise 5.18: The `eqnarray` environment inserts additional spacing where the column separation character `&` appears. This is undesirable when an equation is to be broken and aligned on `+` or `-` within a long summation. For example:

The inverse function of the polynomial expansion $y = f(x) = ax + bx^2 + cx^3 + dx^4 + ex^5 + fx^6 + \dots$ ($a \neq 0$) begins with the elements

$$\begin{aligned} x = \varphi(y) &= \frac{1}{a}y - \frac{b}{a^3}y^2 + \frac{1}{a^5}(2b^2 - ac)y^3 \\ &+ \frac{1}{a^7}(5abc - z^2d - fb^3)y^4 \\ &+ \frac{1}{a^9}(6a^2bd + 3a^2c^2 + 14b^4 - a^3e - 21ab^2c)y^5 \\ &+ \frac{1}{a^{11}}(7a^3be + 7a^3cd + 84ab^3c - a^4f - \\ &28a^2b^2d - 28a^2bc^2 - 43b^5)y^6 + \dots \end{aligned}$$

Select a value for the declaration `\arraycolsep` (Section 4.8.2) such that the distance between the `+` and `-` and the break points are as near as possible to those in the rest of the formula.

5.4.8 Framed or side-by-side formulas



Displayed formulas or equations may be put into vertical boxes of appropriate width, that is, in a `\parbox` command or `minipage` environment. Within the vertical box, the formulas are horizontally centered or left justified with indentation `\mathindent` according to the selected document class option.

Vertical boxes may be positioned relative to one another just like single characters (Sections 4.7.3 and 4.7.7). In this way the user may place displayed formulas or equations side by side.

$$\alpha = f(z) \quad (5.8)$$

$$\beta = f(z^2) \quad (5.9)$$

$$\gamma = f(z^3) \quad (5.10)$$

$$x = \alpha^2 - \beta^2$$

$$y = 2\alpha\beta$$

The left-hand set of equations is set in a `\parbox` of width 4 cm, the right-hand set in one of width 2.5 cm, while this text is inside a `minipage` of width 4.5 cm.

```
\parbox{4cm}{\begin{eqnarray} \alpha &=& f(z) \dots \end{eqnarray}}
\hfill \parbox{2.5cm}{\begin{eqnarray*}
x &=& \alpha^2 - \beta^2 \\
y &=& 2\alpha\beta \end{eqnarray*}}
\hfill \begin{minipage}{4.5cm} The left-hand ... \end{minipage}
```



Vertical boxes can also be useful when equation numbers are placed in an unconventional manner. The `eqnarray` environment generates an equation number for every line, which may be suppressed with `\nonumber`. To add a vertically centered equation number to a set of equations, for example,

$$\begin{aligned} P(x) &= a_0 + a_1x + a_2x^2 + \dots + a_nx^n \\ P(-x) &= a_0 - a_1x + a_2x^2 - \dots + (-1)^n a_nx^n \end{aligned} \quad (5.11)$$

the following text may be given:

```
\parbox{10cm}{\begin{eqnarray*} ... \end{eqnarray*}} \hfill
\parbox{1cm}{\begin{eqnarray}\end{eqnarray}}
```

The actual set of equations is produced here in the `eqnarray*` environment, within a vertical box of width 10 cm, followed by an empty `eqnarray` environment in a box of width 1 cm that generates the equation number. Both boxes are vertically aligned along their center lines.



Emphasizing formulas by framing requires no new construction elements. It is sufficient to put them into an `fbox` (Section 4.7.7). Text formulas `a + b` are simply framed with `\fbox{$a+b$}`. For displayed formulas, `\displaystyle` (Section 5.5.2) must be issued, else they are set as text formulas.

$$\int_0^\infty f(x) dx \approx \sum_{i=1}^n w_i e^{x_i} f(x_i)$$

is produced with

```
\[\fbox{\displaystyle \int^{\infty}_0 f(x)\, \mathrm{d}x \dots}\]
```

An alternative method to frame displayed equations is with the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ `\boxed` command, page 270.

5.4.9 Chemical formulas and bold face in math formulas

In mathematics it is sometimes necessary to set individual characters or parts of the formula in bold face. This can be achieved simply with the math alphabet command `\mathbf` that we met in Section 5.4.2:

`\mathbf{S^{-1}TS = dg(\omega_1, \dots, \omega_n) = \Lambda}`
 produces $\mathbf{S^{-1}TS = dg(\omega_1, \dots, \omega_n) = \Lambda}$.

In this example, the entire formula has been set as the argument of `\mathbf` so that everything should be set in bold face. In fact, only numbers, lower and upper case Latin letters, and upper case Greek letters are set in **bold Roman** with `\mathbf`. Lower case Greek letters and other math symbols appear in the normal *math* font.

If only part of the formula is to be set in bold face, that part must be given as the argument of the `\mathbf` command.

`\mathbf{2\sqrt{x}/y} = z` $2\sqrt{x}/y = z$

The math font style command `\boldmath` will set all characters in bold face, with the following exceptions:

- raised and lowered symbols (exponents and indices)
- the characters `+ : ; ! ? () []`
- symbols that exist in two sizes (Section 5.3.7)

The `\boldmath` declaration may not appear in math mode. It must be called before switching to math mode or within a parbox or minipage. The countercommand `\unboldmath` resets the math fonts back to the normal ones.

$$\oint_C \mathbf{V} \, d\mathbf{r} = \oint_\Sigma \nabla \times \mathbf{V} \, d\mathbf{\sigma}$$

`\boldmath \[\oint\limits_C V`
`\, \mathrm{d}\tau = \oint\limits_\Sigma`
`\nabla\times V, d\sigma \]` `\unboldmath`

If `\boldmath` has been turned on outside the math mode, it may be temporarily turned off inside with `\mbox{\unboldmath$...$}`.

`\boldmath(P = \mbox{\unboldmathmb})\unboldmath`

yields: $\mathbf{P = mb}$. Similarly, `\boldmath` can be temporarily turned on within math mode with the structure `\mbox{\boldmath$...$}`: $W_r = \int \mathbf{M} \, d\boldsymbol{\varphi} = r^2 m \omega^2 / 2$

`\(W_r = \int \mbox{\boldmath$M}, \mathrm{d}\varphi = .. \)`

An alternative method of printing single symbols in bold face is provided by the `bm` package described on page 394.

Chemical formulas are normally set in Roman type, not in italics as for mathematical formulas. This may be brought about by setting the formula as the argument of the font command `\mathrm`:

`\mathrm{Fe_2^{2+}Cr_2O_4}` $\mathrm{Fe}_2^{2+}\mathrm{Cr}_2\mathrm{O}_4$

5.4.10 International typesetting standards



The International Standards Organization (ISO) has established the recognized conventions for typesetting mathematics, the essential elements of which are presented in an article by Beccari (1997), along with a description of how they may be realized with \LaTeX . Some of these rules have already been mentioned and demonstrated in the examples. Here are the major points.

1. Simple variables are represented by italic letters, as $a b c x y z$.
2. Vectors are written in bold face italic, as $\mathbf{B v \omega}$.
3. Tensors of 2nd order and matrices may appear in a sans serif font, as $M D I$.
4. The special numbers e, i, π , as well as the differential operator d , are to be *written in an upright font* to emphasize that they are not variables.
5. A measurement consisting of a number plus a dimension is an indivisible unit, with a smaller than normal space between them, as 5.3 km and 62 kg. The dimension is in an upright font.

Point 1 is fulfilled automatically by \LaTeX . Point 5 is easily achieved by inserting the small space `\,` command between the number and dimension, as `5.3\,km` and `62\,kg`. Using the protected space `\,` instead is very common practice among \LaTeX users, which ensures that the two parts are not split, but with regular, not small spacing: 5.3 km and 62 kg.

Point 2 is not satisfied with the `\vec` command, which produces \vec{B} . Nor does `\mathbf` help, for this yields \mathbf{B} , in an upright font. The best solution is to use the `\boldsymbol` command from the $\mathcal{A}\mathcal{M}\mathcal{S}$ package `amsbsy` (Section 12.2.1) or the `\bm` command from the `tools` package `bm` (Section B.5.4). Otherwise one must resort to defining

```
\renewcommand{\vec}[1]{\mbox{\boldmath\#1$}}
```

for a revised `\vec` command.

Similarly point 3 can be met with the `math` alphabet command `\mathsf`. However, Beccari does point out that even tensor variables should probably be italic. This is more difficult, but it can be accomplished. See example 5 on page 191.

Point 4 is the one that is most often violated, especially for the differential d . We have demonstrated it in the examples in this book and have shown how it may be achieved with the `\mathrm` `math` alphabet command. However, to simplify the application, it is recommended to create some user-defined commands, such as

```
\newcommand{\me}{\mathrm{e}}    for math e
\newcommand{\mi}{\mathrm{i}}    for math i
\newcommand{\dif}{\mathrm{d}}    for differential operator d
```

An upright π is not so easy since this is not provided in the usual math fonts.

With these new commands, the equation on page 119 is more conveniently set with

```
\[ \int^{\infty}_0 f(x)\, \dif x \approx
\sum^n_{i=1} w_i \me^{x_i} f(x_i) \]
```

5.5 Fine-tuning mathematics

5.5.1 Horizontal spacing

Even though $\text{T}_{\text{E}}\text{X}$ has a thorough knowledge of the rules of mathematical typesetting, it cannot hope to understand the mathematical meaning. For example, $y dx$ normally means the joining of the variable y with the differential operator dx , and this joining is designated by a small space between the two. However, $\text{T}_{\text{E}}\text{X}$ removes the blank in the entry `y dx` and prints ydx , the product of three variables y , d , and x . At this point, $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ needs some fine-tuning assistance. (And the d should really be upright, the `\dif` or `\mathrm{d}` of the previous section.)

Small amounts of horizontal spacing can be added in math mode with the commands

<code>\,</code>	small space	= 3/18 of a quad
<code>\:</code>	medium space	= 4/18 of a quad
<code>\;</code>	large space	= 5/18 of a quad
<code>\!</code>	negative space	= -3/18 of a quad

In the following examples, the third column contains the results without the additional horizontal spacing command.

<code>\sqrt{2}\,x</code>	$\sqrt{2}x$	$\sqrt{2}x$
<code>\sqrt{\,}\,\log x</code>	$\sqrt{\log x}$	$\sqrt{\log x}$
<code>\left(1/\sqrt{n}\,)\right)</code>	$O(1/\sqrt{n})$	$O(1/\sqrt{n})$
<code>[\,0,1)</code>	$[0,1)$	$[0,1)$
<code>\log n\,(\log\log n)^2</code>	$\log n (\log \log n)^2$	$\log n (\log \log n)^2$
<code>x^2\!/2</code>	$x^2/2$	$x^2/2$
<code>n/\!\log n</code>	$n/\log n$	$n/\log n$
<code>\Gamma_{\!2}+\Delta^{\!2}</code>	$\Gamma_2 + \Delta^2$	$\Gamma_2 + \Delta^2$
<code>R_{i\!}^j\!_{\!k}</code>	$R_i^j{}_{kl}$	$R_i^j{}_{kl}$
<code>\int_0^x\!\int_0^y</code> <code>\mathrm{d}F(u,v)</code>	$\int_0^x \int_0^y dF(u,v)$	$\int_0^x \int_0^y dF(u,v)$
<code>[\ \int\!\!\!\!\int_D</code> <code>\mathrm{d}x\, \mathrm{d}y \]</code>	$\iint_D dx dy$	$\iint_D dx dy$

Note: In the third last example $R_{i\!}^j\!_{\!k}$ is so constructed that an invisible character of zero width comes after the index of R_i , and it is this dummy character that receives the following exponent. The result is R_i^j , instead of R_i^j which is produced by `R_i^j`.

There are no hard and fast rules for applying the math spacing commands. Some candidates are the differential operator, small root signs in text formulas followed by a variable, the dividing sign $/$, and multiple integral signs. The above examples illustrate many suitable situations.

5.5.2 Selecting font size in formulas

It is possible to alter the font sizes that $\text{T}_\text{E}\text{X}$ selects for the various parts of the formula. First we must explain what sizes are available in math mode and what $\text{T}_\text{E}\text{X}$'s selection rules are.

In math mode there are four font sizes that may be chosen, their actual sizes being relative to the basic font size of the document class:

<code>\displaystyle</code>	<i>D</i>	Normal size for displayed formulas
<code>\textstyle</code>	<i>T</i>	Normal size for text formulas
<code>\scriptstyle</code>	<i>S</i>	Normal size for first sub-, superscript
<code>\scriptscriptstyle</code>	<i>SS</i>	Normal size for later sub-, superscripts

From now on we shall make use of the symbolic abbreviations *D*, *T*, *S*, and *SS*. When math mode is switched on, the active font size becomes *D* for displayed and *T* for text formulas. Their only difference lies in those symbols that appear in two sizes, plus the corresponding style of those superscripts and subscripts (Section 5.3.7). The larger symbols belong to *D*, the smaller to *T*.

Starting from these base sizes, various math elements will be set in other sizes. Once another size has been chosen for an element, it remains the active size within that element.

The table below shows the selection rules:

Active size	Fractions upper	Fractions lower	Super-, subscripts
<i>D</i>	<i>T</i>	<i>T</i>	<i>S</i>
<i>T</i>	<i>S</i>	<i>S</i>	<i>S</i>
<i>S</i>	<i>SS</i>	<i>SS</i>	<i>SS</i>
<i>SS</i>	<i>SS</i>	<i>SS</i>	<i>SS</i>

If the active size is *D*, size *T* is selected for both parts of the fraction. That is, for both numerator and denominator *T* becomes the active size. If they in turn contain further fractions, these will be set in *S*. If the active size is *D* or *T*, superscripts and subscripts (exponents and indices) appear in *S*; within them *S* is the active size and any fractions or shiftings inside them will be set in *SS*.

The $\text{T}_\text{E}\text{X}$ elements `{ \atop }` and `{ \choose }` are treated as fractions.

The active font size inside an array environment is *T*.

The smallest available math font size is *SS*. Once it has been reached, no further reduction is possible, so that all subsequent superscripts and subscripts appear in *SS* as well.

From the table one easily sees that

`\[a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4}}}} \]`

$$a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4}}}}$$

must appear as shown at the right.

Such a math structure, called a *continued fraction*, is normally printed as

$$a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4}}}} \quad \backslash [a_0 + \frac{1}{\displaystyle a_1 + \frac{1}{\displaystyle a_2 + \frac{1}{\displaystyle a_3 + \frac{1}{a_4}}}} \quad \backslash]$$

By explicitly giving the font size within each element, one makes that size active rather than relying on the internally selected size. In this example, D is chosen for each denominator. Thus the next fraction acts as though it were outermost. The `\displaystyle` command may be omitted in the last fraction. (Can you see why?)

The selection table allows one to predict precisely which math font size will be applied at any part of the formula so that an explicit specification may be made if necessary. The effects of such a choice may also be calculated for the following math elements.

In the examples below, the right-hand column shows how the formulas would appear if the math font size is not explicitly specified.

$$\frac{\frac{a}{x-y} + \frac{b}{x+y}}{1 + \frac{a-b}{a+b}} \quad \backslash [\frac{\displaystyle \frac{a}{x-y} + \displaystyle \frac{b}{x+y}}{\displaystyle 1 + \frac{a-b}{a+b}} \quad \backslash] \quad \frac{a}{x-y} + \frac{b}{x+y} \quad 1 + \frac{a-b}{a+b}$$

$$e^{-\frac{x_i-x_j}{n^i+n^j}} \quad \backslash [e^{\textstyle - \frac{x_i-x_j}{n^i+n^j}} \quad \backslash] \quad e^{-\frac{x_i-x_j}{n^i+n^j}}$$

$$\left(\begin{array}{cc} \binom{ab}{cd} & \frac{e+f}{g-h} \\ 0 & \left| \begin{array}{c} ij \\ kl \end{array} \right| \end{array} \right) \quad \backslash [\left(\begin{array}{cc} \displaystyle \binom{ab}{cd} & \displaystyle \frac{e+f}{g-h} \\ 0 & \left| \begin{array}{c} ij \\ kl \end{array} \right| \end{array} \right) \quad \backslash]$$

If an explicit size specification is to be given frequently within a document—say within every entry in an array environment—then considerable writing effort may be avoided by adding to the preamble

```
\newcommand{\D}{\displaystyle}\newcommand{\T}{\textstyle}...
```

In this way the size command may be given simply by typing `\D` or `\T`, etc.



The math font size selection rules given above are in fact a simplification. For those readers who wish to know the exact details, we now present the complete description.

For each of the four math font sizes D , T , S , SS there is a modified version D' , T' , S' , SS' . The difference is that with D , T , S , SS the superscripts (exponents) are somewhat higher than they are with D' , T' , S' , SS' . Compare the positions of the exponent 2 above and below the line: $\frac{x^2}{x^2}$. Otherwise the primed and unprimed font sizes are identical. The true selection rules are given in the table at the right.

Active size	Fractions		Super-	Sub-
	upper	lower	scripts	scripts
D	T	T'	S	S'
D'	T'	T'	S'	S'
T	S	S'	S	S'
T'	S'	S'	S'	S'
S, SS	SS	SS'	SS	SS'
S', SS'	SS'	SS'	SS'	SS'

When the font size is explicitly stated within a numerator or superscript, the unprimed version is selected; and in the denominators and subscripts, the primed fonts.

5.5.3 Manual sizing of bracket symbols

The `\left... \right` commands preceding one of the 22 bracket symbols listed in Section 5.4.1 adjust the symbol size automatically according to the height of the enclosed formula text. However, it is possible to select a size explicitly by placing one of the \TeX commands `\big`, `\Big`, `\bigg`, or `\Bigg` before the bracket symbol.

<code>none</code>	<code>()</code>	<code>[]</code>	<code>{}</code>	<code>]</code>	<code>[</code>	<code>]</code>	<code><</code>	<code>></code>	<code>/</code>	<code>\|</code>	<code>|</code>	<code>|</code>	<code>|</code>	<code>↑</code>	<code>↑</code>	<code>↓</code>	<code>↓</code>	<code>↯</code>	<code>↯</code>
<code>\big</code>	<code>()</code>	<code>[]</code>	<code>{}</code>	<code>]</code>	<code>[</code>	<code>]</code>	<code><</code>	<code>></code>	<code>/</code>	<code>\ </code>	<code> </code>	<code> </code>	<code> </code>	<code>↑</code>	<code>↑</code>	<code>↓</code>	<code>↓</code>	<code>↯</code>	<code>↯</code>
<code>\Big</code>	<code>()</code>	<code>[]</code>	<code>{}</code>	<code>]</code>	<code>[</code>	<code>]</code>	<code><</code>	<code>></code>	<code>/</code>	<code>\ </code>	<code> </code>	<code> </code>	<code> </code>	<code>↑</code>	<code>↑</code>	<code>↓</code>	<code>↓</code>	<code>↯</code>	<code>↯</code>
<code>\bigg</code>	<code>()</code>	<code>[]</code>	<code>{}</code>	<code>]</code>	<code>[</code>	<code>]</code>	<code><</code>	<code>></code>	<code>/</code>	<code>\ </code>	<code> </code>	<code> </code>	<code> </code>	<code>↑</code>	<code>↑</code>	<code>↓</code>	<code>↓</code>	<code>↯</code>	<code>↯</code>
<code>\Bigg</code>	<code>()</code>	<code>[]</code>	<code>{}</code>	<code>]</code>	<code>[</code>	<code>]</code>	<code><</code>	<code>></code>	<code>/</code>	<code>\ </code>	<code> </code>	<code> </code>	<code> </code>	<code>↑</code>	<code>↑</code>	<code>↓</code>	<code>↓</code>	<code>↯</code>	<code>↯</code>

In contrast to the `\left... \right` pairs, the explicit bracket size commands do not have to be contained within one line of a multiline formula. The opening and closing brackets may appear on different lines. This applies also to the commands described in the next paragraph.

5.5.4 Math style parameters



The mathematical style parameters listed below are set to standard values by \LaTeX . The user may alter them at any time with the `\setlength` command in the usual manner.

- `\arraycolsep`
Half the width of the intercolumn spacing for the array environment (see also Section 4.8.2).
- `\jot`
Extra vertical spacing that appears between the rows of multiline equations in the `eqnarray` and `eqnarray*` environments.
- `\mathindent`
The amount of indentation for math formulas when the document class option `fleqn` has been selected.
- `\abovedisplayskip`
The vertical spacing above displayed formulas when the left side of the formula is closer to the left margin than the end of the preceding line of text. Such a formula is designated *long*.
- `\belowdisplayskip`
The vertical spacing inserted below a *long* displayed formula.
- `\abovedisplayshortskip`
Vertical spacing added above a *short* displayed formula. This is one in which the left edge is to the right of the end of the preceding line of text.
- `\belowdisplayshortskip`
Vertical spacing inserted after a *short* displayed formula.
- `\topsep`
The above four spacings are not used with the document class option `fleqn` where instead `\topsep` is inserted above and below displayed formulas (see Section 4.4.2).

All the above parameters, except `\jot`, should be rubber lengths (Section 2.4.2).

5.5.5 Some further advice

Sometimes authors desire horizontal and vertical alignments of their formulas that just cannot be achieved using the means described so far. They should consider placing their formulas inside horizontal or vertical boxes which may then be positioned wherever they please.

Similarly the array environment together with explicit size declarations and the table construction and style elements from Sections 4.8.1 and 4.8.2 should be able to accomplish just about any horizontal and vertical alignment.

Exercise 5.19: Generate this continued fraction.

Note: in contrast to the example on page 146, the 1 here in the numerator appears left justified.

Hint: do you remember the command `\hfil`?

$$a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4}}}}$$

Exercise 5.20: Produce the following set of equations with the array environment.

$$\begin{array}{ll} \sin 2\alpha = 2 \sin \alpha \cos \alpha, & \cos 2\alpha = \cos^2 \alpha - \sin^2 \alpha \\ \sin 3\alpha = 3 \sin \alpha - 4 \sin^3 \alpha & \cos 3\alpha = 3 \cos^3 \alpha - 3 \cos \alpha \\ \sin 4\alpha = 8 \cos^3 \alpha \sin \alpha - 4 \cos \alpha \sin \alpha & \cos 4\alpha = 8 \cos^4 \alpha - 8 \cos^2 \alpha + 1 \end{array}$$

Hint: recall that `@{. . .}` expressions in the formatting field of the `array` environment can be used to insert horizontal spacing and/or mathematical text between the columns (see the first example in Section 5.4.3).

Exercise 5.21: Create the following output with the `array` environment.

Equations for the tangential plane and surface normal		
Equation for the surface	Tangential plane	Surface normal
$F(x, y, z) = 0$	$\frac{\partial F}{\partial x}(X - x) + \frac{\partial F}{\partial y}(Y - y) + \frac{\partial F}{\partial z}(Z - z) = 0$	$\frac{X - x}{\frac{\partial F}{\partial x}} = \frac{Y - y}{\frac{\partial F}{\partial y}} = \frac{Z - z}{\frac{\partial F}{\partial z}}$
$z = f(x, y)$	$Z - z = p(X - x) + q(Y - y)$	$\frac{X - x}{p} = \frac{Y - y}{q} = \frac{Z - z}{-1}$
$x = x(u, v)$ $y = y(u, v)$ $z = z(u, v)$	$\begin{vmatrix} X - x & Y - y & Z - z \\ \frac{\partial x}{\partial u} & \frac{\partial y}{\partial u} & \frac{\partial z}{\partial u} \\ \frac{\partial x}{\partial v} & \frac{\partial y}{\partial v} & \frac{\partial z}{\partial v} \end{vmatrix} = 0$	$\frac{\begin{vmatrix} X - x & Y - y \\ \frac{\partial y}{\partial u} \frac{\partial z}{\partial u} & \frac{\partial z}{\partial u} \frac{\partial x}{\partial u} \end{vmatrix}}{\begin{vmatrix} \frac{\partial y}{\partial v} \frac{\partial z}{\partial v} & \frac{\partial z}{\partial v} \frac{\partial x}{\partial v} \end{vmatrix}} = \frac{Z - z}{\begin{vmatrix} \frac{\partial x}{\partial u} \frac{\partial y}{\partial u} & \frac{\partial x}{\partial u} \frac{\partial z}{\partial u} \\ \frac{\partial x}{\partial v} \frac{\partial y}{\partial v} & \frac{\partial x}{\partial v} \frac{\partial z}{\partial v} \end{vmatrix}}$
$\mathbf{r} = \mathbf{r}(u, v)$	$(\mathbf{R} - \mathbf{r})(\mathbf{r}_1 \times \mathbf{r}_2) = 0$ <p style="text-align: center;">or $(\mathbf{R} - \mathbf{r})\mathbf{N} = 0$</p>	$\mathbf{R} = \mathbf{r} + \lambda(\mathbf{r}_1 \times \mathbf{r}_2)$ <p style="text-align: center;">or $\mathbf{R} = \mathbf{r} + \lambda\mathbf{N}$</p>
<p>In this Table x, y, z and \mathbf{r} are the coordinates and the radius vector of a fixed point M on the curve; X, Y, Z and \mathbf{R} are the coordinates and radius vector of a point on the tangential plane or surface normal with reference to M; furthermore $p = \frac{\partial z}{\partial x}$, $q = \frac{\partial z}{\partial y}$ and $\mathbf{r}_1 = \partial\mathbf{r}/\partial u$, $\mathbf{r}_2 = \partial\mathbf{r}/\partial v$.</p>		

Note: If you succeed in reproducing this mathematical table you should have no more problems with positioning formulas and their parts!

Hints for the solution:

1. Define abbreviations such as `\D` for `\displaystyle` and `\bm` for `\boldmath` and possibly even `\ba` and `\ea` for `\begin{array}` and `\end{array}`.
2. Build the table in stages. Start with the head and only proceed further when it looks reasonable. Watch out that normal text within the `array` environment must be included inside an `\mbox`.
3. Continue with the first mathematical row. Here the first entry in the second column is also an `array` environment that is aligned with the rest of the row by means of the `[t]` positioning argument. Do not forget to activate the size `\D` at the necessary places in the inner structures. Insert a possible strut (Section 4.7.6) to generate the right distance from the head. The distance to the next row can be adjusted with a length specification added to the row terminating command `\[. . .]`.

4. *After this row has been completed successfully, the next should pose no difficulties.*
5. *In the third mathematical row, both the first column and the left side of the second column consist of array environments. The third column contains three fractions whose denominators may be produced either with array or with the T_EX `{... \atop ...}` command; the fractions themselves are placed in two rows with another array environment.*
6. *The second and third columns of the last mathematical row again contain array environments. Some of the sub-formulas in this row appear in `\boldmath`. Recall that this command may only be invoked within text mode, that is, within an `\mbox`.*
7. *In the last row, all three columns of the outer array environment are merged together and the text is set within a parbox of appropriate width:*

$$\backslash multicolumn{3}{|c|}{\parbox{..}{.....}}$$

5.6 Beyond standard L^AT_EX

The typesetting elements presented in this chapter should be able to handle many of the everyday problems of mathematical composition. The American Mathematical Society, \mathcal{AMS} , which has supported T_EX from its beginning, has developed a set of packages to assist authors in composing even more complicated formulas with L^AT_EX. Known as \mathcal{AMS} -L^AT_EX, it includes many extra commands, further environments to supplement `eqnarray`, and many additional symbols. This system is presented in Chapter 12.

In any event, typesetting mathematics is a very complicated issue. It was for this reason that Donald Knuth selected the \$ sign as the switch to math mode: in the old days of movable lead type, setting mathematical formulas was an expensive business because of the extra workload it entailed. Even today, electronic typesetting is far more involved for math than for simple text.

6

Graphics Inclusion and Color

The two topics of this chapter have one thing in common: neither is handled by $\text{T}_{\text{E}}\text{X}$ at all, and thus neither by $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$. Outputting graphics files produced by other programs, or printing in color, are functions of the output device, that is, the printer, the monitor, the electronic output file, and these are controlled by the DVI driver program that converts the DVI output of $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ into the final output form. For each output type, a different set of commands is needed to switch color or to send an image.

What $\text{T}_{\text{E}}\text{X}$ does have is a way of sending special driver-specific commands to the driver by placing them in the `.dvi` file; the command to do this is even named `\special`. $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ exploits this feature to pass driver commands to the `.dvi` file, but to do so, it needs to know which driver is going to be used for the further processing.

With the advent of $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}2_{\epsilon}$, a standardized syntax was introduced, replacing the driver-specific commands that abounded with $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ 2.09 and which caused much confusion. At last the importation of external images had become a basic part of $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ usage, and was no longer an exotic, magical art. Well . . . , nearly.

It is still necessary to tell $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ which driver will be used afterwards, as an option to the `graphics` and `color` packages, but once that is done, all the driver-specific special commands are loaded from a corresponding `.def` files, which the user does not have to worry about. The top-level syntax remains the same for all types.

It is also important to realize that not all image formats can be handled by every driver. PostScript drivers for example will only accept PostScript images, and then only as *encapsulated* PostScript. Image format conversion may be required.

6.1 The graphics packages

Strictly speaking, these packages, referred to as the *graphics collection*, are extensions to the basic $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ installation. We describe them here

because of their indispensability in producing professional documents and camera-ready copy. Provided by Sebastian Rahtz and David Carlisle and many other contributors, they can be expected to be part of every \LaTeX installation. A basic manual is provided in a file named `grfguide.tex`, which may already be preprocessed to `.dvi` or some other form. Even more details on these packages and on advanced applications of PostScript to \LaTeX are to be found in the book *The \LaTeX Graphics Companion* (Goossens *et al.*, 1997).

The commands defined by these packages are the building blocks for other packages that either emulate the older driver-specific ones or provide a more comfortable syntax for these functions. As long as these other packages are based on `graphics` and `color`, they should be equally compatible with all the supported drivers.

These features are not limited to PostScript drivers. As long as a driver can support the inclusion and manipulation (scaling, rotation) of graphics, and/or the use of color, a `.def` file can be written to enable it to make use of the standardized graphics and color commands.

Driver names that may be used as options are

<code>dvipdf</code>	<code>dviwin</code> ◀◻↑	<code>pctexhp</code> ◀◻↑	<code>tcidvi</code> ◻↑
<code>dvipdfm</code>	<code>emt看</code> ◀◻↑	<code>pctexps</code>	<code>textures</code>
<code>dvips</code>	<code>oztex</code>	<code>pctexwin</code> ◀◻↑	<code>truetex</code> ◻↑
<code>dvipsone</code>	<code>pctex32</code>	<code>pdftex</code>	<code>vtex</code>

(Limited functionality: ◀no color support; ◻no scaling; ↑no rotation.)

The `xdvi` previewer (and its Windows equivalent `windvi`) work with PostScript graphics; although there is also an `xdvi` option, it is only an alias for `dvips`.

A driver option *must* be specified when loading the `graphics` and `color` packages, for example, as

```
\usepackage[dvips]{graphics,color}
```

However, it is possible to establish a default for the local configuration, as described in Section 6.1.7. It is conceivable that your installation has already done this, so it is worth doing an experiment to see if a default driver option already exists.

6.1.1 Importing external graphics

We wish to have a graphics file produced by some other program included in the document, possibly scaled to a desired size or rotated by 90°. One wants to do by computer what used to be done with scissors and glue.

There are two packages available for importing and manipulating external graphics files: the basic `graphics` package and the more extended `graphicx` one. They both offer identical functionality, differing only in their syntax.

In addition to the driver names, there are some other options that may be invoked when the packages `graphics` or `graphicx` are loaded:

`draft` does not import but places a framed box where the graphic would appear, with the file name printed inside; this speeds up the processing considerably when one is only working on the text;

`final` counteracts `draft`; needed when the `draft` option has been issued globally in `\documentclass`;

`hidescale`
leaves blank space where scaled text should be;

`hiderotate`
leaves blank space where rotated text should be; this and the option `hidescale` are useful if the previewer cannot handle scaling or rotation;

`hiresbb`
look for bounding box values in `%%HiResBoundingBox` instead of the normal `%%BoundingBox` line.

6.1.2 Importing with the `graphics` package

Package: `graphics` The basic importing command with the `graphics` package is

```
\includegraphics[llx,lly][urx,ury]{file_name}
```

where *llx*, *lly* are the coordinates of the lower left corner, and *urx*, *ury* those of the upper right corner of the *bounding box* containing the part of the picture that is to be included. In other words, they say where the scissors are to be applied. Units may be specified (like `[3cm, 2in]`) but if they are omitted, big points (bp, 72 per inch, 28.3464... per cm) are assumed. If only one optional argument is given, it is the upper right corner, and the lower left is assumed to be `[0,0]`.

If no bounding box coordinates are given, the driver will obtain them some other way, depending on the type of graphics file. For example, for the very common *encapsulated PostScript* files with extension `.eps`, the bounding box information is extracted from the graphics file itself. The figure at the right is stored in such a file and is included simply with the command



```
\includegraphics{clock}
```

(It is not necessary, nor recommended, to include the file extension `.eps` in the file name designation; \LaTeX will automatically test for all the extensions allowed by the selected driver option, something that permits greater flexibility in the source text.)

With `\includegraphics*`, the figure is clipped, so that any drawing outside the specified bounding box is suppressed. This is useful if only part of a figure is to be reproduced. It is also vital with some perverse figures that paint the whole page white!

Scaling

The graphics file in the above commands is transferred to the document in its original size. In order to rescale it, there are two commands available:

```
\scalebox{h_scale}[v_scale]{text}
```

which applies horizontal and vertical scale factors to the contents *text*; if *v_scale* is omitted, it is the same as *h_scale*;

```
\resizebox{h.length}{v.length}{text}
```

adjusts the figure to fit into the specified horizontal and vertical sizes; if either length is given as `!`, the one scale factor is used for both dimensions. A `*`-form allows *v.length* to refer to the height + depth of the box, rather than just to the height. In both cases, the contents *text* may be an `\includegraphics` command, but it may also be any arbitrary text.

Reflection

The contents of a box may be reflected horizontally with

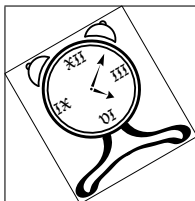
```
\reflectbox{text}
```

Rotation

Rotation of a box about the left-hand end of its baseline is done with

```
\rotatebox{angle}{text}
```

where *angle* is in degrees, and the rotation is counterclockwise.



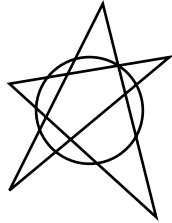
To illustrate this, we have scaled the previous clock figure to a height of 2 cm and then rotated it by 30°, using the commands

```
\rotatebox{30}{\resizebox{!}{2cm}{%
\includegraphics{clock}}}
```

For demonstration purposes, we have added framed boxes around the figure before and after the rotation. It is the inner (tilted) box that is 2 cm high, while the overall outer box is somewhat higher and broader due to its inclined contents. Without these frames the figure seems to have extraneous space above and to the left, something that can be very

puzzling even to experienced users. (The frames would not normally appear with the above commands.)

Exercise 6.1: Copy the lines at the right to a file named *demo.eps* and then include it in a \LaTeX document, with some normal text above and below it. The result should appear as:



```

%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 169 158 233 242
220 200 moveto
200 200 20 0 360 arc
170 170 moveto
230 220 lineto
170 210 lineto
225 160 lineto
205 240 lineto
170 170 lineto
stroke
showpage

```

Note: This file can be copied from the enclosed CD in the directory `\books\Kopka_and_Daly\`, where it is also available in PDF format.

6.1.3 Importing, scaling, rotating with the `graphicx` package

Package: `graphicx` If one selects the `graphicx` rather than the `graphics` package, a different interface is available for both importing and rotation, one making use of keys and values:

```
\includegraphics[key=value,...]{file_name}
```

The keys are of two types: those that take a numerical value, and those that are flags with the values `true` or `false`. Simply giving the name of a flag without a value is equivalent to setting it to `true`. Possible keys and their values are:

`scale= number`; enters the number by which the figure size should be magnified over its natural size;

`width= length`; specifies the width to which the figure should be scaled; if `height` not given, it is scaled with the same factor as the width;

`height= length`; specifies the height to which the figure should be scaled; if `width` is not given, it is scaled with the same factor as the height;

`totalheight= length`; like `height` but specifies the height plus depth of the figure; should always be used in place of `height` if the figure has been rotated;

`keepaspectratio (=true|false)`; if both `height` and `width` are specified, this flag ensures that the original height/width ratio remains unchanged; the figure will not exceed either of the given dimensions;

- `angle= number`; the angle by which the figure is to be rotated counterclockwise, in degrees; any `height` or `width` specifications coming before this key are also rotated, so that the height becomes the width, while the width becomes either the height (positive angle) or depth (negative angle);
- `origin= loc`; determines the point about which the rotation occurs; default is `bl` for bottom left corner; also possible are `c` for center, `t` for top, `r` for right, and `B` for baseline; any sensible combination, such as `tr`, is allowed;
- `draft (=true|false)`; like the `draft` package option but applied to the one graphics file; the figure is not imported, but rather a framed box of the correct size is printed containing the name of the file;
- `clip (=true|false)`; suppresses the printing of any graphic outside the bounding box;
- `bb= llx lly urx ury`; enters the coordinates of the bounding box manually, if they are missing or incorrect in the graphics file, or to be deliberately altered; the specifications are four lengths separated by blanks; units may be given, but if omitted, big points (bp) are assumed; this option should never be used with pdfTeX;
- `viewport= llx lly urx ury`; specifies the bounding box but relative to the lower left corner of the existing one; this is the preferred method for correcting the bounding box, or (with `clip`) to select only a portion of the whole figure; with pdfTeX, this option must be used rather than `bb`;
- `trim= dllx dilly durx dury`; reduces the existing bounding box by the amounts specified;
- `hiresbb (=true|false)`; like the `hiresbb` package option but applied to the one graphics file; reads bounding box information from the `%%HiResBoundingBox` line in the graphics file.

The keys are all optional; they are included as needed. Their order is not important other than that `angle` interchanges any previous `height` and `width` meanings. The sets of key/values are separated from each other by commas. It is often best to set `width` relative to the current line width `\linewidth`, say as `width=0.8\linewidth`.

With the key/value syntax, the tilted, scaled graphic on page 156 is produced with

```
\includegraphics[height=2cm,angle=30]{clock}
```

For compatibility with the `graphics` package, there also exists an `\includegraphics*` version that clips the imported figure; this is equivalent to including the key `clip`.

With the `graphicx` package, the `\rotatebox` command is similarly redefined to accept the optional key `origin`.

Exercise 6.2: Include the graphics file `demo.eps` from Exercise 6.1 scaled by a factor of 2 and rotated by 45° using the `\includegraphics` command with the `graphicx` package. Experiment with various keys, in particular with `height` and `width` together.

6.1.4 Additional graphics packages

Package: Sebastian Rahtz has provided a package `epsfig` that not only updates the earlier (L^AT_EX 2.09) version, but also re-implements Rokicki's `epsf` package by means of the `graphics` commands. This is helpful for users who are accustomed to those syntaxes. For `epsf`, this is

```
\epsfysize=y.size or \epsfxsize=x.size
\epsf[llx lly urx ury]{file_name}
```

The `epsfig` package also defines an importing command that makes use of the regular keys and values to enter its parameters:

```
\epsfig{file=file_name, key=value, ...}
```

For compatibility with some older versions, there is a `\psfig` command which is synonymous with the above.

The `epsfig` package is included in the bundle of `graphics` packages and drivers.

Package: Another extra package in the `graphics` bundle is `lscap`, by David Carlisle. This defines a `landscape` environment that prints its contents rotated 90° on a page for itself. Head and footlines remain as normal. This is intended primarily for inserting figures that are in landscape mode, that is, wider than they are high.

Package: The `rotating` package by Sebastian Rahtz and Leonor Barroca tries to make the interface for rotation somewhat simpler. It defines

```
\begin{sideways} text \end{sideways}
\begin{turn}{angle} text \end{turn}
\begin{rotate}{angle} text \end{rotate}
\turnbox{angle}{text}
```

where `sideways` rotates `text` by 90° , `turn` by an arbitrary angle. The environment `rotate` and command `turnbox` are equivalent: they rotate but in a box of zero size, so that the contents overlap the surroundings.

This package is not part of the `graphics` bundle and must be obtained separately.

6.1.5 Superimposing images

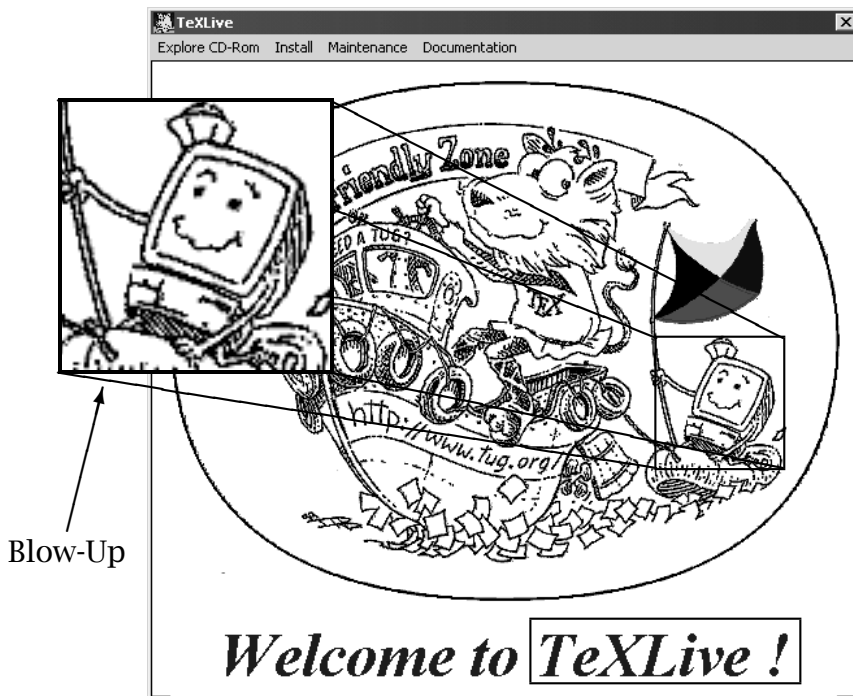


Figure 6.1: An embellished image file

!

Sometimes it is desired to superimpose one image file over part of another, say to add an inset in a corner. Or one may want to add text elements, or even lines and arrows pointing to some feature in the image. One might even want to make some area of the image into a link to another document. The `picture` environment described in Section 13.1 can be used to allow exact placement of such objects.

For example, in the figure on this page, we embellish the TeXLive welcome image from Figure B.1 on page 383 by adding a blow-up of a small section, pointing a labeled arrow to it, and making the area around the text ‘TeXLive!’ into a link. We do this with the following input:

```

\setlength{\unitlength}{0.01\linewidth}
\setlength{\fboxsep}{0pt}
\setlength{\fboxrule}{1.5pt}
\begin{picture}(80,80)
\thicklines
\put(0,0){\includegraphics[width=.8\linewidth]{texlive}}
\put(57,26){\framebox(14.2,14.6){}}
\drawline(57,26)(-10,36.7)

```

```

\drawline(71.2,26)(20.5,36.7)
\drawline(71.2,40.6)(20.5,67.2)
\drawline(57,40.6)(-10,67.2)
\put(-10,37){\fbox{\includegraphics[width=.3\linewidth,
viewport=390 180 490 280,clip]{texlive}}}
\put(-9,19){\vector(1,4){4}}
\put(-9,18){\makebox(0,0)[t]{\large Blow-Up}}
\put(43,2){\hyperlink{info}{\makebox(30,7){}}}
\end{picture}

```

Here the unit length for the `picture` placement has been set to 1/100 of the current line width `\linewidth`, so we can conveniently use 100 units for the full width. The `picture` environment reserves a space of 80×80 units; the image file `texlive` is placed at the lower left corner (location 0,0) and set to a width of 80% of `\linewidth`. We then draw a framed box around a portion of this image, and then add that portion as a second image (selected with `viewport` and clipped) as a blow-up. The `\drawline` commands (from the `epic` package) join the corners of the original and blown-up areas. The order here is important since later images overwrite the earlier ones. Then we add an arrow (`\vector`) and the text 'Blow-up' (with `\makebox`). Finally, the `\hyperlink` command from the `hyperref` package turns the 30×7 unit area around the text '*TeXLive!*' into a active link to the target named `info`.

One can also place objects outside of the reserved `picture` area, so arrows could be added pointing from the main text to some part of an image. This is more appropriate for the production of slides (Chapter 15) where one wants rigid control over the relative locations of graphics and text.

6.1.6 How importation can go wrong



In order to understand better what can go wrong when a graphics file is imported, and to know what to do about it, it is important to realize how the interplay between \LaTeX and the driver program functions.

\LaTeX has no idea what is in the graphics file; for it, the figure is simply a box of a given height, width, and depth, as indeed are all the characters that \LaTeX processes. The information on the graphic's natural size is somehow obtained, either by information in the graphics file itself, or through the optional entries in the `\includegraphics` command or equivalent. After scaling and rotating, \LaTeX knows the final size that it must reserve in the output text for the figure.

What is then written to the `.dvi` file is the name of the graphics file and information on how it should be transformed. Just how this information is coded depends on the graphics driver selected. When the printer driver program processes the `.dvi` file, it interprets these special instructions, reads in the specified graphics file, performs the transformations, and places the result where \LaTeX has said it should go. The end result is that the area inside the designated bounding box coincides with the box that \LaTeX has reserved for it. If the bounding box information is incorrect, the figure is obviously going to be misplaced.

PostScript output

Graphics inclusion was originally developed for PostScript graphics adhering to the *encapsulated* specification that was designed to allow PostScript code to be included within another PostScript file. Tomas Rokicki and his `dvips` driver broke the ground in this field and thus established the standards. It is for that reason that we place so much emphasis on PostScript graphics here. Encapsulated PostScript files may not contain any commands that reset the whole graphics page, and furthermore, they must contain a comment line of the form

```
%%BoundingBox: llx lly urx ury
```

giving the coordinates of the lower left and upper right corners of the bounding box. The units are never specified, always being big points.

PDF output

Today PDF is an important alternative to PostScript, and the `pdfTeX` program (Section 10.2.3) is the most convenient way to produce it with \LaTeX . However, `pdfTeX` is not only a replacement for the classical \TeX program, producing identical output, it also combines the functionality of a DVI-to-PDF driver. Thus no intermediate `.dvi` file is generated at all, with the `.pdf` file being generated directly from the \LaTeX source file in one operation. This has consequences for graphics inclusion with `pdfTeX`. First of all, the number of allowed graphics formats is increased: images may be PNG (`.png` files), JPEG (`.jpg` or `.jpeg` files), TIFF (`.tif` or `.tiff` files) or even a single image in a one-page PDF file. Ironically, PostScript images are absolutely out! Secondly, the concept of bounding box does not really apply to these formats, since they have a natural size anyway. The `viewport` option should therefore be used to make a cutout from the original rather than `bb`.

An alternative method of obtaining PDF output is to employ the true DVI-to-PDF driver, `dvipdfm`, written by Mark A. Wicks. In this case, a `.dvi` file is produced as usual (with the graphics option `dvipdfm`), and then the PDF output is generated with this conversion program. The same set of graphics formats is allowed as for `pdfTeX`, for much the same reasons.

The third method would be to generate DVI, then PostScript, and then convert it to PDF. As far as the graphics are concerned, this is the same as PostScript.

Having pointed out how the importation takes place, we can now discuss what can go wrong along this chain of processes.

Problems with importation: pdfTeX

The single most common error when importing a graphics file with `pdfTeX` is that it does not exist in one of the permitted formats. Many users who are used to using classical \TeX with PostScript simply switch to `pdfTeX` and are astonished to get the error message:

```
! LaTeX Error: Unknown graphics extension: .eps.
```

As explained above, `pdfTeX` cannot handle PostScript files, so the graphics must be converted to, or regenerated in, another format.

The above error message will appear only if one has specified the full name of the graphics file including the extension `.eps`. If the extension is absent, which we recommend, the error message will report that the file cannot be found. This means that it cannot be found with any of the allowed extensions. It might very well be that it exists with the extension `.eps`, but since that is not allowed for pdf \TeX , it will not be sought.

To maintain flexibility, one can have the same graphics file available both as an `.eps` and as a `.pdf` file. Leaving the extension off in the `\includegraphics` command means one does not need to make any changes to the file name when switching between regular \TeX and pdf \TeX .

Problems with importation: PostScript

The most common problems encountered when importing encapsulated PostScript files are listed here.

No bounding box. If the bounding box information is totally missing from the graphics file, L \TeX issues the error message

```
! LaTeX Error: Cannot determine size of graphic
in ... (no BoundingBox).
```

The solution is to determine the bounding box coordinates somehow (see next point) and to include them, either in the `\includegraphics` command, or by editing the graphics file itself. However, if there really is no bounding box information in the file, it is unlikely to conform to the encapsulated standard and will cause other problems.

The placement is incorrect. Both L \TeX and the driver process without error messages, but the figure is either displaced from the expected position, or is far too small.

Most likely the bounding box information is incorrect. Many applications that produce PostScript files are too lazy to calculate the true bounding box, or they think they are generating a whole page with a figure somewhere in the middle. In either case, the bounding box corresponds to the full page even though the printed figure occupies only a portion of it.

Find the true bounding box by one of the following methods:

1. Print the figure, mark the lower left and upper right corners of the box containing the figure, and measure their distances from the left and bottom edges. Enter these distances in the `\includegraphics` command, or edit the PostScript file. In the latter case, convert to big points.

Difficulties with this are that some encapsulated PostScript files cannot be printed on their own, and that the left and bottom

edges of the paper need not be the exact lines from which the printer really measures.

2. Include the figure in a short \LaTeX file such as

```
\setlength{\fboxsep}{-\fboxrule}
\fbox{\includegraphics{test.eps}}
```

and print the output. The apparent bounding box appears as a framed box. Measure the true bounding box relative to the left and bottom edges of the apparent one, and enter the values in the `\includegraphics` command with the `viewport=` key. If necessary, scale the figure down to fit on the page, but then remember to increase the measurements by the same scale factor.

3. Use the GhostView program to fix up the bounding box, either automatically or manually. This is the most convenient method if you have this utility for viewing and manipulating PostScript files.

Immovable graphic. It does not shift, nor scale nor rotate, no matter what is specified. In this case, it violates the encapsulated PostScript rules and contains some global plotting commands. Graphics produced by word processing programs are notorious for this. Often the offending command is `setpagedevice`.

There is little that can be done to correct this, other than trying to regenerate the graphics file with an option for encapsulated PostScript. Judicious editing can remove the troublesome lines, but this could result in the file becoming totally unreadable.

6.1.7 Configuring graphics importation



Although the graphics syntax has been standardized, and most of the driver-specific coding hidden in the `.def` files, there are still a number of items that must be set up for any particular installation and operating system. These are most conveniently placed in the local configuration file `graphics.cfg` which is read in if it is present.

Many installations come with a ready-made configuration file, so there may not be any need to make up your own. On the other hand, you may want to edit or replace it for your own purposes.

Default driver

The choice of driver option must always be given, but a local default can be specified in the configuration file. For example, if `dvi ps` is the standard graphics driver, you may add


```
\ExecuteOptions{dvips}
```

to `graphics.cfg` and you do not need to give the option `dvips` when loading `graphics` or `graphicx`. You may still specify any other graphics driver option if you wish.

Many supplied configuration files go further and determine whether pdf \TeX is activated or not; if so, the default graphics option is set to `pdftex`, otherwise to `dvips`.

The rest of the configuring commands in this section can be issued either in the `graphics.cfg` file, or in the document.

Search path for graphics files

One can specify the directories where \LaTeX is to look for graphics files with

```
\graphicspath{dir_list}
```

where *dir_list* is a list of directory names, each enclosed in brackets `{ }`, with no other separator. The syntax of the local operating system must be used. Without this command, \LaTeX searches for graphics files in the same directories as for all other \TeX files. Example,

```
\graphicspath{{figs/}{eps/}}      for Unix, DOS, Windows
\graphicspath{{:figs:}{:eps:}}    for Macintosh
\graphicspath{{[.figs]}{[.eps]}}  for VMS
```

Note: The Unix syntax works even with DOS and Windows, since the normal backslash in the directory names must be replaced by a slash `/` to avoid looking like a command name.

Default extensions

A list of default extensions for the graphics files can be defined with

```
\DeclareGraphicsExtensions{ext_list}
```

This means that only the root name of the file must be given and \LaTeX will attempt to find it by attaching all the possible extensions. For PostScript drivers, the *ext_list* is usually set to `.eps`, `.ps`. At our installation, we also include the non-standard extension `.psc`. Note that the above command does not add to the list of extensions but rewrites it anew; if you wish to add to the list, you must include all the allowed extensions in the one declaration.

Graphics types

Defining the extensions is only part of the task: one must also associate each extension with a graphics type so that \LaTeX knows how to process it. PostScript recognizes only one type, `eps`, encapsulated PostScript, but there do exist other types such as `bmp` and `pcx` for other drivers. For the non-standard `.psc` extension above, we must also give

```
\DeclareGraphicsRule{.psc}{eps}{}{}
```

to inform \LaTeX that this extension belongs to type `eps`. The other two (empty) arguments specify that the bounding box information is to be read from the file itself, and that no other program needs to be applied to the file.

Compressing graphics files

Since PostScript files are often extremely large, it makes sense to try to compress them with either the `zip` or `gzip` programs. In such a case, the `.eps` file is replaced by a file with extension `.zip`, or `.eps.gz`, or `.eps-gz`. Two problems now arise: first, \LaTeX cannot read such files to obtain the bounding box information, and secondly, the driver needs to unpack such a file to include it in the final output. This can be accomplished with, for example,

```
\DeclareGraphicsRule{.eps.gz}{eps}{.eps.bb}{'gunzip -c #1}
```

which establishes the graphics type as `eps`, with the bounding box information in the file of the same name and extension `.eps.bb`, and that the operating system command `gunzip -c` must be applied to the file (represented as `#1`). The single quote `'` is required to indicate a system command. The `%%BoundingBox` line of the original file must be copied and stored in the `.eps.bb` file.

Such decompression rules are system dependent and thus need to be configured for the local installation. For example, under the VMS operating system, the `gzip` program produces files with extension `.eps-gz` and decompression is performed with `gzip -d` rather than with `gunzip`. The corresponding rule becomes

```
\DeclareGraphicsRule{.eps-gz}{eps}{.bb}{'gzip -d -c #1}
```

6.2 Adding color

The `color` package accepts the same driver options listed on page 154 for the `graphics` package. In addition, it also recognizes the options:

`monochrome`

to convert all color commands to black and white, for previewers that cannot handle color;

`dvipsnames`

makes the named color model of `dvips` (Section 6.2.1) available to other drivers;

`nodvipsnames`

disables the named model for `dvips`, to save memory;

`usenames`

loads all the named colors as defined ones; again, see Section 6.2.1 for details.



A local configuration file `color.cfg` can be set up in the same way as for the `graphics` package. The default driver option is specified in exactly the same way as in Section 6.1.7.

Colors are specified either by a defined name, or by the form

```
[model] {specs}
```

where *model* is one of `rgb` (red, green, blue), `cmk` (cyan, magenta, yellow, black), `gray`, or `named`. The *specs* is a list of numbers from 0 to 1 giving the strengths of the components in the model. Thus `[rgb]{1,0,0}` defines red, `[cmk]{0,0,1,0}` yellow. The `gray` model takes only one number. The `named` model accesses colors by internal names that were originally built into the `dvips` driver, but which may now be used by some other drivers too. This model is described in Section 6.2.1.

A color can be defined with

```
\definecolor{name}{model}{specs}
```

and then the *name* may be used in all the following color commands. Certain colors are automatically predefined for all drivers: `red`, `green`, `blue`, `yellow`, `cyan`, `magenta`, `black`, `white`.

In the following color commands, *colspec* is either the name of a defined color, like `{blue}`, or `[model]{spec}`, like `[rgb]{0,1,0}`.

`\pagecolor colspec` sets the background color for the current and following pages;

`\color colspec` is a declaration to switch to setting text in the given color;

`\textcolor colspec{text}` sets the text of its argument in the given color;

`\colorbox colspec{text}` sets its argument in a box with the given color as background;

`\fcolorbox colspec1 colspec2{text}` like `\colorbox`, with a frame of *colspec1* around a box of background color *colspec2*; the two specifications must either both be defined ones, or both use the same model, which is given only once; for example, `\fcolorbox{red}{green}{Text}` sets ‘Text’ in the current text color on a green background with a red frame;

`\normalcolor` switches to the color that was active at the end of the preamble. Thus placing a `\color` command in the preamble can change the standard color for the whole document. This is the equivalent to `\normalfont` for font selection.

Normally one would try to define all the colors needed as names for the *colspec* entries. This simplifies changing the color definition everywhere should fine-tuning be required after the initial printed results are seen. The same color definition can produce quite different effects on different printers. Even the display on the monitor is no reliable guide as to how the output will appear on paper.

6.2.1 The named color model

One very useful color model is called named and is based on the 68 predefined internal colors of the `dvips` PostScript driver. Sample names are `BurntOrange` or `DarkOrchid`. This model can be activated for other drivers with the option `dvipsnames`, in which case one can define colors as, for example

```
\definecolor{titlecol}{named}{DarkOrchid}
```

The color `titlecol` can then be used as `colspec` in the various color commands.

The named colors can be defined with their own names if one invokes the option `usenames`, which effectively declares

```
\definecolor{BurntOrange}{named}{BurntOrange}
```

and so on, for all 68 colors.

It is possible to generate a palette of the named colors by processing the following short \LaTeX file and sending the output to the desired printer.

```
\documentclass[12pt,a4paper]{article}
\usepackage[dvipsnames]{color}
\usepackage{multicol}
\pagestyle{empty}
\setlength{\oddsidemargin}{0pt}
\setlength{\textwidth}{16cm}
\setlength{\textheight}{22cm}
\setlength{\parindent}{0pt}
\setlength{\parskip}{0pt}

\begin{document}
\renewcommand*{\DefineNamedColor}[4]{%
  \textcolor[named]{#2}{\rule{7mm}{7mm}}\quad
  \texttt{#2}\strut\}

\begin{center}\Large Named colors in \texttt{dvipsnam.def}
\end{center}
\begin{multicols}{3}
\input{dvipsnam.def}
\end{multicols}
\end{document}
```

Remember, each printer can reproduce the colors differently, so it is important to test this table with every color printer that might be used.

Exercise 6.3: Copy the above lines to a file named *palette.tex* or copy it from the enclosed CD from `\books\Kopka_and_DaLy`. Process it and view the output on a color monitor or send it to a color printer.

7

Floating tables and figures

Whether a figure is imported with `\includegraphics` (Chapter 6) or produced with the `picture` environment of Chapter 13, it is inserted in the text where the drawing or importing commands are issued, coming between the previous and following texts. This can present the same difficulties as for tables, described in Section 4.8.5: if the figure is so high that it no longer fits on the current page, that page is prematurely terminated and the figure is placed at the top of the next page, with too much empty space left on the original page.

In Section 4.8.5 we mention how this problem is solved for tables. Here we now give a complete description of the *float* procedures that apply to both figures and tables.

7.1 Float placement

\LaTeX does make it possible to *float* figures and tables, together with their headlines and captions, to an appropriate location without interrupting the text. This is invoked with the environments

```
\begin{figure}[where] figure \end{figure}
\begin{figure*}[where] figure \end{figure*}
\begin{table}[where] table \end{table}
\begin{table*}[where] table \end{table*}
```

The ***-forms apply only to the two-column page format and insert the figure or table across both columns instead of the normal single column. They function exactly the same as the standard forms when the page format is single column.

In the above syntax, *figure* and *table* are the texts for the contents of the float, either a `picture` or `tabular` environment, or an `\includegraphics` command, together with a possible `\caption` command, as described later in Section 7.4.

The argument *where* specifies the allowed locations for the figure or table. There are several possibilities so that *where* consists of from zero to four letters with the following meanings:

- h *here*: the float may appear at that point in the text where the environment is typed in; this is not permitted for the *-form; see also the `here` package and the `H` parameter, page 178;
- t *top*: the float may appear at the top of the current page, provided there is enough room for both it and the previous text; if this is not the case, it is added at the top of the next page; the subsequent text continues on the current page until the next normal page break; (for two-column format, read *column* in place of *page*);
- b *bottom*: the float may be placed at the bottom of the page; the subsequent text continues until the room left on the current page is just enough for the float; if there is already insufficient room, the float will be put at the bottom of the next page; this is not permitted for the *-form;
- p *page*: the float may be put on a special page (or column) containing only figures and/or tables;
- ! used together with any combination of the other letters, suspends all the spacing and number restrictions described in Section 7.3.

The argument values may be combined to allow several possibilities. If none is given, \LaTeX assumes the standard combination `tbp`.

The placement arguments permit certain possibilities for locating the float, but the actual insertion takes place *at the earliest possible point* in accordance with the following rules:

- no float appears on a page prior to that where it is defined;
- figures and tables are output in the order in which they were defined in the text, so that no float appears before a previously defined float of the same type; figures and tables may, however, be mixed in their output sequence; in two-column format, the double column *-floats may also appear out of sequence;
- floats will be located only at one of the allowed positions given by the placement argument *where*; without an argument, the standard combination `tbp` is used;
- unless the ! is included in *where*, the positioning obeys the limitations of the style parameters described in Section 7.3;
- for the combination `ht`, the argument `h` takes priority; the float is inserted at the point of its definition even if there is enough room for it at the top of the page.

When any of the commands `\clearpage`, `\cleardoublepage`, or `\end{document}` is given, all floats that have not yet been output will be printed on a separate page or column regardless of their placement arguments.

Package:
after-
page

Sometimes L^AT_EX gets stuck on a float which holds up the entire queue until the end of the document. One way to clear the queue is to issue `\clearpage` right after the troublesome float. However, that would insert a new page at that point, something that may not be desired. The package `afterpage` in the `tools` collection (Section B.5.4) provides the command `\afterpage` which executes its argument at the end of the current page. Thus `\afterpage{\clearpage}` solves this problem by delaying the `\clearpage` command until the actual page break.

7.2 Postponing floats

Occasionally one wants to prevent floats from appearing on a certain page, for example at the top of a title page. (L^AT_EX automatically corrects that case.) However, there are other situations where a float should be suppressed temporarily. One might want it at the top of a page, but not before the start of the section that refers to it. The command

```
\suppressfloats[loc]
```

sees to it that *for the current page only* no further floats of the specified placement *loc* should appear. If the optional *loc* is omitted, all floats are suppressed; otherwise *loc* may be either `t` or `b`, but not both.

Note that `\suppressfloats` does not suppress all floats for the current page, but only *further* ones that come between the issuing of this command and the end of the page. Thus it is still possible for floats from a previous section to appear on the page.

Package:
flafter

Alternatively, the package `flafter` (Section B.5.3) may be loaded to ensure that *all* floats appear only after their position in the text.

The command `\suppressfloats` and the location parameter `!` are attempts to give the author more control over the sometimes capricious actions of float placement.

7.3 Style parameters for floats



There are a number of style parameters that influence the placement of floats, which may be altered by the user as desired.

`topnumber`

The maximum number of floats that may appear at the top of a page.

`bottomnumber`

The maximum number of floats that may appear at the bottom of a page.

`totalnumber`

The maximum number of floats that may appear on any page regardless of position.

`dbltopnumber`

The same as `totalnumber` but for floats that extend over both columns in two-column page format.

The above parameters are all *counters* and may be reset to new values with the command `\setcounter{ctr}{num}`, where *ctr* is the name of the counter and *num* the new value that it is to take on.

`\topfraction`

A decimal number that specifies what fraction of the page may be used for floats at the top.

`\bottomfraction`

A decimal number that specifies what fraction of the page may be used for floats at the bottom.

`\textfraction`

The fraction of a page that must be filled with text. This is a minimum, so that the fraction available for floats, whether top or bottom, can never be more than $1 - \text{\textfraction}$.

`\floatpagefraction`

The smallest fraction of a float page that is to be filled with floats before a new page is called.

`\dbltopfraction`

The same as `\topfraction` but for double column floats in two-column page format.

`\dblfloatpagefraction`

The same as `\floatpagefraction` but for double column floats in two-column page format.

These style parameters are altered with `\renewcommand{cmd}{frac}` where *cmd* stands for the parameter name and *frac* for the new decimal value, which in every case must be less than 1.

`\floatsep`

The vertical spacing between floats appearing either at the top or at the bottom of a page.

`\textfloatsep`

The vertical spacing between floats and text, for both top and bottom floats.

`\intextsep`

The vertical spacing above and below a float that appears in the middle of a text page with the *h* placement argument.

`\dblfloatsep`

The same as `\floatsep` but for double column floats in two-column page format.

`\dbltextfloatsep`

The same as `\textfloatsep` but for double column floats in two-column page format.

This group of style declarations are rubber lengths that may be changed with the `\setlength` command (Section 2.4.2).

`\topfigrule`

A command that is executed after a float at the top of a page. It may be used to add a rule to separate the float from the main text. Whatever it adds must have zero height.

`\botfigrule`

Similar to `\topfigrule`, but is executed before a float that appears at the bottom of a page.

`\dblfigrule`

Similar to `\topfigrule`, but for double column floats.

These three commands normally do nothing, but they may be redefined if necessary. For example, to add a rule of thickness 0.4 pt below a top float,

```
\renewcommand{\topfigrule}{\vspace*{-3pt}
\rule{\columnwidth}{0.4pt}\vspace{2.6pt} }
```

Because of the negative argument in `\vspace*`, the total vertical spacing is zero, as required.

All the one-column style parameters also function within the two-column page format, but they apply only to floats that fill up one column.

If the style parameters are set to new values within the preamble, they apply from the first page onwards. However, if they are changed within a document, they do not take effect until the next page.

7.4 Float captions

A figure caption or table title is produced with the command

```
\caption[short_title]{caption_text}
```

inside the `figure` or `table` environment. The *caption_text* is the text that is printed with the float and may be fairly long. The *short_title* is optional and is the text that appears in the list of figures or tables (Section 3.4.4). If it is missing, it is set equal to *caption_text*. The *short_title* should be given if the *caption_text* is longer than about 300 characters, or if it is more than one line long.

In the `table` environment, the `\caption` command generates a title of the form ‘Table *n*: *caption_text*’, and in the `figure` environment ‘Figure *n*: *caption_text*’, where *n* is a sequential number that is automatically incremented. In document class `article`, the figures and tables are numbered from 1 through to the end of the document. For the `report` and `book` classes, they are numbered within each chapter in the form *c.n*, where *c* is the current chapter number and *n* is the sequential number reset to 1 at the start of each chapter. Figures and tables are numbered independently of one another.

Table 7.1: Computer Center Budget for 2004

Nr.	Item	51505	52201	53998	Total
1.1	Maintenance	130 000		15 000	145 000
1.2	Network costs	5 000		23 000	28 000
1.3	Repairs	25 000	6 000		31 000
1.4	Expendables		68 000		68 000
1.	Total	160 000	74 000	38 000	272 000

The `\caption` command may be omitted if numbering is unwanted, since any text included in the *float* environment will accompany the contents. The advantages of `\caption` over simple text are the automatic numbering and entries in the lists of figures and tables. However, a manual entry in these lists may be made as described in Section 3.4.4 using

```
\addcontentsline and \addtocontents
```

A *title*, or *headline*, is produced with `\caption` when the command comes at the beginning of the material in the *float* environment: the number and text are printed above the table or figure. A *caption* is added below the object if the command comes after all the other float commands. In other words, the `\caption` is just another item within the float and whether its text appears at the top (as *title*) or below (as *caption*) depends on how the user places it.

The *caption.text* will be centered if it is shorter than one line, otherwise it is set as a normal paragraph. The total width may be adjusted to that of the table or figure by placing the command inside a `parbox` or `minipage`. For example,

```
\parbox{width}{\caption{caption.text}}
```

The following demonstrations contain further examples of how text, table, and picture commands may be combined in floats.

7.5 Float examples

The first two tables are produced with the following texts:

```
\begin{table} \caption{Computer Center Budget for 2004}
  \begin{tabular}{|l|l|l|r|r|r|} ... \end{tabular}
\end{table}
```

(This text was typed in before the last paragraph of the previous section. The second table is entered here in the current text.)

Table 7.2: Estimates for 2004. *A continuation of the previous budget is no longer practical since, with the installation of the new computing system in 2003, the operating conditions have been completely overhauled.*

Nr.	Item	51505	52201	53998	Total
1.1	Maintenance	240 000			240 000
1.2	Line costs	12 000	8 000	36 000	56 000
1.3	Training			50 000	50 000
1.4	Expansion	80 000	3 000		83 000
1.5	Expendables		42 000		42 000
1.	Total	332 000	53 000	86 000	471 000

```
\begin{table}
  \caption{\textbf{Estimates for 2004} \emph{A continuation...}}
  \begin{tabular}{|l|l|l|l|l|l|} ... \end{tabular}
\end{table}
```

Because the placement argument is missing from the `table` environments, the standard values `tbp` are used. The first was placed at the top on the facing page because it was typed in early enough (during the last section) that there was still room for it there. Then the command `\suppressfloats` (Section 7.2) was issued to prevent any more floats appearing on the same page. The second table is therefore forced to float to the top of this page.

Narrow figures or tables may be set beside each other, as shown in the following example (which appears at the bottom of this page). (The `picture` environment is explained in Chapter 13.)

```
\begin{figure}[b]
\setlength{\unitlength}{1cm}
\begin{minipage}[t]{5.0cm}
\begin{picture}(5.0,2.5) ... \end{picture}\par
\caption{Left}
\end{minipage}
```

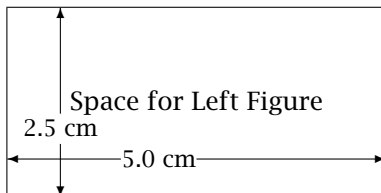


Figure 7.1: Left

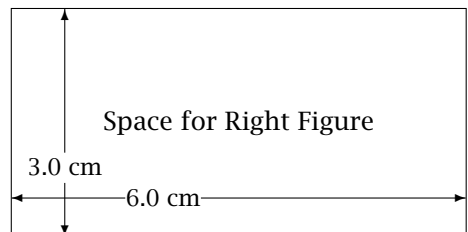


Figure 7.2: Right

```

\hfill
\begin{minipage}[t]{6.0cm}
\begin{picture}(6.0,3.0) ... \end{picture}\par
\caption{Right}
\end{minipage}
\end{figure}

```

The two figures along with their captions are each set in a `minipage` environment of widths 5 and 6 cm. The minipages are separated from one another by an `\hfill` space. The positioning argument `t` has the effect that the minipages are aligned along their first lines (Section 4.7.3). The entire structure within the `figure` environment floats as a single entity.

The question might now arise as to why, since the two figures have unequal heights and are supposedly aligned vertically along their top lines, their bottom edges are at the same level. The explanation is that a `picture` environment establishes an LR box (Section 4.7.1) to contain all the picture commands, and that is viewed by L^AT_EX as a single line of output text with the baseline at the bottom edge of the picture. In both minipages, the `picture` environment is the first entry and is therefore the first logical line of text. It is these baselines that are taken for the vertical alignment of the minipages.

If the two pictures were to be aligned along their top edges, it would be necessary to include a dummy first line (Section 4.7.4) in each minipage before the `picture` environments. This could be something like `\mbox{}`, for example.

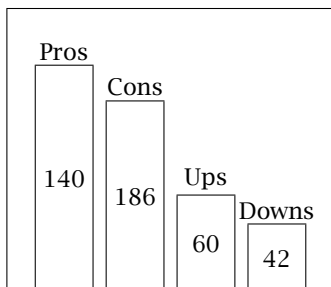
The application of box commands within a float permits completely free positioning. If the caption text is to appear, say, beside the table or figure, instead of above or below it, the objects may be put into minipages or parboxes with suitable alignment arguments. Here is an example:

```

\begin{table}[b]
\centerline{\bfseries Results and Seat Distribution of the...}
\mbox{\small}
\begin{minipage}[b]{7.7cm}

```

Results and Seat Distribution of the 2003 General Election



Seat Distribution
in the Assembly of
2004-2006

Results:
2003 General
Election

Party	Votes	%
Pros	15 031 287	37.7
Cons	12 637 418	31.7
Ups	6 499 210	16.3
Downs	4 486 514	11.3
Others	1 201 078	3.0

```

\begin{minipage}[t]{4.4cm}
  \mbox{}\\ \setlength{\unitlength}{0.75cm}
  \begin{picture}(5.75,5.0) ... .. \end{picture}
\end{minipage} \hfill
\parbox[t]{3.2cm}{\makebox[0cm]{}\\{\bfseries Seat ...} ...}
\end{minipage}
\hspace{-3cm}
\begin{minipage}[b]{7cm}
  \parbox[b]{2.5cm}{{\bfseries Results:}\\ General Election..}
  \hfill
  \begin{tabular}[b]{|l||r|r|} ... .. \end{tabular}
\end{minipage} }
\end{table}

```

!

Here the vertical boxes are nested inside one another. The left side, consisting of graphics and a title at the upper right, is contained in a minipage of width 7.7 cm, in which the picture is in another minipage of width 4.4 cm while the text is in a parbox of width 3.2 cm. Both are aligned with the top lines. A dummy line containing `\mbox{}` (Section 4.7.4) is added before the first picture to provide a top line with which the second parbox can be aligned.

The right-hand side consists of a minipage of width 7 cm, shifted to the left by 3 cm, aligned with the left-hand minipage along the bottom lines. It contains a parbox of width 2.5 cm for the text as well as a table, which is automatically a vertical box. Both of these are aligned with the bottom lines.

7.6 References to figures and tables in text

The automatic numbering of tables and figures has the consequence that the author does not know the numbers at the time of writing. Since he or she would like to be able to refer to these objects by number, as ‘see Figure 3’ or ‘Table 5 illustrates’, another means of referencing must be found. It is not sufficient to keep track of the number of `\caption` calls that have been made, since the document may not be written in the order in which it finally appears, and new figures or tables may be inserted during revision, or some removed.

These problems are solved with the \LaTeX cross-reference system, described in more detail in Section 9.2.1. The basic commands are

```
\label{name} \ref{name}
```

which assign a keyword *name* to the figure or table number that may be used as reference in the text. The keyword *name* may be any combination of letters, numbers or symbols. The assignment is made with the `\label` command given anywhere within the caption text of the `\caption` command; in the main text, the command `\ref` inserts the number that is associated with its keyword.

This is best shown with an example. The budget table on page 174 was actually written as

```
\caption{\label{budget04} Computer Center ... }
```

so that `\ref{budget04}` produces ‘Table 7.1’ when used in the main text.

There is a second referencing command `\pageref` to generate the page number where the referenced object is to be found. For example, a few lines up, the input text on page `\pageref{budget04}` was used to create the text ‘... on page 174’.

7.7 Some float packages

7.7.1 Placing a float right here

Package: The float placement parameter `h`, described on page 170, only permits a float to be placed at the current location, it does not force it to appear there. With Frank Mittelbach’s package `here`, an additional parameter `H` is provided which places the float immediately where it appears in the source text. If there is not enough room for it on the current page, a `\pagebreak` command is first issued. This will most likely lead to an ugly page break.

7.7.2 Flowing text around a float

Package: The package `floatflt` by Mats Dahlgren (based on the earlier and now obsolete `floatfig` by Thomas Kneser) permits one to mix text and floats side by side, with the text flowing around the float at the end, as in the next paragraph.

A figure is placed within the text as shown in the box at the right. Here *pos* determines on which side the figure is to appear: it may be *r* (right), *l* (left), *p* (right for odd, left for even pages), or *v* (like *p* unless a package option is given, in which case, it is used). The mandatory argument *wth* is the width of the figure itself; in fact, some additional space will be included for a border between text and figure. It is advisable to include a `\centering` command at the start of the figure material.

```
\begin{floatingfigure}[pos]{wth}
Figure commands with or without a
\caption command
\end{floatingfigure}
```

The material in the `floatingfigure` environment need not actually be a figure. In the above example, some boxed text in a `minipage` was used for demonstration purposes. However, if the `\caption` command is included in the environment, then a figure number will be printed, in sequence with those of the regular `figure` environment.

Rather than giving the *pos* parameter each time, one can specify a default value as an option when loading the package with `\usepackage`:

`rflt` (right), `lflt` (left), or `vflt` (variable, i.e. p). If no option is given, the default is `vflt`.

```
\begin{floatingtable}[pos]{
\begin{tabular}{table specs}
table entries
\end{tabular}}
Optional \caption command
\end{floatingtable}
```

To include a table with text, the usage is slightly different, as shown at the left. That is, the entire table appears in place of the *wth* for a figure, and only the caption is placed in the environment itself.

Both these environments are to be placed at the start of the paragraph that is to flow around the figure or table. The flowing cannot start in the middle of a paragraph.

There is some very tricky coding to get the flowing text to work properly, and needless to say, there are many things that can go wrong. Please read the accompanying manual for more details.

7.7.3 Defining new floats and styles

Package: For authors who are not satisfied with the standard float style, or who need additional floating environments, we recommend the `float` package by Anselm Lingnau. With this package, one defines a new float type with

```
\newfloat{name}{loc}{ext}[within]
```

where *name* is the name of the new float environment, *loc* is the default placement letters (selection of `tbhph`), *ext* is the extension of the file containing the list of this float type, and the optional *within* is the name of a counter (e.g., `chapter`) within which the numbering is reset.

For example, to define a `plate` environment that behaves just like `figure` but which is numbered separately as *Plate xxx*, with the numbers reset within each chapter, give

```
\newfloat{plate}{p}{lop}[chapter]
\floatname{plate}{Plate}
```

The first line defines the new environment, with default placement on a float page. The second states that the captions associated with this float are to start with the word ‘Plate’; without this, they would be labeled as ‘plate’, the same as the environment name itself.

The information for the list of plates is stored in a file with extension `.lop`, in the same way that the list of figures is in a file with extension `.lof` (Section 3.4.4). This list is printed by reading in this file with the command

```
\listof{plate}{List of Plates}
```

where ‘List of Plates’ is the list title.

The default placement parameters for any float environment, including the standard `figure` and `table` ones, can be redefined with

```
\floatplacement{name}{loc}
```

The `float` package also defines 4 *float styles*:

`plain` much like standard L^AT_EX except the caption is always *below* the float contents;

`plaintop` like `plain` but with the caption always *above* the contents;

`boxed` in which the contents are in a framed box with the caption below it;

`ruled` with the caption above, and with rules above, below, and between caption and float contents.

One selects a float style by issuing `\floatstyle{style}`, where *style* is one of the above possibilities. The style then applies to all new float environments defined with `\newfloat`, until a new style is issued.

Note: the style selection affects the subsequent float *definitions*, not the float environments that are then used. To change the float style for the standard `figure` and `table` floats, issue

```
\floatstyle{ruled}
\restylefloat{figure}
\restylefloat{table}
```

The `float` package also contains the H placement parameter for ‘here and I mean it’, so it is not necessary to include the `here` package with it.

8

User Customizations

\LaTeX allows the user to define his or her own commands and environments. However, since these make extensive use of the \LaTeX counters and lengths, we will first present a more detailed discussion of these objects and how they may be manipulated.

8.1 Counters

8.1.1 \LaTeX counters

\LaTeX manages a number of counters by giving them initial values at the start and by changing these values when certain commands are called. Most of these counters have the same name as the commands that alter them:

part	chapter	paragraph	figure	enumi
	section	subparagraph	table	enumii
	subsection	page	footnote	enumiii
	subsubsection	equation	mpfootnote	enumiv

The meanings of most of these counters are obvious from their names and need no further explanation. The counters `enumi` ... `enumiv` refer to the four levels of the `enumerate` environment (Sections 4.3.4 and 4.3.5), while the counter `mpfootnote` controls the footnote numbering within the `minipage` environment (Section 4.10.4).

The value of a counter is an integer number, usually non-negative. A command may output several numbers at once: the current `\subsection` command outputs 8.1.1, which addresses three counters in all. For example, the `\subsection` command increments the value of the `subsection` counter by one, and prints the values of the `chapter`, `section`, and `subsection` counters, separated by periods. At the same time, this command sets the `subsubsection` counter to zero.

8.1.2 User-defined counters

The user may create new counters with the command

```
\newcounter{counter_name}[in_counter]
```

where *counter_name* is the name of the newly established counter. This may be any combination of letters that is not already the name of an existing counter. Thus none of the names of the L^AT_EX counters listed above may be used as *counter_name* nor any name of a previously defined user counter.

The optional argument *in_counter* is the name of another counter that already exists (L^AT_EX or user defined) and has the effect that the newly defined counter is reset to zero whenever *in_counter* is incremented by one of the commands `\stepcounter` or `\refstepcounter` (see below). For example, the subsection counter is reset to zero whenever the section counter is incremented.

The `\newcounter` command may not appear in any file that is read in with the `\include` command (Section 9.1.2). It is therefore best to put all `\newcounter` commands into the preamble.

8.1.3 Changing counter values

Every counter, whether L^AT_EX or user defined, has an initial value of zero; this can be altered with the following commands:

```
\setcounter{counter}{num}
```

This command is self-explanatory: the specified *counter* is assigned the integer value *num*.

```
\addtocounter{counter}{num}
```

With this command, the value of the *counter* is increased by the integer *num*, which may be positive or negative.

```
\stepcounter{counter}
```

The value of the *counter* is increased by one, and at the same time all its sub-counters (that is, those that have this counter as their *in_counter*) are reset to zero (see above).

```
\refstepcounter{counter}
```

This command has the same effect as `\stepcounter` but also makes *counter* the current counter for the cross-referencing command `\label` (see Section 9.2.1).

This last command may be applied, for example, within the `figure` or `table` environments when the `\caption` command is missing and yet there is to be a reference in the text to the figure or table number using the `\ref` command. Then `\refstepcounter{figure}` or `\refstepcounter{table}` is given within that float environment to bring the corresponding

counter to the right value and to allow that value to be assigned a keyword with the `\label` command (Section 9.2.1).

The value of a counter may be treated as a number with the command

```
\value{counter}
```

which does not change the value at all. This command is mostly used in connection with `\setcounter` or `\addtocounter`. For example, if the user-defined counter `mypage` has been created, it may be set to the same value as the page counter `page` by giving `\setcounter{mypage}{\value{page}}`.

8.1.4 Printing counter values

The numerical value in a counter can be printed with the commands

```
\arabic{counter}  as an Arabic number,
\Roman{counter}  as a capital Roman numeral,
\roman{counter}  as a lower case Roman numeral,
\alph{counter}   as a lower case letter,
\Alph{counter}   as a capital letter,
\fnsymbol{counter} as a footnote symbol.
```

For the commands `\alph` and `\Alph`, the numbers 1 . . . 26 correspond to the letters *a* . . . *z* and *A* . . . *Z*. It is up to the user to ensure that the counter value lies within this range. For `\fnsymbol`, the numbers 1 . . . 9 are output as the symbols * † ‡ § ¶ || ** †† ‡‡. Here again, the user must take care that the counter does not reach a value of 10 or more.

For each counter, a command of the form

```
\thecounter
```

is also available, consisting of `\the` immediately followed by the name of that counter, such as `\thepage`. This type of command is initially identical to `\arabic{counter}`, but may be redefined to be composed of several counter commands. In the document classes `book` and `report`, for example, the command `\thesection` is defined in terms of both the chapter and section numbers: `\arabic{chapter}.\arabic{section}`. Here is the result of printing `\thesection` at this point: 8.1.

The automatic printing of counter values such as the page, equation, or sectioning numbers is accomplished by means of calls to the appropriate `\thecounter` commands. If a different format for some automatic numbering is desired, say alphabetical equation numbers, the definition of the corresponding `\thecounter` command can be altered using the methods described in Section 8.3.

Exercise 8.1: Take your standard *exercise.tex* file and print out the final values of the \TeX counters with `\arabic{counter}` commands at the end. Change some the values with the `\setcounter` and `\addtocounter` commands and print the values out once more.

8.2 Lengths

It has been constantly pointed out in all the descriptions of the length parameters such as `\parskip` or `\textwidth` that new values may be assigned with the `\setlength` command. Some of these parameters expect rubber length values that may stretch or shrink. These are mainly parameters that produce vertical spacing. The types of length units, both fixed and rubber, are described in detail in Section 2.4. This will not be repeated here, but rather additional commands for assigning and handling lengths are discussed in this section.

The standard L^AT_EX method for assigning a value to a length parameter is with the command

```
\setlength{\length_cmd}{length_spec}
```

where *length_spec* may be a length specification (with units) or another length parameter. In the latter case, *length_cmd* takes on the current value of that other parameter. Thus with `\setlength{\rightmargin}{\leftmargin}` the right-hand margin in a `list` environment is set to the same value as that of the left-hand margin.

Lengths may be increased with

```
\addtolength{\length_cmd}{length_spec}
```

which adds *length_spec* to the value of the length parameter *length_cmd*. A negative value for *length_spec* decreases *length_cmd* by that amount. Once again, another length parameter may be used for *length_spec*, with or without a preceding minus sign, and its value will be added or subtracted. A decimal number just before a length parameter multiplies its value by that quantity: `0.5\textwidth` means half the width of the text column and `2\parskip` twice the inter-paragraph spacing.

With the command

```
\settowidth{\length_cmd}{text}
```

the length parameter *length_cmd* is set equal to the natural length of a piece of text.

Similarly the commands

```
\settoheight{\length_cmd}{text}
```

```
\settodepth{\length_cmd}{text}
```

set the *length_cmd* equal to the height and depth of the *text* above and below the baseline, respectively.

Finally, the command

```
\stretch{decimal_num}
```

yields a rubber length that is *decimal_num* times as stretchable as `\fill` (Section 2.4.2).

A user-defined length parameter is created with

```
\newlength{\new_len_cmd}
```

which establishes `\new_len_cmd` as a length with a value of `0pt`. All the above commands may be used to manipulate its value further.



The command

```
\addvspace{length_spec}
```

inserts extra vertical spacing of the amount *length_spec* at that point where it appears. If more than one such command is given, the total inserted spacing will be that of the largest argument and not the sum of them all. This command may only be given *between* paragraphs. Its application for user-defined commands and environments lies in the generation of structures that should behave like paragraphs.

8.3 User-defined commands

New commands may be defined or redefined under \LaTeX with the commands

```
\newcommand{\com_name}[narg][opt]{def}
\renewcommand{\com_name}[narg][opt]{def}
```

The first version is used to define a command `\com_name` that does not yet exist. Its name may be any combination of letters that do not form the name of another command. The second version redefines an already existing command `\com_name`. In both cases, an error message is printed if the incorrect variant is called. The first optional argument *narg* is a number between 1 and 9 specifying how many arguments the new or altered command is to have. A second optional argument *opt* gives the default value for an optional argument that the new command may take. The actual definition of the command is contained in the text *def*.

8.3.1 Commands without arguments

We will first illustrate the use of the `\newcommand` without the optional argument *[narg]*. This form is applied when a fixed combination of \LaTeX or user commands is to be repeated frequently as a command with its own name. For example, the structure x_1, \dots, x_n , called an *x*-vector, often occurs in mathematical formulas and is formed in math mode with `x_1, \ldots, x_n`. Typing

```
\newcommand{\xvec}{x_1, \ldots, x_n}
```

creates a new command named `\xvec` that may be called and used just like any other command. When called, it inserts the sequence of text and commands, in this case `x_1, \ldots, x_n`, into the current text exactly as

if one had typed it oneself. In fact, this is precisely what happens: when `\xvec` is called, it is its definition that goes into the \LaTeX processing.

Since the new command `\xvec` contains a math command (the subscript command `.`), it may only be called within math mode. Thus $\$\xvec\$$ is required to produce x_1, \dots, x_n in text mode. It might therefore seem a good idea to include the switching to math mode in the definition itself, as

```
\newcommand{\xvec}{\$x_1, \ldots, x_n\$}
```

Now `\xvec` yields x_1, \dots, x_n . However, this command may only be applied in text and never in math mode. There is a trick to enable the command to be called in both modes: define it as

```
\newcommand{\xvec}{\ensuremath{x_1, \ldots, x_n}}
```

Now both `\xvec` and $\$\xvec\$$ are allowed, both with the same result.

The above text mode example was actually written as `\xvec{}`, since \TeX treats it as a command without arguments, terminating its name with the first non-letter that it finds. If this character is a blank, it only ends the command name and does not insert interword spacing (Section 2.1). Thus `\xvec` and `...` produces ‘ x_1, \dots, x_n and ...’ without any spacing between. This problem is solved by adding a space command `_` or the empty structure `{}` after the command name, in this case as `\xvec_` or `\xvec{}`.

It would also have been possible to include the blank in the definition of `\xvec`, as `{\ensuremath{x_1, \ldots, x_n} }`. Now the blank following the command name is still removed, but the command itself inserts one to make up for it. However, this is not recommended practice since this ‘programmed’ blank will always be present, even when some punctuation or other symbol directly follows the command.

Package:
xspace

A better solution is provided by the `xspace` package in the `tools` collection (Section B.5.4). With this package, one adds the command `\xspace` at the end of a definition where a space may appear:

```
\newcommand{\xvec}{\ensuremath{x_1, \ldots, x_n}\xspace}
```

This command prints a blank unless it is followed by punctuation, in which case it does nothing.

The different versions of the above example were all illustrated with the command `\newcommand`, although in fact this command may only be used once to initiate a user-defined command that does not already exist. Once `\xvec` has been created, a revised definition can only be given with the command `\renewcommand`. This was indeed done with the second and subsequent definitions of `\xvec`.

Following this example, the user may employ `\newcommand` (or alternatively `\renewcommand`) to combine any set of commands and text to form a command under a new name that may then be called whenever

necessary. In this way, a considerable amount of typing can be avoided and the possibility of error reduced, especially for complex mathematical structures.

If it is not known whether or not a command with the chosen name already exists, one may use instead

```
\providecommand{\com_name}[narg][opt]{def}
```

which has the same syntax as `\newcommand` and `\renewcommand`. The difference is that if the command already exists, the new definition will be ignored. The opposite effect (overwriting the current definition of a command without knowing if it already exists) can be achieved by first calling `\providecommand` to ensure the command exists, and then issuing the true definition with `\renewcommand`. However, this should be done only with great care!

Exercise 8.2: Define the commands `\iint`, `\iiint`, and `\idotsint`, to make the multiple integrals shown at the right as displayed formulas, or as the following text formulas: \iint , \iiint , $\int \cdots \int$

$$\iint \quad \iiint \quad \int \cdots \int$$

Exercise 8.3: Change the `\thechapter`, `\thesection`, and `\thesubsection` commands so that for the document classes *book* and *report* the chapter numbering is done with capital letters, such as B, the section numbering with capital Roman numerals after the chapter letter, in the form B-III, and the subsection numbering with lower case Roman numerals following a comma: B-III,v. Hint: the original versions of these commands in *book* and *report* are defined as

```
\newcommand{\thechapter}{\arabic{chapter}}
\newcommand{\thesection}{\thechapter.\arabic{section}}
\newcommand{\thesubsection}{\thesection.\arabic{subsection}}
```

Now apply `\renewcommand` to make the required changes.

8.3.2 Commands with arguments

In addition to the vector x_1, \dots, x_n , there are equivalent vectors y_1, \dots, y_n and z_1, \dots, z_n in mathematics. It would be possible to define commands `\yvec` and `\zvec` following the pattern for `\xvec`. However, it is also possible to define a generalized vector command and to specify the variable part as an argument. In the present example, the variable part is the letter x , y , or z . A command with *one* variable part is created with the optional argument [1]. For example,

```
\newcommand{\avec}[1]{\ensuremath{\#1_1, \dots, \#1_n}}
```

defines the general vector command `\avec{arg}`. Calling `\avec{x}` yields x_1, \dots, x_n while invoking `\avec{y}` prints out y_1, \dots, y_n . The character

#1 in the command definition is a dummy argument representing the text of *arg* that replaces all occurrences of #1 when the command is called. By imagining an *x* or a *y* at each location of the #1 in the definition, the desired structures in each case can be recognized.

The digit 1 in the dummy argument #1 seems at first to be rather pointless. In fact, for a command with only one argument it really has no meaning. However, its function becomes more obvious for commands with *multiple* arguments. Let us say, for example, that we want a command to generate structures such as u_1, \dots, u_m as well as v_1, \dots, v_n . This requires two arguments, one to specify the letter *u*, *v*, etc., and a second to determine the last subscript *n*, *m*, and so on. Such a command is created with

```
\newcommand{\anvec}[2]{\ensuremath{\#1_1, \ldots, \#1_{\#2}}}
```

and invoked as `\anvec{u}{n}` for u_1, \dots, u_n and as `\anvec{v}{m}` for u_1, \dots, u_m . The optional argument [2] for `\newcommand` says that the command being defined contains two arguments; in the definition part, #1 is replaced by the first argument and #2 by the second. By imagining *u* or *v* in place of #1 and *n* or *m* where #2 stands, one can see how the command `\anvec{arg1}{arg2}` operates.

This pattern may be carried on for even more arguments. With

```
\newcommand{\subvec}[3]{\ensuremath{\#1_{\#2}, \ldots, \#1_{\#3}}}
```

a command `\subvec` is defined with three arguments. It should be clear from the definition that calling `\subvec{a}{i}{j}` produces a_i, \dots, a_j .

A command argument that consists of only a single character need not be put into curly brackets `{ }` but may be given directly. If it is the first argument, it must be separated from the command name with a blank, as usual. Thus the sequence `\subvec a ik` is the same as `\subvec{a}{i}{k}`, and `\subvec x1n` produces the same structure x_1, \dots, x_n as our first user-defined example `\xvec`.

Arguments must be enclosed in curly brackets `{ }` when they contain more than one character, since the brackets indicate that the contents are to be treated as a unit. Thus `\subvec{A}{ij}{lk}` prints out A_{ij}, \dots, A_{lk} . The three replacement arguments are *A* for #1, *ij* for #2, and *lk* for #3.

Why does `\subvec{A}{ij}{lk}` produce A_{ij}, \dots, A_{lk} and not the expected result A_{ij}, \dots, A_{lk} ? The answer is that, although the arguments within curly brackets are set as units into the definition text, the brackets themselves are not. The command text after replacement is `\ensuremath{A_{ij}, \ldots, A_{lk}}` so that only the first characters following the subscript symbols `_` are actually lowered. In order that both letters be lowered, they must be seen as a unit within the command text, that is as `A_{ij}, \dots, A_{lk}`. This may be achieved with the `\subvec` command by including an extra set of brackets in the arguments: `\subvec{A}{{ij}}{lk}`. A better solution, however, is to put the brackets in the definition to begin with:

```
\renewcommand{\subvec}[3]{\ensuremath{\#1_{\#2}, \ldots, \#1_{\#3}}}
```

which will always produce the desired result with only a single set of brackets per argument: `\subvec{A}{ij}{lk}` prints A_{ij}, \dots, A_{lk} .



8.3.3 Commands with an optional argument



As we have seen, many \LaTeX commands may take *optional* arguments, including the command `\newcommand` itself. It is also possible to define user commands with one optional argument. The advantage of this is that, although an argument is provided, in most applications it will usually take some standard value that need not be given explicitly.

As an example, the user-defined vector command `\subvec` in the last section has three arguments, for the letter and for the first and last subscripts. However, it may be that the letter is normally x , so it makes sense to include it as an optional argument, which is to be specified only for a different letter. This is accomplished with

```
\renewcommand{\subvec}[3][x]
  {\ensuremath{\#1_{\#2}, \dots, \#1_{\#3}}}
```

The difference between this and the previous definition is the addition of `[x]` after the `[3]` argument. This states that the *first* of the three arguments is to be optional, and its standard value is x . Now `\subvec{i}{j}` prints x_i, \dots, x_j while `\subvec[a]{1}{n}` produces a_1, \dots, a_n .

There may only be one optional argument in the user-defined command, and it will always be the first one, the `#1` in the definition.

8.3.4 Additional examples of user-defined commands

In the above explanation of user-defined commands, a very simple case of a vector structure was taken as an example. We would now like to demonstrate some more complex situations, in which counters, lengths, and even some special \TeX commands are applied.

Example 1: In Section 5.4.6, the \TeX commands `\atop` and `\choose` were presented as useful mathematical commands even for \LaTeX applications. Unfortunately, the syntax of these commands deviates considerably from that of the similar \LaTeX command `\frac`. However,

```
\newcommand{\latop}[2]{\#1\atop\#2}          and
\newcommand{\lchoose}[2]{\#1\choose\#2}
```

define two commands `\latop` and `\lchoose` that yield the same results with a syntax like that of \LaTeX : `\latop{upper}{lower}`.

Example 2: The command `\defbox{sample.text}` is to set a box width equal to the length of the text `sample.text`. A subsequent call to the command `\textbox{text}` centers `text` within a frame with the same width as `sample.text`.

```
\newlength{\wdth}
\newcommand{\defbox}[1]{\settowidth{\wdth}{\#1}}
\newcommand{\textbox}[1]{\framebox[\wdth]{\#1}}
```

First, a new length parameter `\width` is created, then `\defbox` is defined so that `\width` is set equal to the length of its argument (Section 8.2), and finally `\textbox` makes a framed box of that same width containing its argument, centered. (Do not name the length parameter `\width`, for this already exists, Section 4.7.5.)

```
as wide as this text\
```

as wide as this text

```
\defbox{as wide as this text}\textbox{}
```

text

```
\textbox{text}\
```

longer text

```
\textbox{longer text}
```

Example 3: A footnote command `\myfnote` is to be created that behaves as the normal command `\footnote{text}` in putting *text* into a footnote, but instead of using numbers as the marker, it should take the symbols `* † ‡ § ¶ || ** †† ‡‡` one after the other, starting again with the symbol `*` on each new page. First a new counter must be established that will be reset to zero every time the page counter is incremented. This is done with (see Section 8.1.2)

```
\newcounter{myfn}[page]
```

making a user-defined counter `myfn` that is set to zero every time the page counter is incremented.* Next the command

```
\renewcommand{\thefootnote}{\fnsymbol{footnote}}
```

redefines the footnote marker to be that symbol in the sequence given by the counter `footnote` (Sections 4.10.2 and 8.1.4). Now the actual new footnote command can be constructed with

```
\newcommand{\myfnote}[1]{\setcounter{footnote}{\value{myfn}}%
\footnote{#1}\stepcounter{myfn}}
```

yielding the desired results. The user-defined command `\myfnote` possesses one argument, which is passed to the \LaTeX `\footnote` command after the \LaTeX counter `footnote` has been set equal to the value of the user counter `myfn`. Once the command `\footnote` has been executed, the counter `myfn` is then incremented by one with `\stepcounter{myfn}`. This counter, however, is reset to zero whenever the page counter is incremented, that is, whenever a new page begins.

The footnote on the previous page was generated with the command `\myfnote` as described. It is now used here[†] and again here[‡], demonstrating how the symbols have been reset on a new page.

Example 4: A command `\alpheqn` is to be set up so that once it has been called, the subsequent equations will all have the same number but be

* Actually the page counter is not incremented exactly at the end of the page; \LaTeX reads in the whole paragraph before it decides if and where a page break should occur. This can cause problems with resetting the `myfn` counter near the top of a page.

[†]another footnote

[‡]and yet another footnote

followed by letters a, b, \dots , separated by a hyphen ‘-’ from the number. The command `\reseteqn` restores the numbering scheme to its original style. Thus a sequence of equation numbers could be 4, 5, 6-a, 6-b, 7.

```
\newcounter{saveeqn}
\newcommand{\alpheqn}{\setcounter{saveeqn}{\value{equation}}%
\stepcounter{saveeqn}\setcounter{equation}{0}%
\renewcommand{\theequation}
{\mbox{\arabic{saveeqn}-\alph{equation}}}}
\newcommand{\reseteqn}{\setcounter{equation}{\value{saveeqn}}%
\renewcommand{\theequation}{\arabic{equation}}}
```

The example should be easy to comprehend with the help of the commands and counters in Section 8.1. The current value of counter `equation` is saved in the counter `saveeqn` and then incremented, while `equation` itself is set to zero. The form of the equation marker, `\theequation`, is redefined using these two counters. The equation numbering routines will operate on `equation` as usual, leaving `saveeqn` unchanged. The resetting command `\reseteqn` puts the value of `saveeqn` back into `equation` and restores the definition of `\theequation`.

This example is only appropriate for the document class `article`. For `report` and `book`, the definition of `\theequation` is

```
\arabic{chapter}.\arabic{equation}
```

The necessary modifications are left as an exercise for the user.

The `\mbox` command in the first `\renewcommand{\theequation}` defining the combined equation number is necessary because the result will be printed in *math mode*, where the hyphen ‘-’ is interpreted as a binary operator (minus sign) with extra spacing between it and its two ‘operands’, `\arabic{saveeqn}` and `\alph{equation}`. Thus $6 - a$ would be output instead of 6-a. The `\mbox` command causes a temporary switch out of *math* into *text* mode.

Example 5: In Section 5.4.10, the international standards for mathematical typesetting are outlined, in which tensor and matrix variables should be set in a sans serif typeface, preferably italic or slanted. The `math` alphabet command `\mathsf` accomplishes this only for an upright font. The solution is to create a new `math` alphabet `\mathsfs` for use in a `\tensor` command.

```
\DeclareMathAlphabet{\mathsfs}{OT1}{cmss}{m}{s}
\newcommand{\tensor}[1]{\mathsfs{#1}}
```

The NFSS system of font attributes is presented in Section A.1, and the `\DeclareMathAlphabet` command is explained in Section A.3.3.

The Computer Modern sans serif fonts do not possess an italic form which is why the slanted shape is taken instead. If one were to select italic with `{i}` in place of `{s}`, L^AT_EX would automatically substitute the slanted version.

!

In Section 5.4.10, several new commands are suggested to simplify typing math according to the ISO standard. These are:

```
\newcommand{\me}{\mathrm{e}}
\newcommand{\mi}{\mathrm{i}}
\newcommand{\dif}{\mathrm{d}}
\renewcommand{\vec}[1]{\boldsymbol{#1}}
```

These permit the *constants* e, i, and differential operator d to be printed upright, and not italic. The redefinition of the `\vec` command requires the $\mathcal{A}\mathcal{M}\mathcal{S}$ math package `amsbsy`, either directly or as part of the `amsmath` package (Chapter 12).

Here one could also include the abbreviation for the *electron volt*, mentioned on page 30, and its multiples:

```
\newcommand{\eV}{\mbox{e\hspace{-.12em}V}}
\newcommand{\keV}{\mbox{k\eV}}
\newcommand{\MeV}{\mbox{M\eV}}
```

If these commands are used frequently in many different documents, we recommend saving them in a separate file, say `isomath.tex`, to be input at the start of those documents, with `\input{isomath}`.

Exercise 8.4: Define \LaTeX commands `\Lbrack` and `\Lbrace` in the same manner as in Example 1 for `\l atop` and `\l choose` corresponding to the \TeX commands `\brack` and `\brace`. These \TeX commands behave as `\choose` from Section 5.4.6 except that they enclose their contents in square brackets [`\Lbrack`] or curly braces [`\Lbrace`]. (Note that the names `\lbrack` and `\lbrace` are already defined and so should not be used for these commands.)

Exercise 8.5: Generalize Example 4 with a command `\vareqn{num}{type}` to make the subsequent equation numbers have the value `num` followed by a running number in square brackets printed as `\alph...` `\Roman`, as given by the argument `type`. For example, `33[A]`, `33[B]`, would result from calling `\vareqn{33}{\A\alph}`.

Exercise 8.6: Generalize the integral commands in Exercise 8.2 to include an argument to represent the area of integration set centered below the entire symbol. Thus `\iint{D}`, `\iiint{V}`, and `\idotsint{G}` should produce:

$$\iint_{(D)} \iiint_V \int_{\cdot\cdot\cdot} \int_G$$

Hint: the second command can be made simply with a subscript on the middle integral (but see `\limits` in Section 5.2.5). For the other two, negative horizontal shifting of the subscripted symbol is needed using `\hspace{-. . .}`.

Exercise 8.7: The `\tensor` command defined in Example 5 above sets tensor variables in a slanted, sans serif font. If matrices are to be set instead in an upright, sans serif font, define a command `\mtrx` to produce this.

Note: do not name this command `\matrix` because that already exists to produce matrices, not their variable names.

8.3.5 Conditional text

Package: Practiced T_EX users will be familiar with the conditional commands that are available, both for T_EX and L^AT_EX. However, their usage is not always straightforward and often requires extensive knowledge of T_EX's deeper principles. Leslie Lamport has provided a package named `ifthen`, extended by David Carlisle, which not only simplifies their application, but also gives them a L^AT_EX syntax.

The package is loaded as usual with the command

```
\usepackage{ifthen}
```

in the preamble. It then makes available the two commands `\ifthenelse` and `\whiledo`, which have the following syntaxes:

```
\ifthenelse{test}{then.text}{else.text}
\whiledo{test}{do.text}
```

In both cases, *test* is a logical statement (explained below); for the first command, *then.text* or *else.text* is inserted into the text depending on whether *test* is *<true>* or *<>false>*. For the second command, the *do.text* is inserted (executed) as long as *test* evaluates to *<true>*. (The *do.text* must alter the inputs to *test* or it will never stop!) The texts may also contain commands, or even define or redefine commands.

There are four types of basic logical statements which may be combined to form more complicated ones.

Testing numbers

To compare two numbers or commands that evaluate to numbers, simply put one of the relational operators `<`, `=`, or `>` between them, which stand for *less than*, *equals*, and *greater than*, respectively. The value of a counter may be tested by putting its name as the argument of the `\value` command. Examples:

```
\newcommand{\three}{3}
\ifthenelse {\three = 3} {O.K.} {What?}
\ifthenelse {\value{page} < 100 }
  {Page xx} {Page xxx}
```

The first case prints 'O.K.' since `\three` is equal to 3; in the second case *Page xx* is printed if the current page number is less than 100, else *Page xxx*. (The blanks above are added for clarity, since spaces between arguments are always ignored.)

Whether a number is even or odd can be tested with `\isodd`

```
\ifthenelse {\isodd{\value{page}}}
  {odd} {even}
```

Testing text

To test if two commands evaluate to the same piece of text, or if a command is defined as a certain *string* of text, use

```
\equal{string1}{string2}
```

where *string1* and *string2* are texts or commands that reduce to text. For example, with

```
\ifthenelse {\equal{\name}{Fred}} {Frederick} {??}
```

the text `Frederick` is inserted if `\name` has been defined to be `Fred` (with `\newcommand`), otherwise two question marks are printed.

Testing lengths

Another logical statement compares two lengths.

```
\lengthtest{relation}
```

where *relation* consists of two lengths or length commands separated by a relational operator `<`, `=`, or `>`. For example,

```
\newlength{\horiz} \newlength{\vert}
\newlength{\min}
. . . . .
\ifthenelse {\lengthtest{\horiz > \vert}}
  {\setlength{\min}{\vert}} {\setlength{\min}{\horiz}}
```

sets `\min` to be the smaller of `\horiz` and `\vert`.

Testing switches

A *boolean switch* is a parameter that is either *(true)* or *(false)*, also called a *flag*. Three commands exist to handle them:

<code>\newboolean{string}</code>	creates a new switch
<code>\setboolean{string}{value}</code>	assigns a value <code>true</code> or <code>false</code>
<code>\boolean{string}</code>	tests its value

The last of these is used as *test* in `\ifthenelse` and `\whiledo`.

There are a number of internal \LaTeX switches that may also be tested (but never reset!). The most useful of these are `@twoside` and `@twocolumn` for checking if two-side or two-column modes are active. Since they contain the character `@`, they may only be used inside a class or package file (Appendix D).

Combining logical statements

Any of the above logical statements may be combined to form a more complex statement by means of the logical operators

```
\and \or \not \(\ \)
```

which should be straightforward to anyone familiar with boolean logic. For example, to set `\textwidth` to 10 cm if two-column mode is active or if `\paperwidth` is greater than 15 cm and the page counter is below 100,

```
\ifthenelse {\lengthtest{\textwidth > 10cm} \or
\(\ \lengthtest{\paperwidth > 15cm} \and
\value{page} < 100 \) }
{\setlength{\textwidth}{10cm}} {}
```

will accomplish this.

Such conditionals are fairly complicated, and they are most appropriate for defining new commands that may have alternative actions, or for including in package and class files (Appendix D).

A relatively simple example: suppose one is uncertain whether British or American spelling is wanted by the publisher. One can write the document with both included in the text, with a switch in the preamble to make the final selection.

```
\newboolean{US}
\setboolean{US}{true} %For American spelling
%\setboolean{US}{false} %For British spelling
\newcommand{\USUK}[2]{\ifthenelse{\boolean{US}}{#1}{#2}}
```

Now `\USUK` is a command that prints its first or second argument according to the setting of the flag `US`. Thus in the text one may write

```
... the \USUK{color}{colour} of music ...
```

which will yield American spelling if `\setboolean{US}{true}` has been specified, otherwise the British version. In fact, different sections of the work could have different spelling simply by changing the value of the switch at the appropriate point.

As an example of `\whiledo`: one wishes to write some text n times, where both the text and n are to be variable.

```
\newcounter{mycount}
\newcommand{\replicate}[2]{\setcounter{mycount}{#1}
\whiledo{\value{mycount}>0}{#2\addtocounter{mycount}{-1}}
```

Now `\replicate{30}{?}` will print 30 question marks.

8.4 User-defined environments

Environments may be created or changed with the commands

```
\newenvironment{env_name}[narg][opt]{beg_def}{end_def}
\renewenvironment{env_name}[narg][opt]{beg_def}{end_def}
```

where the arguments have the following meanings:

env_name: the name of the environment; for `\newenvironment`, it may not be the same as any existing environment or command name, whether \LaTeX or user-defined. For `\renewenvironment`, on the other hand, there must already be an environment bearing this name. Any changes to \LaTeX environments should only be undertaken if the user knows what he or she is doing.

narg: a number between 1 and 9 that states how many arguments the environment is to have; if the optional argument *narg* is omitted, the environment is to have no arguments.

opt: the default text for the first argument (`#1`) if it is to be optional; this behaves the same as for `\(re)newcommand` (page 185).

beg_def: the *initial* text to be inserted when `\begin{env_name}` is called; if this text contains entries of the form `#n`, with $n = 1, \dots, narg$, then when the environment is started with the call

```
\begin{env_name}{arg_1}...{arg_n}...
```

each occurrence of `#n` within *beg_def* is replaced by the text of the argument *arg_n*.

end_def: the *final* text that is inserted when `\end{env_name}` is called; here the dummy arguments `#n` are not allowed since they are only to appear in the *beg_def* text.

8.4.1 Environments without arguments

Just as for user-defined commands, environments without the optional argument *narg* will be illustrated first. A user-defined environment named `sitquote` is created with

```
\newenvironment{sitquote}{\begin{quote}\small
\itshape}{\end{quote}}
```

which sets the text appearing between `\begin{sitquote}` text `\end{sitquote}` in the typeface `\small\itshape`, and indented on both sides from the main margins, as demonstrated here.

In this case, *beg_def* consists of the command sequence `\begin{quote}` `\small\itshape` while *end_def* is simply `\end{quote}`. Now the call

```
\begin{sitquote} text \end{sitquote} is the same as
\begin{quote}\small\itshape text \end{quote}
```


which produces the desired result.

This example does not appear to be very practical since the same effect can be achieved with less typing by adding `\small\itshape` at the beginning of the `quote` environment. However, it is more consistent with the concept of *logical markup* introduced in Section 1.2.2. This special quotation environment may be used throughout the document without worrying about its typographical details, which are specified in its definition located in the document preamble. Doing it this way not only ensures consistency, it also simplifies any substitution that may be demanded later by a typographical expert.

Let us expand the previous example somewhat as follows:

```
\newcounter{com}
\newenvironment{comment}
{\noindent\slshape Comment:\begin{quote}\small\itshape}
{\stepcounter{com}\hfill(\arabic{com})\end{quote}}
```

where now *beg.def* contains the text and commands

```
\noindent\slshape Comment:\begin{quote}\small\itshape
```

and *end.def* is

```
\stepcounter{com}\hfill(\arabic{com})\end{quote}
```

where `com` is a user counter created by the `\newcounter` command. Now since the command `\begin{comment}` inserts the text *beg.def* at the start of the environment and `\end{comment}` the text *end.def* at the finish, it should be clear that

```
\begin{comment} This is a comment.
  Comments should ...
  ... in round parentheses.
\end{comment}
```

will generate the following type of structure:

Comment:

This is a comment. Comments should be preceded by the word Comment: the text being in a small, italic typeface, indented on both sides from the main margins. Each comment receives a running comment number at the lower right in round parentheses. (1)

The user should examine the sequence of commands with the replacement text of this example to see precisely what the effect of this environment is. Two weaknesses should become apparent: what would happen if `\begin{comment}` were called in the middle of a line of text without a blank line before, and what would happen if the last line of the comment text were so long that there was no more room for the running comment number on the same line?

The following revision removes these two problems:

```

\renewenvironment{comment}
{\begin{sloppypar}\noindent\s\shape Comment:
  \begin{quote}\small\itshape}
{\stepcounter{com}\hspace*{\fill}{\arabic{com}}}\end{quote}
\end{sloppypar}}

```

With the `\begin{sloppypar}` command, the call to the environment always starts a new paragraph in which no *overflow* line can occur upon line breaking. If the comment number does not fit on the last line of text, a new line begins with the number right justified because of the command `\hspace*{\fill}`. Again the user should examine carefully just what is inserted into the processing between the `\begin{comment}` and the `\end{comment}`.

8.4.2 Environments with arguments

Passing arguments over to an environment is carried out exactly as for commands. As an example, the comment environment will be modified so that the name of the person making the comment is added after the word *Comment:*, and this name will be an argument when the environment is invoked.

```

\renewenvironment{comment}[1]
{\begin{sloppypar}\noindent\s\shape Comment: #1
  \begin{quote}\small\itshape}
{\stepcounter{com}\hspace*{\fill}{\arabic{com}}}%
\end{quote}\end{sloppypar}}

```

The text

```

\begin{comment}{Helmut Kopka} This is a modified ...
... environment argument \end{comment}

```

now produces

Comment: Helmut Kopka

This is a modified comment. Comments should be preceded by the word Comment:, followed by the name of the commenter, with the text of the comment being in a small, italic typeface, indented on both sides from the main margins. Each comment receives a running comment number at the lower right in round parentheses. The name of the commenter is transferred as an environment argument. (2)

This example will now be modified once again by interchanging the comment number and the name of the commenter. Placing the running number after the word *Comment:* is no problem, for it is simply necessary to insert those commands from `{end.def}` at the location of the `#1` dummy argument. However, putting the symbol `#1` where the comment number used to be will produce an error message during the L^AT_EX processing since

this violates the syntax of the `\newenvironment` command: ‘*No dummy arguments shall appear within the {end_def}.*’ If the dummy argument comes after `\begin{quote}`, the name will be printed at the wrong place, at the beginning of the comment text.

There is a trick to solve this problem:

```
\newsavebox{\comname}
\renewenvironment{comment}[1]
{\begin{sloppypar}\noindent\stepcounter{com}\s\shape
  Comment \arabic{com}\sbox{\comname}{#1}
  \begin{quote}\small\itshape}
{\hspace*{\fill}\usebox{\comname}\end{quote}\end{sloppypar}}
```

The commands `\newsavebox`, `\sbox`, and `\usebox` are all described in Section 4.7.1. Here `\comname` is the name of a box that has been created with `\newsavebox`, in which the first argument, the commenter’s name, is stored. With this new definition, a comment now appears as follows:

Comment 3

In this form, every comment is assigned a sequential number after the word Comment. The comment text appears as before, while the name of the commenter is entered as the environment argument and is placed at the right of the last line. *Helmut Kopka*

The implementation of more than one argument for environments is the same as for commands and needs no further explanation.

8.4.3 Environments with an optional argument

Similarly, environments may be defined with an optional argument, just as commands. To take our last example once more, if we feel that most comments will be made by Helmut Kopka, we could alter the first line of the definition to

```
\renewenvironment{comment}[1][Helmut Kopka]{..}{..}
```

Now it is only necessary to specify the name of the commenter if it is someone else. With

```
\begin{comment}[Patrick W. Daly]More than ...
... appropriate.\end{comment}
```

we obtain

Comment 4

More than one person may want to make a comment, but perhaps one person makes more than others do. An optional argument for the name is then appropriate. *Patrick W. Daly*

Exercise 8.8: Extend the definition of the comment environment so that a page break cannot occur either between the heading ‘Comment n’ and the comment text or between the comment text and the commenter’s name.

Exercise 8.9: Create a new environment making use of the `minipage` environment, to be named `varpage` and possessing one argument that is a sample text to determine the width of the minipage. The call

```
\begin{varbox}{‘As wide as this sample text’}
. . . . .\end{varbox}
```

should pack the enclosed text into a minipage that has a width equal to that of the text ‘As wide as this sample text’.

Hint: a user-defined length parameter must first be established, say `\varwidth`. See Section 8.2 for details on assigning lengths to text widths.

Exercise 8.10: Generate an environment named `varlist` with two arguments that behaves as a generalization of the sample list in Section 4.4.3. The first argument is to be the item word that is printed on each call to `\item`; the second is the numbering style of the item numeration. For example, with the call

```
\begin{varlist}{Sample}{\Alph} . . . . \end{varlist}
```

every `\item` command within the environment should produce the sequence ‘Sample A’, ‘Sample B’, The indentation should be 1 cm larger than the width of the item word, which itself should be left justified within the label box.

Hint: once again a user-defined length, say `\itemwidth`, is necessary for this solution. After the length of the item word has been stored with `\settowidth`, the indentation may be set with

```
\setlength{\leftmargin}{\itemwidth}
```

to be equal to the width of the item word, and then with

```
\addtolength{\leftmargin}{1cm}
```

to be 1 cm larger. Length assignments for `\labelwidth` and `\labelsep` may be similarly set to appropriate values.

All further details may be obtained from Section 4.4.

8.5 Some comments on user-defined structures

8.5.1 Reusing sets of definitions

User definitions are created to alter page formats, to reorganize the document layout, to invent new structures, and to define shortcuts. That is, they either directly specify typographical elements like the text width, or indicate how new or existing logical elements are to be rendered typographically. As such, they belong in the preamble, where they can be conveniently redefined as needed, effecting the entire document.

Once a set of user definitions has been established, what is the best way to reuse them? There are several possibilities:

1. Write a new class file based on an existing one, incorporating the your own changes. This should be reserved for major changes to the layout or document organization, which will be used very frequently.
2. Write your definitions to a package file with the extension `.sty` to be loaded with the `\usepackage` command. You can take advantage of special package features, like internal commands and options.
3. Write the definitions to a file with the extension `.tex` and load it with `\input{filename}`. No extra features are possible, and the file can be loaded anywhere within the source file.
4. Just copy the definitions from one source file to the next.

Methods 1 and 2 are more sophisticated, and should be considered for user definitions that have a wide generality. They are explained in Appendix D. Method 3 is perfectly good for a personal collection of shortcut commands, or common (re)definitions that are applied to many documents. By having one depository for all such customizations, it is easier to maintain them centrally.

Finally method 4 is applicable for a short list of uncomplicated definitions.

8.5.2 Unwanted spaces

Occasionally user-defined structures generate spacing where none was expected, or more spacing than was desired. This is almost always due to blanks or new lines in the definition, included only to improve the legibility of the input text but interpreted as spacing when the structure is invoked.

For example, if the `%` character had been left out of the first line of the `\myfnote` definition on page 190, a new line would have been added to the command text at that point, and converted into a blank. This blank would be inserted between the previous word which should receive the footnote marker and the call to the `\footnote` command that actually generates the marker, with the result that it would be displaced from that word (for example, `wrong *` instead of `right*`).



At this point we should like to point out that many \LaTeX commands are *invisible*, in that they do not produce any text at the point where they are called. If such an invisible command is given separated by blanks from the surrounding text, it is possible that two blanks will appear.

For example `\rule{0pt}{0pt}` produces

‘For example produces’ twice the interword spacing between ‘example’ and ‘produces’. Invisible commands without arguments do not present this problem since the trailing blank acts solely as a command name terminator and disappears. Furthermore, the following \LaTeX commands and environments always remove the subsequent blanks even when arguments are present.

<code>\pagebreak</code>	<code>\linebreak</code>	<code>\label</code>	<code>\glossary</code>	<code>\vspace</code>	<code>figure</code>
<code>\nopagebreak</code>	<code>\nolinebreak</code>	<code>\index</code>	<code>\marginpar</code>		<code>table</code>

8.5.3 Identical command and counter names

In the previous examples a number of counters were introduced for application to specific commands or environments, such as `myfn` for the command `\myfootnote` on page 190, or `com` for the environment `comment` on page 197. In these cases, the counter and the corresponding command or environment were given different names. This was not necessary: *counters may have a name that is identical to that of a command or environment*. \LaTeX knows from the context whether the name refers to a counter or to a command/environment.

The different names were chosen in the examples in order to avoid confusion for the beginner. In fact, it is reasonable to give a counter the same name as the command or environment with which it is coupled, a practice that \LaTeX itself constantly employs (Section 8.1.1). In the above-mentioned examples, the counters could just as easily have been named `myfootnote` and `comment` to emphasize their interdependence with the command and environment of the same names.

8.5.4 Scope of user definitions

User structures that are defined within the preamble are valid for the entire document. Command and environment definitions that are made inside an environment remain in effect only until its end. Even their names are unknown to \LaTeX outside the environment in which they were defined. Thus if they are to be defined once again in another environment, it is `\newcommand` or `\newenvironment` that must be used and not the `\renew` versions.

For command and environment names that have been globally defined, that is, in the preamble, all further new definitions of these names must be made with the `\renew` version. However, these subsequent definitions will apply only locally within the environment in which they are declared; outside, the previous global definitions will be valid once more.

The same applies to structure definitions within nested environments. A definition in the outer environment is effective within all inner ones, but a new definition must be made at the deeper levels with `\renewcommand` or `\renewenvironment`. On leaving the inner environment, the new definition will no longer be operative, but rather the old one will be re-established.

Warning: Structures that have been created with `\newsavebox` or with `\newcounter` are globally defined. If they are given within an environment, their definitions remain effective even outside that environment. Similarly `\setcounter` functions globally, although `\savebox` does not.

Local definitions are really not to be recommended. It is far better to place all user definitions at the beginning, in the preamble, where they are most easily visible. A local redefinition of a standard command can lead to puzzling effects that are hard for others, or even for the author, to trace down. Of course, some special effects might just be wanted.

8.5.5 Order of definitions

User-defined structures may be nested within one another. If one user definition contains another user-defined structure, it is often the case that the inner one has already been defined. However, this is not necessary. *User definitions may contain other user structures that are defined afterwards.* What is important is that the other structure is defined before the first command is invoked.

For example, a normal sequence of definitions would be

```
\newcommand{\A}{defa}
\newcommand{\B}{defb}
\newcommand{\C}{\A \B}
```

where `\C` is defined in terms of `\A` and `\B`. However, it is also permissible to write

```
\newcommand{\C}{\A \B}
normal text, but without calling \C
\newcommand{\B}{defb}
\newcommand{\A}{defa}
further text with any number of calls to \A, \B and \C
```

8.5.6 Nested definitions



User definitions may be nested inside one another. A structure such as

```
\newcommand{\outer}{\{\newcommand{\inner} . . .}}
```

is permissible. The command that is defined with the name `{\inner}` is valid and known only within the command `{\outer}`, according to the remarks on the scope of definitions on the facing page. Although the \TeX macros make copious use of nested command definitions to limit the lifetime of temporary commands, it is not recommended to nest \LaTeX definitions excessively since it is too easy to lose track of the bracketing. A forgotten bracket pair will produce an error message on the *second* call to the outer command, since the inner definition still exists as a leftover from the first call. Nevertheless, here is an example:

```
\newcommand{\twentylove}
  {\{\newcommand{\fivelove}
    {\{\newcommand{\onelove}
      {I love \LaTeX!}%
      \onelove \onelove \onelove \onelove \onelove}}}}
  \fivelove\ \fivelove\ \fivelove\ \fivelove}}
```

The entry `My opinion of \LaTeX:\ \twentylove` now produces:

My opinion of \LaTeX :

```
I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX!
I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX!
I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX!
I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX! I love \LaTeX!
```

Indenting the lines of the definition, as shown above, can help to keep track of the nesting levels; each line of the same level starts in the same column, ignoring braces.

!

If both the *inner* and *outer* definitions are to be provided with arguments, the symbols for the inner and outer dummy arguments must be distinguished. The symbols for the *inner* definition are `##1 . . . ##9`, while those for the *outer* one are the normal `#1 . . . #9`. For example:

```
\newcommand{\thing}[1]{\newcommand{\color}[2]{The ##1 is ##2.}
  \color{#1}{red} \color{#1}{green} \color{#1}{blue}}}
```

The entry `The colors of the objects are\ \thing{dress}\ \thing{book}\ \thing{car}` produces
The colors of the objects are

```
The dress is red. The dress is green. The dress is blue.
The book is red. The book is green. The book is blue.
The car is red. The car is green. The car is blue.
```

The separate definition and calling as in Section 8.5.5 is easier to follow and would be:

```
\newcommand{\thing[1]}{\color{#1}{red} \color{#1}{green}
  \color{#1}{blue}}
\newcommand{\color}[2]{The #1 is #2.}
```

!

If one were ever to go to a third level of definitions, the dummy arguments are given as `####1 . . . ####9`. And for the fourth level one writes 8 # signs!

Part II

Beyond the Basics

9

Document Management

This chapter describes those features of \LaTeX that justify the subtitle of Leslie Lamport's original books, 'A Document Preparation System'. Whereas in the previous chapters we have concentrated more on markup, logical and typographical, we now present topics that are essential for producing large, complex documents in an efficient manner. The subjects included here are the splitting of a document into several files, selective processing of parts of a document, cross-references to sections, figures, and equations, automated production of bibliographies, indices, and glossaries.

9.1 Processing parts of a document

As often pointed out, a \LaTeX document consists of a preamble and the actual text part. Short documents, such as those that a beginner might have, are written to a single file by means of a text editor, and might be corrected after the first trial printing. As the user gathers experience and confidence, the \LaTeX documents will rapidly expand in length until one is faced with the task of producing an entire book of more than a hundred pages.

Such long documents could theoretically be kept in one file, although that would make the whole operation increasingly clumsy. The file editor functions less efficiently on longer files and the \LaTeX processing takes correspondingly more time. A better idea is to split the work into several files which \LaTeX then merges during the processing.

9.1.1 The `\input` command

The contents of another file may be read into a \LaTeX document with the command

```
\input{filename}
```

where the name of the other file is *filename.tex*. It is only necessary to specify the full name of the file if the extension is something other than *.tex*. During the L^AT_EX processing, the text contained in this second file is read in at that location in the first file where the command is given.

The result of the `\input` command is the same as if the contents of the file *filename.tex* had been typed into the document file at that position. The command may be given anywhere in the document, either in the preamble or within the text part.

Since the `\input` command may be given in the preamble, it is possible to put the whole preamble text itself into a separate file. The actual L^AT_EX processing file could even be reduced to simply `\begin{document} . . . \end{document}` with a number of `\input` commands. A preamble file makes sense if one has a series of documents all of the same type requiring a common preamble. This also simplifies any later change to the specifications that must be made in *all* the documents. Different preamble files may be prepared for various types of processing and may then be selected with `\input{proc.type}`.

A file that is read in by means of the `\input` command may also contain further `\input` commands. The nesting depth is limited only by the capacities of the computer.

In order to obtain a listing of all extra files read in, give the command

```
\listfiles
```

in the preamble. The list appears both on the computer monitor and in the transcript file, at the end of the processing run. The version numbers and any other loading information are also printed. This provides a check as to which files have been input. See Section D.2.9 for a demonstration.

Exercise 9.1: Put the preamble of your standard exercise file *exercise.tex* into a separate file *preamble.tex*. Split the text part into three files *exer1.tex*, *exer2.tex*, and *exer3.tex*. What should the main file now contain to ensure that L^AT_EX processes the whole exercise text?

9.1.2 The `\include` command

Splitting the document into several files may be practical for writing and editing, but when the files are merged with the `\input` commands, it is still the entire document that is processed. Even if only one file contains a small correction, all files will be read in and processed once again. It would therefore be desirable to be able to reprocess only the one corrected file.

One rough-and-ready method is to write a temporary main file containing only the preamble (which may be read in) and an `\input` command to read in that specific file. The disadvantage is that all automatic numbering of page numbers, sections, figures, equations, etc. will start from 1, since

all the information from the previous files will be missing. Furthermore, all cross-references from other files will be absent.

A much better method is to employ the L^AT_EX command

```
\include{filename}
```

which is only allowed within the text part of the document, together with

```
\includeonly{file.list}
```

in the preamble, containing a list *file.list* of those files that are to be read in. The file names are separated by commas and the extension *.tex* is left off.

If *filename* is in the *file.list*, or if `\includeonly` is missing from the preamble, the command `\include{filename}` is identical to

```
\clearpage \input{filename} \clearpage
```

However, if *filename* is not contained within the *file.list*, `\include` is equivalent to `\clearpage` and the file contents are not read in. However, an auxiliary *.aux* file is read in that sets all the counters and cross-referencing information for that file.

Since `\include` always begins a new page, the document must be split into files at those points where a new page occurs, such as between chapters. Furthermore, `\include` commands may not be nested: they may only appear in the main processing file. However, an `\input` command may be given within a file that is `\included`.

The great advantage of the `\include` command is that the additional information about page, section, and equation numbers will be supplied by the *.aux* files that are read in in place of the *.tex* files so that the selective processing takes place with the correct values of these counters. Cross-reference information from the other files is also available so that the `\ref` and `\pageref` commands (Section 9.2.1) yield the correct results. All these values will have been determined during a previous processing of the entire document.

If the changes in the file that is being selectively processed lead to an increase or reduction in the number of pages, the following files will also have to be reprocessed to correct their page numbers. The same is true if sections are added or removed, or if the number of equations, footnotes, figures, etc. is altered.

For example, suppose *file.3* ends on page 17, but after the selective processing it now extends to page 22. The following *file.4* still begins on page 18, and all further files also have their original starting page numbers. If *file.4* is now selectively processed, it will receive the correct number for its first page, 23, based on the stored information in the revised *file.3*. So far so good. However, if instead *file.6* were to be selectively processed right after *file.3*, it would receive its starting page number from *file.5*, which has not yet been corrected and would be in error by 5. The same

applies to all other structure counters. Their correct values can only be guaranteed when the files have been reprocessed in their proper order.

In spite of these restrictions, the `\include` command is extremely useful for large documents, saving considerable computation time. Longer documents are normally written and edited in many stages. The `\include` command permits one to reprocess selective alterations in a short time, even if the numbering systems temporarily go awry. This can be repaired later on with a complete reprocessing of the entire document, by deactivating the `\includeonly` command in the preamble.

A file that is read in with `\include` may not contain any `\newcounter` declarations. This is not much of a restriction, since they should normally be given in the preamble.

For example, each chapter of a book might be written to a separate file with names `chap1.tex`, `chap2.tex`, The processing file itself contains the text

```
\documentclass{book}
. . . . .
\includeonly{...}
\begin{document}
\frontmatter
\include{toc}
\mainmatter
\include{chap1}
\include{chap2}
. . .
\backmatter
\include{back}
\end{document}
```

where the file `toc.tex` contains only commands for the title page, table of contents, and other listings:

```
\begin{titlepage} ... \end{titlepage}
\tableofcontents \listoftables \listoffigures
```

and `back.tex` those for bibliography and index:

```
\bibliography{..}
\printindex
```

The chapters to be processed are selected by adding them to the argument of `\includeonly`, not by changing the `\include` commands, which must always be present to ensure that all the `.aux` are input every time. For example, by giving `\includeonly{toc, chap3}` one processes the table of contents and chapter 3.

9.1.3 Monitor input and output

There are times when it is desirable that L^AT_EX write a message to the computer monitor during processing. This can be achieved with the command

```
\typeout{message}
```

where *message* stands for the text that is to appear on the monitor. This text is printed when the L^AT_EX processing reaches this command. It is also written to the transcript file, but does not appear in the processed output.

If *message* contains a user-defined command, it will be interpreted and its translation appears on the monitor. The same thing applies to L^AT_EX commands. This could have dire consequences if the commands, either user or L^AT_EX, are not really printable. To print the command name literally, precede it with the command `\protect`.

The command

```
\typein[\com_name]{message}
```

also writes the *message* text to the monitor, but then it waits for the user to enter a line of text from the keyboard, terminated by typing the `<return>` key. If the optional argument `\com_name` is missing, the line of text is inserted directly into the processing. In this way, one could, for example, reuse the same text for a letter for several addressees, entering the name each time from the keyboard. Suppose the text contains

```
Dear \typein{Name:}\ \ ...
```

then what appears on the monitor is:

Name:

\@typein=

At this point, one enters the name of the recipient. If on successive processings 'George', 'Fred', and 'Mary' are entered, the result will be a set of identical letters differing only in their salutations as 'Dear George', 'Dear Fred', and 'Dear Mary'.

If the `\typein` command contains the optional argument `\com_name`, this is treated the same as

```
\typeout{message} \newcommand{\com_name}{entered definition}
```

In this case the definition is stored under the command name `\com_name` interactively and may be invoked and executed in the rest of the document like any other L^AT_EX command.

With some experience in L^AT_EX methodology, it soon becomes obvious that *interactive* processing with the `\typein` command can be very practical. For example, if the preamble contains

```
\typein[\files]{Which files?}
\includeonly{\files}
```

the following appears on the monitor:

```
Which files?

\files=
```

Now L^AT_EX waits for the user to type in the names of one or more files (separated by commas) to be processed. This avoids having to modify the main processing file with an editor every time.

A similar procedure may be employed when a form letter is to be sent to various recipients. One can enter the name and address and even the salutation interactively. Complete forms may be processed by L^AT_EX in this way, with the entries being made from the keyboard.

Warning: The `\typein` command may not be used as the argument of another L^AT_EX command! It may, however, be given in environments such as `minipage`.

Exercise 9.2: Change the main file from Exercise 9.1 so that the files `exer1.tex`, `exer2.tex`, and `exer3.tex` may be read in with the `\include` command. Arrange that you can determine interactively which of the files is to be processed.

Exercise 9.3: Generate output of the form

Certificate Olympic Spring Games Walterville 1992

Finger Wrestling

Gold	A. T. Glitter	AUR	7999.9	Points
Silver	S. Lining	ARG	7777.7	Points
Bronze	H. D. Tarnish	CUP	7250.0	Points

so that the following enquiries appear on the monitor one after the other

```
Message   Command= Input
Sport:    \@typein= Finger Wrestling
Unit:     \unit   = Points
Gold:     \@typein= A. T. Glitter
Country:  \@typein= AUR
Value:    \@typein= 7999.9
Silver:   \@typein= S. Lining
. . . . . = . . . . .
```

and the appropriate entries are made interactively. The third column contains the answers necessary to produce the above sample output. Repeat the program with different entries. Let your imagination run wild.

9.2 In-text references

In a longer text, one often wants to refer to other chapters, sections, tables, and figures, or to pages where some other description has been given. One also needs an index of certain keywords that occur throughout the document. In the days before electronic text processing, such cross-references and indices meant an enormous amount of extra work for the author or secretary. Today the computer can alleviate much of this burden.

In the old days, referring to earlier parts of the text by page number was tedious but feasible. Referencing future parts that had not yet been written had to be limited to section numbers since the page numbers were not yet known, or space had to be left for the page number to be entered at a later date.

The production of a book is usually a progressive and constantly shifting process. The manuscript may not necessarily be written in the order in which it is to appear, and even once the initial draft version is finished, there will be major changes due to new considerations by the author or to knowledgeable advice from reviewers. Revisions, deletions, and insertions of entire sections or even chapters are commonplace, not to mention possible reordering of parts of the text.

L^AT_EX relegates all the problems associated with such major alterations to the past. No matter what changes the author makes, the information necessary for the cross-references and keyword index is stored for use at any point in the text.

9.2.1 Cross-references

As already pointed out in several places, the command

```
\label{marker}
```

is used to store the current value of the relevant counter (section, equation, etc.) at that point in the text, which may then be referred to at other places. The value is assigned to the key *marker*, which may be any combination of letters, numbers, and characters, even those that are normally special symbols.

The page number on which the `\label` command was issued can be printed with

```
\pageref{marker}
```

at any point earlier or later in the document.

If the `\label` command is given after a sectioning command, or within an equation, `eqnarray`, or `enumerate` environment, or inside the argument of a `\caption` within the `figure` or `table` environments, the command

```
\ref{marker}
```

prints the number of that section, equation, figure, table, or enumeration that was current when *marker* was defined, and in the correct format. For `enumerate`, the same number is printed as is generated by the `\item` command where the `\label` appeared. Reference may also be made to theorem-like structures created by a `\newtheorem` command if the `\label` is given within the text of that theorem command. For example, a `\label` with marker text `bo-wei` was issued in the text of the Bolzano-Weierstrass theorem on page 80:

```
\begin{theorem}[Balzano--Weierstrass]
  \label{bo-wei}...\end{theorem}
```

so that the input text

```
Theorem~\ref{bo-wei} on page~\pageref{bo-wei}
```

generates the output ‘Theorem 1 on page 80’. Similarly, the input text

```
for Table~\ref{budget04} on page~\pageref{budget04},
see also Section~\ref{sec:figref}
```

produces ‘for Table 7.1 on page 174, see also Section 7.6’, since that section contains the marker `\label{sec:figref}`.

Note that the counter whose value is stored by the `\label` command depends on the context in which the command is given. This is normally fairly self-evident. Within regular text, it will be the counter and its value for the last issued sectioning command, which might not be immediately visible. Therefore, when reference to a section number is desired, it is best to place the `\label` command immediately after the appropriate sectioning command, or even within its argument, as part of the title text. This is in fact the recommended method. Put the `\label` command within the body of the text only when you want to refer to the page number at that point.

A list of all label markers, their translations, and page numbers may be produced by processing the file `lablst.tex`, provided with the L^AT_EX installation.

9.2.2 How cross-referencing works



It is useful to know how the cross-referencing information is managed. What the `\label` command actually does is to write the key name together with the current value of the appropriate counter(s) and the current page number to an auxiliary file with the root name of the document file plus the extension `.aux`. The `\ref` and `\pageref` commands obtain their information from this `.aux` file, which is read in at the beginning of the next processing by the `\begin{document}` command. The same situation as for the table of contents (Section 3.4.2) also applies here: on the first run, the `.aux` file does not exist so that no cross-reference information

can be output; instead the information is gathered and written to a new `.aux` file at the end of the run. A warning message is printed at the end if the auxiliary information has changed and a new run is necessary.

If selective processing is being done with `\includeonly` and a set of `\include` commands, then an `.aux` file exists for each included files, as well as for the main source file. These `.aux` files are read in on every processing run, whether or not the corresponding `.tex` file is input. In this way, counter and cross-referencing information for the entire document is maintained even when only parts of it are processed.

9.2.3 Referencing parts of other documents

Package: It is possible to refer to the marker keys in another L^AT_EX document by means of David Carlisle's `xr` package, which is part of the tools collection (Section B.5.4). With

```
\externaldocument{filename}
```

all the keys in the specified file become available in the current document, to be printed with `\ref{key}` as usual. Difficulties arise if there are duplicate key names in any of the external or current files. To circumvent this problem, an optional argument can be given, for example as `\externaldocument[x-]{filename}`, in which case all the markers in the external file will be prefixed with `x-`. Thus the external key `intro` is referred to with `\ref{x-intro}`.

9.2.4 Smart referencing: the `varioref` package

Package: When the object being referenced is so close that you know it will be `varioref` on the same or adjacent page, you very likely will want to alter the text accordingly. However, it might later switch from 'same' to 'adjacent' after another revision and you will have to change that text once more. The tools package `varioref` by Frank Mittelbach does this for you. It defines a command `\vref{key}` which is almost the same as '`\ref{key}` on page `\pageref{key}`.' However, if `\label{key}` is on the current, previous, or next page, it prints appropriate text. Thus depending on the relative locations, `Fig. \vref{f1}` automatically produces one of

Fig. 5	<i>when \label on same page,</i>
Fig. 5 on the preceding page	<i>on previous page,</i>
Fig. 5 on the next page	<i>on following page,</i>
Fig. 5 on the facing page	<i>on opposite page with twoside option,</i>
Fig. 5 on page 24	<i>when two or more pages away.</i>

The command `\vpageref` prints only the page part of the text, or 'on this page' if `\label{key}` is on the current page. It may also take one or two optional arguments: the texts for the current page and non-current pages. For example, the example `\vpageref[above]{f1}` prints one of

the example above	when <code>\label</code> on same page,
the example on the previous page	on following page,
the example on page 24	when two of more pages away,

while the `\vpageref[above example][example]{f1}` outputs one of:

the above example	when <code>\label</code> on same page,
the example on the next page	on the following page,
the example on page 24	when two of more pages away.

A range of numbers and pages can be produced with the command `\vrefrange`, which takes two mandatory arguments, both label keys. It prints text like ‘5 to 7 on pages 212–214’, or ‘5 to 7 on the next page’, and so on. It takes one optional argument, the text to print when both labels are on the current page.

The page part of `\vrefrange` only is printed with `\vpagerefrange`, which also takes two mandatory (label key) arguments and one optional (text) one. If both labels are on the same page, it behaves like `\vpageref`; the optional argument is printed if both are on the current page.

Since English text is automatically printed by the above commands, they would not be very useful for documents, say, in Italian. The `varioref` package therefore accepts all the language options recognized by the `babel` system (Chapter 11) to reprogram the texts. With the option `italian`, one will get texts like *in questa pagina* for ‘on this page’ and *nella pagina precedente* for ‘on the preceding page’, and so on.

All the texts are stored in special commands which can be redefined by the user:

<code>\reftextbefore</code>	previous but non-facing page
<code>\reftextfacebefore</code>	previous but facing page
<code>\reftextafter</code>	next but non-facing page
<code>\reftextfaceafter</code>	next but facing page
<code>\reftextfaraway{key}</code>	more than one page away
<code>\reftextpagerange{key1}{key2}</code>	page range of 2 labels
<code>\reftextlabelrange{key1}{key2}</code>	range of 2 different labels.

The last three must be redefined with 1 or 2 arguments, as

```
\renewcommand{\reftextfaraway}[1]{on page \pageref{#1}}
\renewcommand{\reftextpagerange}[2]{on pages \pageref{#1}%
                                     --\pageref{#2}}
\renewcommand{\reftextlabelrange}[2]{\ref{#1} to \ref{#2}}
```

There is also `\vreftextvario{text1}{text2}` to provide altering texts for the above commands, so that the same text is not printed every time.

9.3 Bibliographies

Academic publications normally include a list of references, or bibliography, containing the names of other works that are cited within the text

by means of a running number. This is the system supported by standard L^AT_EX, described in the next section. The alternative citation method, with author name and year of publication, can be achieved with various extension packages, as described in Section 9.3.4).

Often the bibliography has not been finalized before the main text is started. Especially for numerical bibliographies, it would be a great nuisance to have to go through the whole text and change all the numbering every time something was added to the bibliography. Therefore L^AT_EX is programmed not only to format the bibliography but also to keep track of its alterations and additions in order to modify the references in the text automatically.

The bibliography is generated most conveniently and efficiently from a general database with the help of the B_IB_TE_X program that should be part of the L^AT_EX installation. How to prepare such databases is explained in Chapter 14. The advantages of a database is that its entries can be reused again and again for all future documents, while the formatting style in each bibliography listing can vary according to the requirements of each document. One can, however, write it by hand without B_IB_TE_X.

9.3.1 Bibliography by hand

The actual bibliography, whether created by B_IB_TE_X or by hand, is placed inside the environment

```
\begin{thebibliography}{sample_label}
  entries
\end{thebibliography}
```

The individual *entries* in the bibliography each begin with the command

```
\bibitem[label]{key} entry_text
```

Without the optional argument *label*, `\bibitem` produces a running number in square brackets as the label for the reference in the text. With *label*, one can give whatever indicator one wishes, such as an abbreviation of the author's name, or an arbitrary reference number. The mandatory argument *key* is a reference key, much like that for the cross-referencing `\label` command (page 213), which is used to make the actual citation in the main text. The key name can be made up of any combination of letters, numbers, and symbols except commas.

The bibliography information itself is contained in *entry_text*, such as 'author, title, publisher, year, edition, page numbers', possibly in various typefaces. The output text will be indented after the first line by a width equal to that of the *sample_label*, so this should be as large as the longest label in the bibliography. For the standard application with running numbers, *sample_label* should be a dummy number with as many digits

as the largest label (for example 99 if there are more than 10 but less than 100 entries).

For bibliographies with author-year citations (Section 9.3.4) the entries in the `thebibliography` are the same, except that the optional *label* must be present, taking a special form that will transfer the author and year texts to the citation commands.

A sample (numerical) `thebibliography` environment could look as follows:

```
\begin{thebibliography}{99}
  \bibitem{lamport} Leslie Lamport. \textsl{\LaTeX\ -- A Document
    Preparation System}, 2nd edition. Addison-Wesley,
    Reading, MA, 1994
    . . . . .
  \bibitem{knuth} Donald E. Knuth. \textsl{Computers and
    Typesetting Vol.\ A--E}. Addison-Wesley,
    Reading, MA, 1986
  \bibitem[6a]{knuth:a} Vol A: \textsl{The {\TeX}book}, 1986
    . . . . .
  \bibitem[6e]{knuth:e} Vol E: \textsl{Computer Modern
    Typefaces}, 1986
\end{thebibliography}
```

Here `lamport`, `knuth`, and `knuth:a` have been chosen as keys. The sample label is given as 99 since a two-digit number produces sufficient indentation for the standard form of `\bibitem`. The entry with the key `knuth` is the sixth in the list and thus it automatically receives the label [6]; in order for its sub-entries `knuth:a` . . . `knuth:e` to be printed as [6a] . . . [6e], it is necessary to set their optional *label* arguments to 6a . . . 6e. (Yes, this does violate the automatic labeling system.)

The bibliography is normally printed near the end of the document by placing the `thebibliography` environment at the desired location. For document classes `book` and `report`, the word **Bibliography** appears as an unnumbered chapter title at the beginning, whereas for `article` the word **References** is written as an unnumbered section heading. The above sample bibliography appears as:

- [1] Leslie Lamport. *LaTeX - A Document Preparation System*, 2nd edition. Addison-Wesley Co., Inc., Reading, MA, 1994

- [6] Donald E. Knuth. *Computers and Typesetting Vol. A-E*. Addison-Wesley Co., Inc., Reading, MA, 1986
- [6a] Vol A: *The TeXbook*, 1986

- [6e] Vol E: *Computer Modern Typefaces*, 1986

Exercise 9.4: Produce a bibliography with the `thebibliography` environment, with a label consisting of the first three letters of the author's name followed

by the last digits of the year of publication. If the same author has more than one work in a given year, add a running letter to distinguish them, for example *knu86c*, *knu86d*. With such labels, it is appropriate to make the reference keys the same as the labels. The indentation depth should be 1.5 cm.

Note: The indentation depth is determined by the argument *sample_label* in the `thebibliography` environment. This is usually a dummy text with the right width. This width can be given precisely with `\hspace{width}`.

Exercise 9.5: Copy the `thebibliography` environment from the above exercise to the end of your standard exercise file (but ahead of the `\end{document}` command). Refer to the entries in the bibliography by inserting `\cite` commands into your text. Make sure that the key in the `\cite` command is written exactly as in the `\bibitem` command in the `thebibliography` environment.

9.3.2 Bibliography with BibTeX

Bibliographic databases and the BibTeX program are fully described in Chapter 14. Here we just review the essential aspects for the L^AT_EX source file.

- All the information for the literature references is placed in one or more databases. Each entry is given an identifying key (the *key* in the `\bibitem` argument) which is the handle to refer to it.
- In the source text, citations to the references are made with various commands like `\cite`, `\citet`, `\citep`, taking the *key* as argument.
- The *bibliography style* must be specified somewhere in the document with `\bibliographystyle{bib_style}`; the *bib_style* determines how the bibliography is to be formatted; the basic style is `plain` for numerical citations, or `plainnat` with the `natbib` package.
- Give the command `\bibliography{database}` where the bibliography is to appear; *database* is a list of all databases to be searched.
- Process the source file with L^AT_EX; run BibTeX and then L^AT_EX twice.

BibTeX writes a bibliography following the formatting specifications of *bib_style* into a `thebibliography` environment, storing it in a file with extension `.bb1`; this file is input by the `\bibliography` command.

9.3.3 Numerical citations

Standard L^AT_EX can only handle numerical bibliographies and citations. In this case, the citation in the text is made with the command

```
\cite[extra]{key}
```

where *key* is the reference key that appears in the `\bibitem` command. With the sample bibliography on page 218, the source text

```
For additional information about \LaTeX\ and \TeX\ see
\cite{lampport} and \cite{knuth, knuth:a}.
```

yields: For additional information about L^AT_EX and T_EX see [1] and [6, 6a].

If the optional argument *extra* is included in the `\cite` command, this text is added after the label(s) but still inside the square brackets.

```
The creation of a bibliographic database is described in
\cite[Appendix B]{lampport}, while the program \BibTeX\
itself is explained in \cite[pages 74, 75]{lampport}.
```

The creation of a bibliographic database is described in [1, Appendix B], while the program B_BT_EX itself is explained in [1, pages 74, 75].

9.3.4 Author-year bibliographies with `natbib`

An alternative bibliographic citation style, used in this book and in many scientific journals, makes reference to other published works by citing the author's name and year of publication. In this case, the entries in the bibliographic listing are not numbered. The citation itself may be either parenthetical [*Jones et al.*, 1999] or textual, as shown by *Jones et al.* [1999]. There may be some variations within this style: for example, in this book parentheses are used in place of square brackets and the name is left in normal type. None of this is supported by standard L^AT_EX, but rather by additional packages.

There are a number of packages developed to deal with this situation, each requiring a different syntax for the optional *label* argument in the `\bibitem` command in order to transfer the author and year information to the citation commands. And each has its own bibliography style (`.bst`) file to allow B_BT_EX to accomplish this.

Package:
`natbib`

The `natbib` package by Patrick W. Daly is the most universal of these, being compatible with the `\bibitem` syntaxes, and thus with the `.bst` files, of other author-year packages such as `apalike`, `chicago`, and `harvard`, to name just a few. Furthermore, `natbib` can even produce numerical or superscript citations as well, and will also function with the standard (numerical) bibliography styles and `\bibitem` syntax, albeit only with numerical citations.

Furthermore, `natbib` is integrated with the `hyperref` package (Section 10.2.4) to make citations into automatic links to the bibliographic entry.

The author-year `\bibitem`

The required `natbib` form of the 'optional' *label* argument to `\bibitem` within the `thebibliography` environment is


```
\bibitem [short(year)long] {key} ...
```

where *short* is the short author list (e.g. Jones et al.) and *long* is an optional full author list. A sample bibliography might be:

```
\begin{thebibliography}{99}
\bibitem[James et al.(2001)James, Jones, and Smith]{JAM01}
  P. R. James, F. J. Jones, and R. T. Smith, ... 2001.
\bibitem[Jones et al.(1999)Jones, Baker, and Toms]{JON99}
  F. J. Jones, H. P. Baker, and W. V. Toms, ... 1999.
\bibitem[Jones et al.(2000a)Jones, Toms, and Baker]{JON00}
  F. J. Jones, W. V. Toms, and H. P. Baker, ... 2000a.
\bibitem[Jones et al.(2000b)Jones, Toms, and Baker]{JON00b}
  F. J. Jones, W. V. Toms, and H. P. Baker, ... 2000b
\end{thebibliography}
```

Such bibliographies will be automatically produced by $\text{BIB}\text{T}_\text{E}\text{X}$ when a bibliography style is invoked with the `\bibliographystyle` command that is compatible with `natbib`. Three such `.bst` files are provided with `natbib`, as substitutes for 3 of the 4 basic $\text{BIB}\text{T}_\text{E}\text{X}$ styles: `plainnat`, `unsrnat`, and `abbrvnat` (Section 14.1). However, many others also exist as contributions for specific publishers and journals.

Author-year citations

There is a flexible citation syntax permitting parenthetical (`\citep`) and textual (`\citet`) citations, with the abbreviated or full author list, with optional notes both before and after the citations. For example,

<code>\citet{JON99}</code>	\Rightarrow Jones et al., (1999)
<code>\citet[pg.~22]{JON99}</code>	\Rightarrow Jones et al., (1999, pg. 22)
<code>\citep{JON99}</code>	\Rightarrow (Jones et al., 1999)
<code>\citep[pg.~22]{JON99}</code>	\Rightarrow (Jones et al., 1999, pg. 22)
<code>\citep[e.g.][]{JON99}</code>	\Rightarrow (e.g. Jones et al., 1999)
<code>\citep[e.g.][pg.~22]{JON99}</code>	\Rightarrow (e.g. Jones et al., 1999, pg. 22)
<code>\citet*{JON99}</code>	\Rightarrow Jones, Baker, and Toms (1999)
<code>\citep*{JON00}</code>	\Rightarrow (Jones, Toms, and Baker, 2000)

The citation punctuation (type of brackets, points between multiple citations, dates, and so on) can be selected by options when loaded, specified by declarations, or programmed to be associated with the bibliography style. See below.

Multiple citations are available as usual, with compression of repeated authors:

<code>\citet{JON99, JAM01}</code>	\Rightarrow Jones et al. (1999); James et al. (2001)
<code>\citep{JON99, JAM01}</code>	\Rightarrow (Jones et al., 1999; James et al., 2001)
<code>\citep{JON99, JON00}</code>	\Rightarrow (Jones et al., 1999, 2000a)
<code>\citep{JON00, JON00b}</code>	\Rightarrow (Jones et al., 2000a,b)

In numerical citation mode, the command `\citep` behaves like the standard `\cite` command, printing the reference's number in brackets, while `\citet` gives the authors' names followed by the reference's number. This is textual citation in numerical mode, allowing the author to use the same syntax for both citation modes.

<code>\citet{JON99}</code>	⇒ Jones et al. [21]
<code>\citet[pg. ~22]{JON99}</code>	⇒ Jones et al. [21, pg. 22]
<code>\citep{JON99}</code>	⇒ [21]
<code>\citep[pg. ~22]{JON99}</code>	⇒ [21, pg. 22]
<code>\citep[e.g.][] {JON99}</code>	⇒ [e.g. 21]
<code>\citep[e.g.] [pg. ~22] {JON99}</code>	⇒ [e.g. 21, pg. 22]
<code>\citep{JON00, JON00b}</code>	⇒ [21, 32]

The commands `\citeauthor{key}` and `\citeyear{key}` print just the author names and year, respectively; a starred version `\citeauthor*` prints the full author list.

There also exist capitalized variants of these citation commands, `\Citet`, etc., for use at the beginning of a sentence, when the first author name begins with something like 'von'.

<code>\citet{deLaM89}</code> has shown ...	⇒ de la Mar has shown ...
<code>\Citet{deLaM89}</code> has shown ...	⇒ De la Mar has shown ...

Package options

Many aspects of formatting the citations can be controlled by options specified when loading `natbib` with the `\usepackage` command:

`round` citations in round parentheses (default);

`square` citations in square brackets;

`curly` citations in curly braces;

`angle` citations in angle brackets;

`colon` to separate multiple citations with semicolons (default);

`comma` to use commas as separators;

`authoryear`
for author-year citations (default);

`numbers`
for numerical citations;

`super` for superscripted numerical citations;

- `sectionbib`
 puts the bibliography in a section instead a chapter; for use with the `chapterbib` package (Section 9.3.5);
- `sort` orders multiple citations into the sequence in which they appear in the list of references;
- `sort&compress`
 as `sort` but in addition multiple numerical citations are compressed if possible (as 3–6, 15);
- `longnamesfirst`
 makes the first citation of any reference the equivalent of the starred variant (full author list) and subsequent citations normal (abbreviated list).

Note: `natbib` defaults to author–year citations, but if any single `\bibitem` command does not conform to any of the recognized author–year syntaxes, it will switch automatically to numerical citations.

Further customizations

There are several formatting commands in `natbib` that may be (re)defined by the author to achieve special effects in the bibliography, such as font or spacing between entries. In standard L^AT_EX, these are all fixed.

- `\bibsection`
 can be redefined to the desired sectioning command for introducing the list of references. This is normally `\section*` or `\chapter*`.
- `\bibpreamble`
 is printed after the bibliography heading but before the actual list of references; is normally undefined, but can be defined to insert any desired leading text.
- `\bibfont`
 can be a font declaration, e.g. `\small` to apply to the whole list of references; is normally undefined.
- `\citenumfont`
 can be a font declaration or command like `\itshape` or `\textit` for formatting numerical citations; normally undefined.
- `\bibnumfmt`
 is a command with an argument to format the numbers in the list of references; the default definition is `[#1]`.

`\bibhang`

is the indentation after the first line of each reference; change this with the `\setlength` command.

`\bibsep`

is the vertical spacing between references; change this with the `\setlength` command.

There are many other customization possibilities and specialized features to `natbib` which can be found in the supplied documentation (process `natbib.dtx` if it not already provided as a `.dvi` or `.pdf` file) or in the short summary `natnotes.tex`.

9.3.5 Multiple bibliographies

Package: `chapterbib`
Package: In standard \LaTeX , with or without \BibTeX , there can only be one bibliography per document. However, it is not uncommon for a book to consist of independent chapters, each with its own bibliography and local citations.

The `chapterbib` package by Donald Arseneau solves this problem. It requires that the document be broken up into individual source files that are read into the main file with the `\include` command of Section 9.1.2. Each such file must contain its own `thebibliography` environment, or its own `\bibliographystyle` and `\bibliography` commands if \BibTeX is to be used. The citation commands will work locally within each file. Even if the same reference appears in several bibliographies, with a different number each time, the citations will refer to the one in the local file.

One must process \BibTeX individually on each of the separate files, creating a series of `.bbl` files. Then the document is reprocessed with \LaTeX , at least twice; the `.bbl` files are read in by the individual `\bibliography` commands.

If you cannot make use of the `\include` commands because you do not want each file to begin on a new page, you can still localize the bibliographies and their citations with the `cbunit` environment. This does not work with \BibTeX , however. In that case, you must still put the bibliographic units into separate files, and then read them in with the `\cbinput{file}` command. Set the package option `draft` when loading `chapterbib`, process with \LaTeX , process each file with \BibTeX , remove the `draft` option, process with \LaTeX at least twice.

With classes `book` and `report`, the bibliography is placed in an unnumbered chapter; this is undesirable if each chapter is to have its own bibliography. In this case, add the package option `sectionbib` to change the bibliography to an unnumbered section instead.

The `chapterbib` package is compatible with `natbib` except for the `sectionbib` option. The two packages clash on their redefinitions of `bibliography`. In this case, add the option to `natbib` instead of to `chapterbib`.

9.4 Keyword index

L^AT_EX itself does not produce a keyword index automatically as it does a table of contents, but it can prepare input data for the MakeIndex program (Section 9.4.3) that does generate such an index, in a form that L^AT_EX can use on a later run.

9.4.1 The index environment

A keyword index is formatted in the environment

```
\begin{theindex} index_entries \end{theindex}
```

which switches to a two-column page format with a running head *INDEX*. The first page of the index carries the heading **Index** in the same size as a chapter heading for the *book* and *report* document classes, and as a section heading for the *article* class. (More precisely, the actual word printed is contained in the command `\indexname` which may be redefined for other languages.) The individual entries are made with commands

```
\item \subitem \subsubitem and \indexspace
```

followed by the keywords and their page numbers. For example,

commands, 18	<code>\item</code> commands, 18
arguments, 19, 101	<code>\subitem</code> arguments, 19, 101
multiple, 103, 104	<code>\subsubitem</code> multiple, 103, 104
replacement symbol, 20	<code>\subsubitem</code> replacement symbol, 20
as environments, 42	<code>\subitem</code> as environments, 42
used as arguments for sectioning commands, 41, 42	<code>\subitem</code> used as arguments for sectioning commands, 41, 42
	<code>\indexspace</code>
displayed text, 21-32	<code>\item</code> displayed text, 21--32

If the text entry is too long for one line, it is broken and continued on the next line, indented deeper than all other lines, as in the above example ‘used as argument for sectioning commands, 41, 42’. The command `\indexspace` leaves a blank line in the index.

9.4.2 Preparing the index entries

The `theindex` environment only sets up a suitable format for the index. The entries themselves, as well as their page numbers, are generated by the MakeIndex program described in Section 9.4.3. This program requires input information from the L^AT_EX file in the form of unsorted keywords and page numbers. The author enters this information in the text file with the command

```
\index{index_entry}
```

where *index_entry* is the text to be entered into the index. It may contain any combination of letters, numbers, and symbols *including even command characters and blanks*. This means that even commands may be included in the *index_entry*, such as `\index{\LaTeX\ logo}`. Even the one command that may otherwise never be used as an argument, `\verb`, may be included. However, if *index_entry* does contain a command, `\index` may not be used as an argument of another command.

Normally all the `\index` commands are ignored by \LaTeX and do absolutely nothing. They are activated only when the preamble contains the command

```
\makeindex
```

in which case, a file with the document's root name plus the extension `.idx` is opened. Now the `\index` commands write *index_entry* and the current page number to this file in the form

```
\indexentry{index_entry}{pagenumber}
```

It is this `.idx` file that is the input to the MakeIndex program. There are special symbols that may be used in the *index_entry* to indicate main and subitems and other refinements.

The MakeIndex program expects the `\index` entries to be of one of the three forms:

```
\index{main_entry}
\index{main_entry!sub_entry}
\index{main_entry!sub_entry!sub_sub_entry}
```

The individual main and sub-entries may contain any combination of characters with the exceptions of `!`, `@`, and `|`. The exclamation point is the divider between the various entry fields. If the `\index` command contains only a main entry, this will become the text for an `\item` command. The main entries will be in alphabetical order.

If the `\index` command contains a main and a sub-entry, the text *sub_entry* will be assigned to a `\subitem` command underneath the corresponding *main_entry*. The texts for the `\subitem` will also be in alphabetical order. Similarly the text of a *sub_sub_entry* will appear following a `\subsubitem` command, alphabetically ordered, below the appropriate *sub_entry* text.

The main and sub-entries may also contain special characters and even \LaTeX commands that are to be neglected during alphabetization. This is indicated by an entry of the form *lex_entry@print_entry*, in which *lex_entry* is used for the alphabetical ordering while *print_entry* is the actual text to be output. For example, in the keyword index in this book, which was generated with MakeIndex, all the command names appear as input text and are ordered without the preceding `\` character. These entries were made in the text as `\index{put@\verb=\put=}`.

An entry may be terminated with the character sequences |(or |) to designate the beginning and end of a range of page numbers. For example,

```
\index{table|(} on page 95
\index{table|)} on page 110
```

produces the entry 'table' with page numbers given as 95–110.

Instead of having the page number printed after the entry, a reference may be made to another index entry. For example, with

```
\index{space|see{blank}}
\index{table|seealso{array}}
```

the entries 'space, *see* blank' and 'table, *see also* array' are made in the index.

The three characters !, @, and | therefore have special functions for the MakeIndex program. In order to print these characters literally as text without their functions, the *quote* character " must precede them. For example, "! represents a literal exclamation point and not the entry divider.

The quote character itself is thus a fourth special symbol and must be entered literally as "". However, there is a special rule in MakeIndex syntax that says a quote character preceded by a backslash will be interpreted as part of a command: thus \" may be used to put a German umlaut in an entry (as in \index{Knappen, J\"org}). This special rule can lead to additional problems at times: in this book the index entry \! had to be typed as "\\!".

It is possible to specify varying fonts for the page number. For example, in the index of this book, page numbers are set in bold face to indicate the page where a command is defined or first explained. This is achieved with an entry of the form

```
\index{blank} on page 11, and
\index{blank|textbf} on page 22
```

which in the second case puts the page number for this entry as the argument of a command \textbf. The line in the theindex environment becomes

```
\item blank, 11, \textbf{22}
```

Note: The vertical bar in the \index entry is not a typing error, but must replace the backslash as the \LaTeX command symbol under these circumstances.

There is a file `idx.tex` in the \LaTeX installation, which can improve the readability of the `.idx` files. By processing the `idx.tex` file (that is, calling `latex idx`), the user is prompted for the name of the `.idx` file to list:



```
***** After the root name of the .idx file has
* Enter idx file's first Name. * been entered from the keyboard, a two-
***** column page format is output contain-
ing the index_entry texts listed under
\filename= page headings of the form Page n. No
further information is obtained through such a formatted listing, but it is far
easier to work with than a straightforward output of the .idx file alone.
```

Even if the `\index` commands have no effect without the `\makeindex` command in the preamble, it is a good idea to include them in the text from the initial development of the document. The `\makeindex` command can be included later when the final version of the document is ready. At this point, the `MakeIndex` program can be run to produce the `theindex` environment from the data in the `.idx` file just as `BBTeX` produces the `thebibliography` environments. This tool is described in the next section.

Package:
`showidx`

The \LaTeX installation also contains the package `showidx`, which prints the index entries from the `\index` commands as marginal notes, beginning at the top of the page on which they occur. This is useful for going through a preliminary version of the document to check that all index entries are really on the proper page or whether additional entries have to be made.

If `showidx` is used, it is a good idea to increase the width of the marginal note box with the declaration `\marginparwidth` (Section 4.10.6) in the preamble. Unfortunately, the present book format is not suitable for such a demonstration.

9.4.3 Running MakeIndex

The tiresome drudgery of making up the `theindex` environment for a keyword index can be dispensed with if the program `MakeIndex` is available. This program was written by Pehong Chen with the support of Leslie Lamport. We will give only an abbreviated description of its use here. More details are in the documentation accompanying the program package.

The program `MakeIndex` processes the `.idx` file, producing as output another file with the root name of the document and the extension `.ind`, containing the complete `theindex` environment. It is run by clicking the appropriate icon in the editor shell, or from a command line with

```
makeindex root_name.idx or simply makeindex root_name
```

Package:
`makeidx`

A subsequent \LaTeX processing outputs the index at the location of the `\printindex` command which, together with the `\see` command, is defined in the package `makeidx`. Thus the production of an index in this way requires the package file `makeidx` to be loaded with the `\usepackage` command.

The alphabetical ordering of `MakeIndex` normally follows the standard ASCII code, first *symbols*, then *digits*, and finally *letters*, where upper case comes before lower case. Blanks are included as symbols. There are a

number of options that allow these rules to be changed. How the options are invoked when the program is called depends on the computer type, but we assume here a hyphen preceding the option letter, as in

```
makeindex -g -l root_name
```

The most important options are:

- l Letter ordering: blanks are ignored when sorting;
- c Compress blanks: multiple and leading blanks are removed as they are in normal L^AT_EX;
- g German ordering: following the German rules in which *symbols* precede *letters* (*lower* before *upper* case) which precede *numbers*; the sequences "a", "o", "u", and "s (the codes for *ä*, *ö*, *ü*, and *ß* in the usual L^AT_EX adaptations for German) are treated as though they were ae, oe, ue, and ss, which is standard German practice;
- s Style specification: allows the name of an index formatting file to be included to redefine the functioning of MakeIndex.

The `-s` option reads in an index style file containing commands to define both the input and output of the MakeIndex program. For example, it is possible to change the special symbols `!`, `@`, `|`, and `"` so that different characters execute their functions and they themselves revert to being pure text.

The style-defining file consists of a list of pairs in the form *keyword attribute*. The attribute is either one character in single quotes (for example, 'z'), or a character string in double quotes ("a string"). The most important keywords, together with their default definitions, are:

- quote '"' defines the quote symbol;
- level '!' defines the entry separation symbol;
- actual '@' defines the lexical switch symbol;
- encap '|' defines the dummy command symbol for page formatting.

There are many more keywords for defining complicated output structures. These are described in the documentation that should be included with the MakeIndex program package.

The file `makeindex.tex` contains a short manual by Leslie Lamport (but without mentioning style definitions).

9.4.4 Glossary

A ‘glossary’ is a special index of terms and phrases alphabetically ordered together with their explanations. To help set up a glossary, L^AT_EX offers the commands

```
\makeglossary           in the preamble and
\glossary{glossary_entry} in the text part
```

which function just like the commands for making up a keyword index. The entries are written to a file with extension `.glo` after the command `\makeglossary` has been given in the preamble. The form of these file entries from each `\glossary` command is

```
\glossaryentry{glossary_entry}{pagenumber}
```

The information the `.glo` file can be used to establish a glossary. However, there is no equivalent to the `theindex` environment for a glossary, but a recommended structure is the `description` environment (Section 4.3.3) or a special `list` environment (Section 4.4).

PostScript and PDF

PostScript is a printing and plotting language developed by the Adobe Systems Inc. Unlike the printing instructions for other types of printers, the PostScript code may be written to an ASCII file, viewed on a computer monitor, put online, downloaded, included in emails. It therefore represents a type of electronic paper.

It is also a programming language, and thus offers enormous possibilities for including special effects that cannot easily be inserted with other output formats. Several packages exist to exploit these, packages which are then limited to PostScript output. However, the PostScript advantages are so attractive that this can be justified.

Portable Document Format, PDF, is another Adobe product, a successor to PostScript, inheriting many of its properties. However, PDF includes many features to make it applicable to true electronic documents: internal and external links, bookmarks, animation, encryption, etc., features that have no correspondence in paper. It represents a revolutionary new type of information medium.

PostScript has played a very important role in the development of \LaTeX , setting the standards for graphics inclusion, and offering additional font families over the standard Computer Modern set. Now PDF carries on that tradition. With the pdf \TeX program, PDF is actually married to \TeX and thus to \LaTeX .

In the next sections we describe the generation of PostScript output with \LaTeX , the usage of PostScript (type 1) fonts, and then the production of PDF output with all its bells and whistles.

10.1 \LaTeX and PostScript

PostScript output is best produced with the `dvips` driver program written by Tomas Rokicki, available with most \TeX installations. It is this very powerful and flexible program that has set the standard for DVI conversion programs.

Its two most significant features are the inclusion of graphics as *encapsulated* PostScript images, as described in Chapter 6, and the capability of making use of PostScript fonts in place of the Computer Modern ones (Section G.5). There are also enhanced drawing capabilities, as demonstrated in Sections 13.2.2 and 13.3.2.

10.1.1 The dvips driver

The dvips driver program operates on the DVI result from T_EX, with or without L^AT_EX, to generate PostScript output, which may be written to a file or sent directly to a printer. One either clicks the appropriate icon in the editor shell, or issues the command from a command line prompt:

```
dvips myfile
```

to process `myfile.dvi` and generate `myfile.ps`. (The L^AT_EX source text was of course in `myfile.tex`.) The PostScript file may be viewed with a PostScript viewer like GhostView or sent to a PostScript printer, or included in an email.

There are many options that may be included in the command line, appearing between `dvips` and the file name. For example, to output five pages only starting at the 10th, sending them to a file named `p5-15.ps`, give

```
dvips -p 10 -n 5 -o p5-15 myfile
```

You may also specify the first (`-p`) and last (`-l`) page numbers, whether only odd (`-A`) or even (`-B`) pages are to be printed, or in reverse order (`-r`). The page numbers with `-p` and `-l` refer to the actual page numbers in the document, or rather to its first occurrence. Hence `-p 8` might start with page *viii* rather than page 8. Specifying `-p =8` will start with the 8th page, regardless of its actual number. The list of options can be printed to the monitor with `dvips --help`.

One useful option is `t landscape` to rotate the output into landscape mode, which should be done if the document has been processed with the `landscape` option in `\documentclass`. However, `dvips` has another way of accomplishing this: add the driver-specific command

```
\special{landscape}
```

in the source text itself and `dvips` will automatically print in landscape mode.

The output is written to a file with the same root name as the input, but with extension `.ps`, unless the option `-o filename` is given. To send the output directly to a printer, specify that printer as the output ‘file’, as `-o \lpt1`. Beware, if that printer is not a PostScript printer, it will simply output the PostScript code directly as text, something that normally uses a considerable amount of paper.

A full manual for `dvips` should be available as `dvips.ps` or `dvips.pdf`; otherwise the source file `dvips.tex` can be processed (with T_EX, not L^AT_EX!).

The program is configured to the local installation by means of a file `config.ps` that should be located in `texmf\dvips\config`. This sets up certain parameters for the default printer, as well as various paper formats, indicating which is to be the default (European A4 or American letter). This can be overridden with `-t a4` or `-t letter`. Another important configuration item is a list of font mapping files (Section 10.1.3), to associate T_EX font names with actual PostScript fonts and their files.

Additional configuration files are usually provided, for specific printers or other font mappings, all with the name `config` plus a different extension. They may be invoked on the command line with the option `-P` plus extension. For example, `config.cx` contains lines for a generic PostScript printer with resolution of 300 dpi; with `-P cx`, this file is input, overriding the default values in `config.ps`. Another example for adding PostScript fonts is given in Section 10.1.3.

Of course, the `dvips` driver manages not only PostScript fonts but also the standard T_EX pixel fonts generated by the METAFONT program (Section G.3). These bitmaps are stored in `.pk` files that need to be generated for the desired printer, size, and resolution. Originally, the user had to ensure that they were present before the driver program could address them. Fortunately, `dvips` has revolutionized this process by calling METAFONT itself if the needed `.pk` files are missing.

However, it is the use of PostScript fonts that make `dvips` especially interesting. We describe in some detail how they are integrated into the T_EX/L^AT_EX system in the next sections since almost all of this applies equally well to PDF output.

10.1.2 Invoking PostScript fonts

Under the New Font Selection Scheme of Appendix A, it is relatively simple to invoke the PostScript fonts, provided that the font definition `.fd` files are provided. These are normally to be found in the directory `psnfss` in the standard installations. It also contains packages for the 35 standard PostScript fonts, plus those for a number of other commercially available fonts. These packages are actually quite simple; for example, the `times.sty` file contains only four lines, which are listed on page 379. All these packages do is redefine the three font families, `\rmdefault`, `\sfdefault`, `\ttdefault` and the bold face default attribute `\bfdefault`.

The packages for the 35 standard fonts, and the three assignments that they make, are listed in Table 10.1 on the next page. (The 35 fonts include italic and bold variants of these.)

These packages are only meaningful when the resulting DVI output is to be transformed with `dvips` to PostScript or PDF files, or when the L^AT_EX source is to be processed with `pdfTEX` to generate PDF directly. Other

Table 10.1: The psnfss packages and their fonts

Package	\rmfamily	\sffamily	\ttfamily
times.sty	Times-Roman	Helvetica	Courier
palatino.sty	Palatino	Helvetica	Courier
newcent.sty	NewCenturySchlbk	AvantGarde	Courier
bookman.sty	Bookman	AvantGarde	Courier
avant.sty		AvantGarde	
helvet.sty		Helvetica	

drivers can only handle the \TeX pixel fonts described in Appendix G (also known as type 3 fonts). Some drivers, in particular the monitor previewers `xdvi` and `windvi`, will also invoke programs to generate the bitmap `.pk` files from the PostScript `.pfb` source files.

Why bother to use these packages when `dvips` is capable of including the pixel fonts just as well? The answer is that the standard PostScript fonts are well known from other applications, and there are additional commercially available fonts in PostScript format; they therefore offer a wider choice than simply the traditional Computer Modern fonts that are limited to \TeX and \LaTeX .

Furthermore, although the pixel fonts can be included in PDF output, the results viewed on the monitor are simply atrocious. They are slow to draw and appear very fuzzy. (They do print all right, however.) PDF should make use of PostScript fonts exclusively. In Section G.6 we explain how the standard Computer Modern and Extended Modern fonts are now available in PostScript encoding, especially for this need.

10.1.3 Installing PostScript fonts



The packages listed in the previous section invoke the PostScript fonts by means of the NFSS system, provided they have been properly included in the installation. This means that the following files must be present:

- `.tfm` the font metric files for both the virtual and raw fonts;
- `.fd` the NFSS font definition files associating the font attributes to precise virtual font names; these and the `.tfm` files are the only ones read by \LaTeX itself;
- `.vf` virtual font files that instruct the DVI driver how to produce the characters; usually this refers to characters in a real font with different encoding;
- `.map` mapping files that tell the `dvips` driver the true internal names of the real fonts, plus any re-encodings or distortions that must be undertaken.

The `.map` files are a feature of `dvips` that has been taken over by `pdfTEX` and other programs that make use of PostScript fonts. It translates the L^AT_EX names for the fonts into the internal names used by PostScript itself. For example, the line

```
ptmr8r Times-Roman "TeXBase1Encoding ReEncodeFont" <8r.enc
```

says that the font known to L^AT_EX as `ptmr8r` is really the *Times-Roman* font. Furthermore, the text in quotes is also inserted into the PostScript output; in this case, it is a command to state that the symbol assignments (the encoding) should be that of the `TeXBase1Encoding` vector. The definition of this encoding vector is to be found in the file `8r.enc`, which must also be inserted, since it is not part of basic PostScript.

Note that type 1 fonts are essentially a collection of symbols identified by name, whereas application programs like L^AT_EX address characters by positional number. It is the encoding vector that associates those numbers with symbol names for the benefit of the application. However, they are not intrinsic to the font itself.

For fonts other than the 35 standard ones included in every PostScript output device, additional files must also be input. For example

```
h1hr8r LucidaBright "TeXBase1Encoding ReEncodeFont"
                                <8r.enc <h1hr8a.pfb
```

says that the file `h1hr8a.pfb` must also be inserted into the PostScript output, containing the drawing instructions for the *LucidaBright* font.

The `.map` files are listed in the `config.ps` file that configures `dvips`. Often there is a single mapping file named `psfonts.map`, included with the line

```
p psfonts.map
```

in `config.ps`, or individual mapping files are listed, as

```
p psnfss.map
p +pazo.map
p + . . . .
```

prefixed with a `+` sign after the first one.

In some cases, the map file listings are also included in additional `config` files, such as `config.cms` for the PostScript versions of the standard Computer Modern fonts. If these are not already contained in `config.ps` or in `psfonts.map`, they may be added on the `dvips` command line with the option `-P cms`. Other families of PostScript fonts can be included in the same manner.

10.1.4 Long road from input code to output character



Let us illustrate with an example how L^AT_EX translates an input character with given font attributes into a particular symbol in a specific font. Suppose we have the following attributes (Section A.1):

```
Encoding: OT1    Family: ptm    Series: b    Shape: s1
```

The encoding and family indicate the font definition file that associates these attributes with real font names, in this case `ot1ptm.fd`. In that file, one finds this set of attributes to be assigned to font `ptmbo7t`; this is the Berry name for *Times-BoldOblique, 7-bit-text* (Tables G.2 and G.3 on pages 504 and 505).

Our sample input code is `\AE`; according to file `ot1enc.def`, this corresponds to character 29 in the OT1 encoding. \LaTeX thus writes instructions to the `.dvi` file to output the symbol in position 29 of font `ptmbo7t`. And with that, \LaTeX is finished with its part of the operation.

The next step is to process the `.dvi` file with the `dvips` driver. When this program searches for a font, it first looks in the map files, then it seeks the `.vf` virtual font files, and finally it tries to find it as a `.pk` pixel file. In our case, it discovers the virtual font `ptmbo7t.vf`, which tells the driver that character 29 is to be symbol 198 of font `ptmbo8r`. This is the same basic font but with 8-bit-raw encoding. Again `dvips` searches for this next font, and finds it in a mapping file, containing the line

```
ptmbo8r Times-Bold ".167 SlantFont TeXBase1Encoding
                                ReEncodeFont" <8r.enc
```

This tells the driver that it is to use the font with the internal name *Times-Bold* slanted by a factor 0.167 and encoded according to the `TeXBase1Encoding` encoding vector. The file `8r.enc` must also be copied into the output.

Finally, the output `.ps` file is sent to a PostScript printer or other PostScript interpreter. The specified encoding vector indicates that character 198 is the symbol with the internal name `AE`, which is then printed from the *Times-Bold* font, distorted as required. The long road has come full circle.

10.2 Portable Document Format (PDF)

In 1993, Adobe Systems Inc. published the *Portable Document Format*, or PDF, as a page-oriented format for electronic documents. As a successor to PostScript, which is also an Adobe creation, it combines fixed textual contents with hypertext elements, compression methods, and security measures. It corresponds to true electronic publishing with a fixed layout but still with hardcopy possibilities. Compared to PostScript files, the PDF output is considerably smaller, especially when graphics are included. Today it is considered the ideal medium for storage and transmitting large documents electronically in final format.

10.2.1 Producing PDF output

Adobe has made the PDF specification public and freely available so that anyone is entitled to write software to produce and to read files in this format. They have also made available a free reader program, *Acrobat Reader*, so it is hardly worthwhile writing another one, at least not commercially. (Ghostscript can also interpret PDF as well as PostScript.)

Where Adobe makes its money is in the sales of programs to produce and manipulate PDF files. Of these, the main ones are:

- Acrobat Distiller to convert PostScript into PDF, and
- Acrobat program to modify existing PDF files.

In the latter case, ‘modification’ means adding links, changing colors, including navigational aids, and inserting notes; it does not mean altering the actual textual content in any way.

Today most graphical and text processing programs are capable of generating PDF output. For the L^AT_EX user, there are three routes that may be taken to produce PDF output. The obvious one is `.tex` → `.dvi` → `.ps` → `.pdf` using `dvips` to generate the PostScript and then Distiller or Ghostscript to create the PDF file.

The other two methods are to employ a DVI-to-PDF driver, or the pdf_TE_X program to go directly to PDF, by-passing the intermediate DVI output. We describe each of these in the next sections.

Used on their own, all of these methods produce a simple PDF file containing nothing more than the text itself, a sort of electronic paper. The hypertext features that make an electronic document really live can be added automatically with the help of the `hyperref` package described in Section 10.2.4.

10.2.2 The `dvipdfm` driver

The driver program `dvipdfm` by Mark A. Wicks is the equivalent of `dvips` for PDF output. As its name implies, it converts DVI to PDF output. (The `m` suffix is to distinguish it from a previously announced `dvipdf` program that never came to fruition.)

Graphics input can be included with the `graphics` or `graphicx` packages (Section 6.1) by specifying the option `dvipdfm`. The allowed graphics formats are JPEG, PNG, and PDF.

The program is called from a command line with

```
dvipdfm myfile
```

to convert `myfile.dvi` to `myfile.pdf`. As for `dvips`, there are many options that may be included. It is best to read the provided manual in `dvipdfm.pdf` or `dvipdfm.dvi`, or produce it by processing `dvipdfm.tex` with T_EX.

The configuration is set up by means of a file named `config` in the `dvipdfm` directory. This is set up similarly to the `config.ps` file for `dvips`, including the list of mapping files, although these have a different syntax to those of `dvips`.

Hypertext features and other PDF additions can be added with the `hyperref` package (Section 10.2.4).

10.2.3 The pdfTeX program

The most direct method of getting PDF output is to process the L^AT_EX file with pdfTeX, a variation on the T_EX program developed by Hàn Thê Thành. The following points should be noted:

- pdfTeX behaves just like the regular T_EX program unless the declaration `\pdfoutput=1` is issued before the first page is output; in this case, it generates PDF instead of DVI output and activates many new T_EX-like commands for including PDF features.
- Since pdfTeX combines the functionality of both the T_EX program and a DVI driver, it must be able to deal with fonts in the way that a driver program would. Originally this meant that it could only handle PostScript type 1 fonts, but now it can also cope with METAFONT bitmap fonts (type 3) as well as TrueType fonts. The bitmap fonts however look very bad when viewed, but this is a viewer problem.
- When started, the program reads a configuration file `pdftex.cfg` which can set many parameters, as such page size, offsets, PDF compression level, and specifies the names of font mapping files. It may also set the default output to PDF, avoiding having to set `\pdfoutput` in the source text.
- The font map files are identical to those used by `dvips` (page 236); they relate the T_EX name for the font to various characteristics, encoding scheme, true name, and specify the file containing the character drawing instructions.
- New T_EX-like commands exist to include PDF features, like compression level, page attributes, document information, opening setup, forms, annotations, links, bookmarks, and article threads.
- Graphics can be included in PNG, TIFF, or JPEG formats; PDF files may be inserted provided they contain only a single page without any fonts or bitmaps. The graphics packages (Section 6.1) support pdfTeX by means of a `pdftex graphics` option.

To run pdfTeX with L^AT_EX (often referred to as pdfL^AT_EX), it is necessary to generate a L^AT_EX format (Section B.1.3) using pdfTeX instead of T_EX, with the `-ini` option, renaming the resulting `latex.fmt` to `pdflatex.fmt`; it is then called with the command

```
pdftex &pdflatex
```

Most installations contain a command `pdflatex` that translates to this combination. The editor shell should also have an icon that invokes this command.

We do not describe the new T_EX-like commands to add PDF features to the output, preferring to use the L^AT_EX-like commands of the `hyperref` package. For information on the intrinsic new pdfT_EX commands, see *The L^AT_EX Web Companion* (Goossens and Rahtz, 1999), which also explains the `hyperref` package in detail. The pdfT_EX manual should also be available on your system under `texmf\doc\pdftex\` in various formats.

So which of the above methods is to be recommended? The PostScript + Distiller is the most inelegant, involving two intermediate steps (DVI and PS) and requires purchasing the Distiller program. Alternatively one can use the free GhostView program for the conversion to PDF, but one still has the intermediate steps. And if one selects this route, one must be certain that `dvips` uses the PostScript version of the Computer Modern fonts, by setting up the mapping files accordingly.

The `dvipdfm` program is in the original spirit of T_EX, that uses DVI as a universal intermediate format for all outputs. Purists might tend to respect this ideal. After all, no one ever considered rewriting T_EX to produce PostScript output directly. That said, one must consider that T_EX was invented in the days when no one printer specification dominated the field. Today, PDF is much more than a printer format; it is *the* means of representing documents electronically. That alone would not justify preferring pdfT_EX over a DVI-to-PDF converter, nor would the fact that it saves a processing step; the deciding argument is that pdfT_EX has established itself as reliable, robust, and flexible.

In the end, it is likely a question of which program one is more comfortable with, and which one has given the better results for the particular user.

10.2.4 The `hyperref` package

Package: `hyperref` Sebastian Rahtz has written an ambitious package `hyperref` to add automatic hypertext links to L^AT_EX documents that are intended to become HTML (using L^AT_EX2HTML, Section E.1.1 or T_EX4ht, Section E.1.2) or PDF files (using any of the methods described above). Not only do all internal cross-references link to their reference points, citations are also linked to the list of references, table of contents to the section headings, and index listings to the original text. Additional links to external documents are possible by means of a single syntax for all types of output. And it does this with a uniform syntax even though all the conversion methods have their own syntaxes.

Because this package redefines many aspects of the L^AT_EX kernel and of many other packages, it should always be loaded as the very last one to be sure that it has the final word.

It is especially for PDF output, whether by means of PostScript plus Distiller, with `dvipdfm`, or directly with pdfT_EX, that this package is extremely useful. Figure 10.1 on the next page gives an example of such a

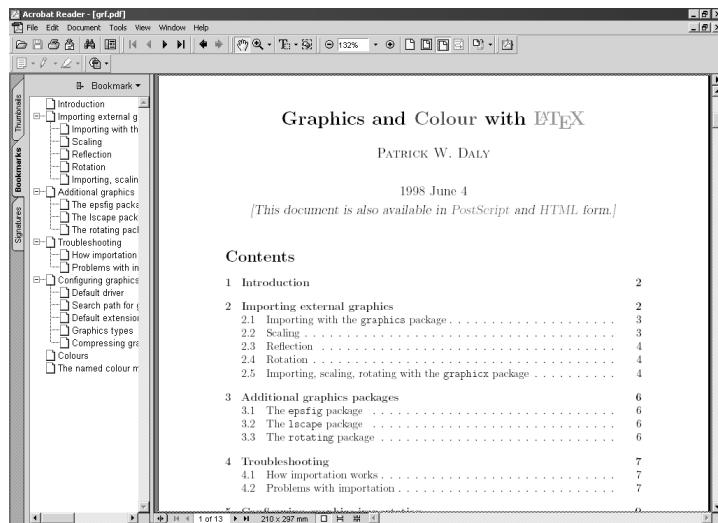


Figure 10.1: Output produced by pdf \TeX with the `hyperref` package for automatic links, with an outline list at the left.

PDF file, where it should be noted that the table of content entries are all links to their sections, as are the entries in the left-hand outline, which is also generated automatically. The package provides $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ -like commands for the PDF features.

Before we go any further, we should explain certain terms that are used below.

Links are indicated as a piece of text in a different color, or surrounded by a frame, or may be an image, which when clicked cause the viewer to jump to another document or some other place in the current document.

Anchors (also called *targets*) are the destinations for links. They are provided with an identifying name so that the link can find them. Some anchors are meant only for internal linking within the document, while others are visible from outside.

Thumbnails are small images of the pages that are displayed in a thumbnail window by the viewer. They may be used to locate a certain page more quickly, especially if it has an obviously different appearance because of a figure it contains. Double clicking the page image causes the viewer to jump to that page.

Bookmarks are special links to places in the document, associated with a *view*, usually meaning a zoom factor, or a specification like ‘fit

page to width of window'. The bookmark window displays all these, and by double clicking them, one jumps to that location and view. Bookmarks are ordered within a tree, with sub-bookmarks and so on. The bookmark display may have the tree opened or closed.

Outline is the usual use for bookmarks, building a table of contents, or outline, for the whole document. The word 'outline' is used here, but the PDF viewers refer to 'bookmarks'. The latter is really far more general.

Options for hyperref

There are a large number of parameters that may be configured for the package, either as options in the `\usepackage` command, or with the `\hypersetup` command, or with a configuration file. An example of setting options with the first method is:

```
\usepackage[pdftex,
  pdftitle={Graphics and Color with LaTeX},
  pdfauthor={Patrick W Daly},
  pdfsubject={Importing images and use of color in LaTeX},
  pdfkeywords={LaTeX, graphics, color},
  pdfpagemode=UseOutlines,
  bookmarks,bookmarksopen,
  pdfstartview=FitH,
  colorlinks,linkcolor=blue,citecolor=blue,
  urlcolor=red,
]
{hyperref}
```

Options that take a value are given with an equals sign and the value; for multiple values, or text, the values must be placed within curly braces, as shown in the example. Options that are either `true` or `false` are simply given (to make them `true`) or equated to `false`. Options may also be given with the `\hypersetup` command, as for example:

```
\hypersetup{colorlinks, linkcolor=blue}
```

Values that are colors must be a name of a defined color, as explained in Section 6.2; the name must be defined before it is first used. However, some color values must be the three numbers of the `rgb` model. The colors of link borders may only be given as `rgb`. The `hyperref` package automatically loads the `color` package if `colorlinks` is given.

One option must specify the driver name for which the output is intended; in the above example this is `pdftex`, but other possibilities are:

```
dvipdf      dvipdfm  dvips   dvipsone dviwindo hypertex
latex2html  pdftex   tex4ht  textures  vtex
```

The option `hypertext` is not for any particular driver, but rather for any that conforms to the HyperTeX guidelines, such as `dvips`. There is also a `draft` option that turns off all hypertext features.

The next four options in the example (`pdftitle`–`pdfkeywords`) are entries for the PDF document information stored in the file and displayed only when the viewer shows the document summary. The complete set of such options is:

```
pdfauthor    pdfcreator pdfkeywords
pdfproducer pdfsubject pdftitle
```

The standard paper size options of Section 3.1.1 are all recognized and one of them must be given, either as an option to `hyperref` or as a global option in the `\documentclass` command. This is necessary to set up the size of the PDF page. Reminder, these are:

```
a4paper      a5paper    b5paper
executivepaper legalpaper letterpaper
```

Here is a list of all of the remaining options, with default value in brackets.

- 4 `(false)` use Acrobat 4 features;
- `anchorcolor`
 `(black)` set color of anchors (targets of internal links);
- `backref`
 `(false)` adds links in the bibliography back to the citation; with `pagebackref`, a list of pages is added to the bibliography, each being a link back to the citation;
- `baseurl`
 determines the prefix for URLs given with `\href`;
- `bookmarks`
 `(true)` make bookmarks out of sectioning commands;
- `bookmarksnumbered`
 `(false)` include section numbers in bookmark text;
- `bookmarksopen`
 `(false)` start document with bookmarks tree opened;
- `bookmarksopenlevel`
 `(max)` the level to which bookmarks are opened;
- `bookmarkstype`
 `(toc)` specifies which ‘contents’ file used for bookmarks;
- `breaklinks`
 `(false)` allows link text to break over lines;

- `citebordercolor`
(0 1 0) the color of the border around citations;
- `citecolor`
(green) color of citation links when `colorlinks` given;
- `colorlinks`
(false, but true for `tex4ht` and `dviwindo`) link and anchor texts are to be colored, according to color specifications for the various types of links; without this, link text is surrounded by a frame;
- `debug` (false) output diagnostic messages;
- `draft` (false) turn off all hyperlinking;
- `extension`
(`dvi`) default extension of linked files using the `xr` package (Section 9.2.3); the package tries to guess whether the file specified by `\externaldocument` should be `.dvi` or `.pdf`; with PDF output, the viewer will open that external file and switch to it;
- `filebordercolor`
(0 .5 .5) color of the border around file links;
- `filecolor`
(cyan) color of file links when `colorlinks` given;
- `frenchlinks`
(false) use small caps instead of color for links;
- `hyperfigures`
(false) make figures into hyperlinks;
- `hyperindex`
(true) make index entries into links back to referenced text;
- `hypertextnames`
(true) use guessable (obvious) names for links;
- `implicit`
(true) redefine \LaTeX internal commands;
- `linkbordercolor`
(1 0 0) color of the border around links;
- `linkcolor`
(red) color of link text when `colorlinks` given;
- `linktocpage`
(false) the page numbers in the table of contents (or list of figures/tables) are the links, rather than the text itself;

- `menubordercolor`
(1 0 0) color of the border around Acrobat menu links;
- `menucolor`
(red) color for Acrobat menu links when `colorlinks` given;
- `naturalnames`
(false) use L^AT_EX-computed names for links;
- `nesting`
(false) links are allowed to be nested, although none of the existing drivers support this;
- `pageanchor`
(true) an anchor (target) is placed automatically on every page, something that is necessary of the table of contents is to act as links;
- `pagebackref`
(false) adds to each entry in the bibliography a list of page numbers linked to their citations;
- `pagebordercolor`
(1 1 0) color of the border around page links;
- `pagecolor`
(red) color of page links when `colorlinks` given;
- `pdfborder`
(0 0 1, but 0 0 0 with `colorlinks`) width of the border around links in PDF files; the first two numbers are always zero, the third is the line thickness in points;
- `pdfcenterwindow`
(false) positions the document window in the center of the computer monitor when the PDF file is opened;
- `pdfffitwindow`
(false) resizes the document window to fit the first page when the PDF file is opened;
- `pdfhighlight`
(/I) determines how the Acrobat menu buttons behave when clicked; /I for inverse, /N for none, /O for outline, /P inset highlighting;
- `pdfmenubar`
(true) makes the menu bar in the PDF viewer visible;
- `pdfnewwindow`
(false) a new window is opened when the PDF viewer switches to another file;

pdfpagelayout

(SinglePage) determines the page layout for the PDF viewer; other values are OneColumn (all pages in a continuous column), TwoColumnLeft (two columns, with odd numbers on the left), TwoColumnRight (two columns, with odd numbers on the right);

pdfpagemode

(None) determines initial display in the PDF viewer; other values are UseThumbs (show thumbnails), UseOutline (show bookmarks), FullScreen (no tool or menu bars, window is full screen);

pdfpagescrop

a set of four numbers determining the crop box when the the PDF file is opened, similar to a bounding box;

pdfpagetransition

(R) determines how the pages are changed; possible values are Split (like opening a curtain), Blinds (like Venetian blinds), Box (a rectangle opens from the center), Wipe (vertical line moves across page), Dissolve (old page dissolves into new), Glitter (variation on dissolve), R (replace); additional parameters can be added where appropriate: /Dm (with Split and Blinds) followed by /H (horizontal) or /V (vertical), /Di (with Wipe and Glitter) followed by 90, 180, 270 for the direction of motion, /M (with Split and Box) followed by /I (inwards), /O (outwards); see page 344 for a simplified interface to this feature;

pdfstartpage

(1) the first page number to be displayed when the PDF file is opened;

pdfstartview

(Fit) determines the initial view when the PDF file is opened; takes values of Fit (fit page to window), FitH (fit to width), FitV (fit to height), FitB (fit to bounding box), FitBH (fit to bounding box width), FitBV (fit to bounding box height), XYZ (no change);

pdftoolbar

(true) makes the tool bar in the PDF viewer visible;

pdfview

(XYZ) determines the page view when a link moves to a new page; takes same values as pdfstartview;

pdfwindowui

(true) makes the user interface elements (bookmarks, thumbnails) in the PDF viewer available; if false, they are permanently switched off;

plainpages

(`true`) makes the anchors for the pages to be their Arabic form; if `false`, the page anchors are as the page numbers are formatted, highly recommended if the document contains both Roman and Arabic page numbers;

raiselinks

(`false`) with the `hypertex` driver, makes the border around links the actual height of their contents, rather than the current baseline separation;

runbordercolor

(`0 .7 .7`) color of the border around 'run' links;

unicode

(`false`) enables Unicode encoded PDF strings;

urlbordercolor

(`0 1 1`) color of the border around URL links;

urlcolor

(`magenta`) color of URL links when `colorlinks` given;

verbose

(`false`) issues many extra messages.

Using a configuration file

Very often a user will find that he or she needs the same set of options in almost every document. Rather than issuing that set again and again, it is possible to prepare a configuration file named `hyperref.cfg` containing a `\hypersetup` command with all the option settings that one normally wants. One effectively resets the default values. Any settings in the \LaTeX source text itself will override those defaults.

The `hyperref.cfg` file must be located somewhere where it will always be found by the \LaTeX processing. It might very well be that a file of that name already exists, and will be read in in preference to yours. To check just which location is being used, examine the `transcript.log` file for the full path name, and then edit that version of `hyperref.cfg`.

Linking commands

The main purpose of the `hyperref` package is to add the automatic links between cross-referencing commands and tables of contents. However, it also enables access to PDF features with \LaTeX -style commands. One of these is the ability to add manual links within the file and to other documents, locally or on the Web. The commands to achieve this are:

`\hyperbaseurl{url_pre}`

sets a prefix for all external URLs specified by other commands, so that the common part of a set of URLs need only be given once; this is the same as the `baseurl` option, but can be changed within the document;

`\href{url}{text}`

makes *text* into a link to the full URL given by *url* prefixed with the current base URL; special characters like # and & can be type in *url* directly;

`\hyperimage{url}{image_url}`

inserts the image referenced by *image_url*;

`\hyperdef{category}{name}{text}`

establishes *text* as a target (anchor) with name *category.name*;

`\hyperref{url}{category}{name}{text}`

makes *text* a link to *url#category.name*;

an alternate syntax is `\hyperref[key]{text}` to make *text* an internal link to the location marked with `\label{key}`;

`\hypertarget{name}{text}`

establishes *text* as an internal target (anchor) with the name *#name*;

`\hyperlink{name}{text}`

makes *text* a link to the internal target *#name*.

The cross-referencing commands `\ref{key}` and `\pageref{key}` (Section 9.2.1) automatically create links to the corresponding `\label{key}` location. As pointed out above, one can also create a manual link with `\hyperref[key]{text}`.

The `hyperref` package also provides starred versions `\ref*` and `\pageref*` which function as the regular ones but without creating a link.

Adding Acrobat buttons

An electronic document is active, as indicated by the links within it for jumping to other sections. But it is also possible to insert other types of ‘actions’, in the form of buttons which, when clicked, do something, like flipping to the next page, opening another document, or even quitting.

The `hyperref` package can add such functionality for the Acrobat viewers, by means of the command

```
\Acrobatmenu{action}{text}
```

Table 10.2: Actions available from the Acrobat menus (after Goossens and Rahtz, 1999, page 48)

<i>Acrobat Menu</i>	<i>Available options for \Acrobatmenu</i>
File	Open, Close, Scan, Save, SaveAs, Optimizer:SaveAsOpt, Print, PageSetup, Quit
File→Import	ImportImage, ImportNotes, AcroForm:ImportFDF
File→Export	ExportNotes, AcroForm:ExportFDF
File→DocProps	GeneralInfo, OpenInfo, FontsInfo, SecurityInfo, Weblink:Base, AutoIndex:DocInfo
Edit	Undo, Cut, Copy, Paste, Clear, SelectAll, Ole:CopyFile, TouchUp:TextAttributes, TouchUp:FitTextToSelection, TouchUp:ShowLineMarkers, TouchUp:ShowCaptureSuspects, TouchUp:FindSuspect, Properties
Edit→Prefs	GeneralPrefs, NotePrefs, FullScreenPrefs, Weblink:Prefs, AcroSearch:Preferences(Windows)or, AcroSearch:Prefs(Mac), Cpt:Capture
Edit→Search	AcroSrch:Query, AcroSrch:Indexes, AcroSrch:Results, AcroSrch:Assist, AcroSrch:PrevDoc, AcroSrch:PrevHit, AcroSrch:NextHit, AcroSrch:NextDoc
Edit→Fields	AcroForm:Duplicate, AcroForm:TabOrder
Document	Cpt:CapturePages, AcroForm:Actions, CropPages, RotatePages, InsertPages, ExtractPages, ReplacePages, DeletePages, NewBookmark, SetBookmarkDest, CreateAllThumbs, DeleteAllThumbs
View	ActualSize, FitVisible, FitWidth, FitPage, ZoomTo, FullScreen, FirstPage, PrevPage, NextPage, LastPage, GoToPage, GoBack, GoForward, SinglePage, OneColumn, TwoColumns, ArticleThreads, PageOnly, ShowBookmarks, ShowThumbs
Tools	Hand, ZoomIn, ZoomOut, SelectText, SelectGraphics, Note, Link, Thread, AcroForm:Tool, Acro.Movie:MoviePlayer, TouchUp:TextTool, Find, FindAgain, FindNextNote, CreateNotesFile
Window	ShowHideToolBar, ShowHideMenuBar, ShowHideClipboard, Cascade, TileHorizontal, TileVertical, CloseAll
Help	HelpUserGuide, HelpTutorial, HelpExchange, HelpScan, HelpCapture, HelpPDFWriter, HelpDistiller, HelpSearch, HelpCatalog, HelpReader, Weblink:Home
Help(Windows)	About

where *text* becomes a button to execute *action* when clicked. Of course, *text* can be more than mere text, it is often a graphics that really does look like a button.

The actions available are those provided by the Acrobat and Acrobat Reader programs. These are not documented by Adobe, but are listed in Table 10.2 on the facing page, which is taken from Goossens and Rahtz (1999), who credit Merz (1998) for having figured them out. These actions are therefore specific to these viewers only, and may change with later versions. They may all be executed by the viewers themselves, by means of pull-down menus in the menu bar, indicated in the left column of Table 10.2.

The main purpose of this command is to set up navigational controls on each page of a document that is meant essentially for screen viewing. The regular tool bar may be turned off, which is why the document itself must provide it. This is best put into a footline, and that is most conveniently done with the `fancyhdr` package (Section 3.2.2).

```

\documentclass[a4paper]{article}
\usepackage{fancyhdr}
\usepackage[pdftex,colorlinks,
pdftoolbar=false,pdfmenubar=false,
pdfwindowui=false,
pdfpagemode=FullScreen,
]{hyperref}
\pagestyle{fancy}
\cfoot{\navbar}

\newcommand{\navbar}{%
\Acrobatmenu{FirstPage}{$\Leftarrow$}
\Acrobatmenu{PrevPage}{$\leftarrow$}
\Acrobatmenu{NextPage}{$\rightarrow$}
\Acrobatmenu{LastPage}{$\Rightarrow$}
\Acrobatmenu{Close}{$\bullet$}
}

```

The above produces a footline containing

← ← → → •

(by default in red) as clickable buttons to jump to the first page, to the previous page, to the next page, to the last page, respectively. And clicking the bullet • closes the document. Of course, it looks even better if icons are made up and inserted with `\includegraphics`.

Multilingual L^AT_EX

The original versions of T_EX and L^AT_EX were set up for the English language, American variant. The built-in hyphenation patterns were for English only, and several English words such as ‘Figure’ and ‘Bibliography’ were included explicitly in certain commands. This in fact violates the rules of good programming which forbid doing anything explicitly. In Europe, L^AT_EX users quickly made customizations for their particular languages. The adaptation for German, `german.sty`, is a set of macros from many contributors collected together by H. Partl of the Technical University of Vienna, and has become the standard for the German-speaking T_EX Users Group (DANTE). It contains some facilities for other languages, including French and English.

The key to the `german` package and other language adaptations is the fact that the standard L^AT_EX document styles (and later classes for L^AT_EX 2_ε) had been altered so that explicit English words in the output were replaced by reprogrammable command names. These names had become standardized among European users for application to all languages. The modified L^AT_EX version by J. Schrod from Darmstadt was known as I^AT_EX, for International L^AT_EX. These names and their standard English values are to be found on page 459.

As of December 1, 1991, these naming features became part of the L^AT_EX standard. They represent good programming practice, since they allow even English-speaking users to change certain titles easily, for example ‘Abstract’ into ‘Summary’ or ‘Contents’ into ‘Table of Contents’. Naturally, they were taken over, and extended upon, by L^AT_EX 2_ε.

Another important feature for multilingual usage is the T_EX `\language` counter which allows more than one set of hyphenation patterns to be stored in the format with `initex` (Section B.1.3). Different patterns are activated by setting `\language` to the appropriate number. This is now standard for all T_EX version over 3.0, which should now be universal.

Individual language packages such as `german` maintained by Bernd Raichle and `french` by Bernard Gaulle have now been superseded to a large extent today by the universal multilanguage system: `babel`.

11.1 The babel system

The babel system has been developed by Johannes Braams at the Dutch PTT Research Laboratories. Its main purpose is to provide a standard means of switching languages with a flexible method for loading the hyphenation patterns. It has been written to work with both T_EX and L^AT_EX.

The three main requirements for a single language adaptation are: translation of the explicit English words, special commands to simplify certain features of that language, and selection of the appropriate hyphenation patterns. To these babel adds: removal of the special commands and testing for the current language. The language-specific files must conform to the babel selection command structure. The concept of ‘dialects’ is also included, that is, two ‘languages’ that share a common set of hyphenation patterns. Examples are German and Austrian as well as British and US English, which only differ in the form of the dates.

At present, the babel package contains definition files for the following languages (more can be added at any time):

Afrikaans, Bahasa, Basque, Breton, Bulgarian, Catalan, Croatian, Czech, Danish, Dutch, English, Esperanto, Estonian, Finnish, French, Galician, German, Greek, Hebrew, Hungarian, Icelandic, Irish Gaelic, Italian, Latin, Lower Sorbian, North Sami, Norwegian, Polish, Portuguese, Romanian, Russian, Scottish Gaelic, Spanish, Slovakian, Slovenian, Swedish, Serbian, Turkish, Ukrainian, Upper Sorbian, Welsh

The necessary definition files are delivered with the installation. The hyphenation patterns for the various languages must be obtained from another source, however. For most of these files, there are no special commands for accents or punctuation: they only redefine the naming commands for those words that normally print English text.

The `german.sty` package has been a great inspiration for babel. However, because of the name conflict, it was necessary to create a new `germanb.sty` (and `ngermanb.sty` for the new German grammar rules) for babel applications, which contains the same set of special commands, but with a few babel additions. Similarly, the babel French file had to be named `frenchb.sty` to distinguish it from the existing `french.sty`.

To exploit the babel features most fully, one should produce a L^AT_EX format (Section B.1.3) that incorporates it directly. To this end, the `hyphen.cfg` supplied with babel must be used with the `language.dat` file configured for the local languages and hyphenation patterns that are to be pre-loaded. Only in this way can one conveniently get the right word division for each language.

Alternatively, one can use a normal L^AT_EX format and load babel as a regular package, as illustrated below. The switching of hyphenation

patterns will then be questionable.

The babel files

The babel installation provides the following files for its implementation:

`babel.def` contains some of the basic macros for running babel, and must be loaded by the first language file read in; the remaining macros are either already in the format itself (loaded from `hyphen.cfg`) or read in from `switch.def`; `babel.def` determines which is the case and reacts accordingly;

`switch.def` contains the additional babel macros, to be read in if these macros are not already stored in the L^AT_EX format;

`hyphen.cfg` contains the same macro definitions as in `switch.def`, plus some more that are to be run by `initex`; if this file is available during the creation of the L^AT_EX format (Section B.1.3), these macros are built into that format and file `switch.def` is not necessary at run time;

`babel.sty` is a master package that loads the language files specified as options;

`language.dat` contains a list of languages and the file names of their hyphenation patterns; this file is read in by `hyphen.cfg` during the `initex` run; it is the only file that may (must!) be edited for the particular installation (Section 11.2);

`esperant.ldf` . . . the language definition files.

`esperant.sty` . . . compatibility files that read in the `.ldf` files.

Invoking babel

The babel package is loaded with the desired languages as options:

```
\usepackage[english,esperanto]{babel}
```

Alternatively, the language names may be used as global options, something that is recommended if there are other packages that take the languages as options, as

```
\documentclass[english,esperanto]{article}
\usepackage{babel,varioref}
```

In both cases, the last named language is the one that is immediately active.

The recognized language names that may be used as options are:

afrikaans	=canadian	=polutoniko-	=portuguese
bahasa	esperanto	greek	=brazilian
basque	estonian	hebrew	=brazil
breton	finnish	magyar	romanian
bulgarian	french	=hungarian	russian
catalan	=français	icelandic	scottish
croatian	=canadien	irish	spanish
czech	=acadian	italian	slovak
danish	galician	latin	slovene
dutch	german	lowersorbian	swedish
english	=germanb	samin	serbian
=USenglish	=ngerman	norsk	turkish
=american	=austrian	=nynorsk	ukrainian
=UKenglish	=naustrian	polish	uppersorbian
=british	greek	portuges	welsh

Those names preceded by = are synonyms for the language option above them. (The equals sign is *not* part of the option name.) For example, both `hungarian` and `magyar` load the file `magyar.lfd`.

If the `babel` package is loaded, all it does is read in the specified language packages; they in turn read in `babel.def` and possibly `switch.def` (if its macros are not already in the format).

Language switching commands

The normal user needs to know very little about the `babel` internal operations. The new high-level user commands are:

```

\selectlanguage{language}
\begin{otherlanguage}{language} text \end{otherlanguage}
\begin{otherlanguage*}{language} text \end{otherlanguage*}
\foreignlanguage{language}{text}
\iflanguage{language}{yes.text}{no.text}

```

The `\selectlanguage` command and the `otherlanguage` environment are two ways to switch to another language, with all its features and translations. The `\foreignlanguage` command and the `otherlanguage*` environment also switch to *language* but without the translations or date changes; they are meant for setting short sections of text in a language different from the regular one.

The `\iflanguage` executes *yes.text* if *language* is current otherwise *no.text*.

In addition, `\language` contains the name of the currently selected language.

Of course, each language definition file can also have its own special commands to assist typing accented and special characters. For example,

in German, one may type "a as a shorthand for \a. To find out what special commands are available for each language, and any other special considerations, one must read the documentation for that language. Documentation should be found in the `texmf/doc/tex/generic/babel` directory, or you can process the desired *language.dtx* file in the `texmf/source/tex/generic/babel` directory. (These paths might be different on your system.)

Contents of a language definition file

Although one does not normally need to know anything about how the switching mechanism functions, we will outline it here for the interested user.

Two additional internal babel commands are:

```
\addlanguage{lang_num} and
\adddialect{lang_num.1}{lang_num.2}
```

where *lang_num* is an internal language number for specifying the set of hyphenation patterns. The command `\addlanguage` sets its argument equal to the next available language number. The form of *lang_num* used in babel is `\l@language`; for example, `\l@english`. This command is executed on those language names listed in `language.dat` during the `initex` run. The command `\adddialect` sets the first argument equal to the second so that the two languages make use of the same set of hyphenation patterns. For example, in `english.ldf` there is the command `\adddialect{\l@american}{\l@english}`.

A language definition file must provide four commands:

```
\captionlang to redefine the naming commands like \tablename
(see Section D.4.1);
\datelang to define \today (see Section D.4.2);
\extralang to define any language-specific commands;
\noextralang to remove the language-specific commands.
```

If the language *lang* is not one of those with prestored hyphenation patterns in the current format file (that is, if `\l@lang` is undefined), it is set to be a ‘dialect’ of language number 0.

Finally, the language definition file calls `\selectlanguage{lang}` to activate that language. This is accomplished by

- calling `\language\l@lang` to select the set of hyphenation patterns,
- invoking `\originalTeX` in order to remove any existing language-specific commands,
- activating `\captionlang`, `\datelang`, and `\extralang` to invoke the language-specific names, date, and commands,

- redefining `\originalTeX` to be `\noextralang` so that the next language switch will remove those features specific to *lang*.

11.2 Contents of the `language.dat` file

As has been mentioned before, with T_EX version 3.0 and later it is possible to store more than one set of hyphenation patterns in the format file. The counter `\language` is used to switch between them by setting it to a different number.

However, there is no standard to dictate which languages belong to which numbers. If a package were to assume a certain ordering, it would most certainly function incorrectly at installations other than the one for which it was designed. The `babel` system invokes a more reliable procedure.

During the production of the format by `initex` (Section B.1.3), the file `hyphen.cfg` is input, which in turn reads in `language.dat`, the only file to be tailored to the local installation. This file contains a list of languages to add as well as the name of the file with the hyphenation patterns and the name of any additional file to be included. It also indicates names of dialects that use the same hyphenations by prefixing the name with an equals sign. For example, if `language.dat` contains

```
=USenglish
american ushyphen.tex
english ukhyphen.tex
=UKenglish
=british
french frhyphen.tex
german dehyphn.tex
ngerman dehyphn.tex
```

the hyphenation patterns stored in files `ushyphen.tex`, `ukhyphen.tex`, `frhyphen.tex`, `dehyphn.tex`, and `dehyphn.tex` are loaded under the language numbers 0 to 4 respectively, and `\l@american`, `\l@english`, `\l@french`, `\@german`, and `\l@ngerman` are defined as numbers 0 through 4 for use with the `\selectlanguage` command. Languages `\l@USenglish` and `\l@UKenglish` are synonyms for the current language, in this case 0 and 1, respectively. Similarly `\l@british` is identical to `\l@UKenglish`.

Math Extensions with $\mathcal{A}\mathcal{M}\mathcal{S}$ - \LaTeX

The American Mathematical Society, $\mathcal{A}\mathcal{M}\mathcal{S}$, has supported the development and usage of \TeX since its first release. It in fact owns the \TeX logo as a registered trademark.

Shortly after \TeX 82 became available, the $\mathcal{A}\mathcal{M}\mathcal{S}$ produced a macro package for generating a special format `amstex`, described in *The Joy of \TeX* by Spivak (1986). The macros in this $\mathcal{A}\mathcal{M}\mathcal{S}$ - \TeX complement the mathematical typesetting features of Plain \TeX by adding additional ones and simplifying others.

However, $\mathcal{A}\mathcal{M}\mathcal{S}$ - \TeX is not a documentation preparation system like \LaTeX , describing the logical layout of a document by means of markup commands, but rather is simply an extension to Plain \TeX .

The great popularity of \TeX as a text formatting program is due primarily to the availability of \LaTeX as a user-friendly interface to the underlying \TeX machinery. Many authors therefore asked the $\mathcal{A}\mathcal{M}\mathcal{S}$ to provide \LaTeX with the same mathematical features as in $\mathcal{A}\mathcal{M}\mathcal{S}$ - \TeX . The $\mathcal{A}\mathcal{M}\mathcal{S}$ - \LaTeX project was thus launched in 1987, with version 1.0 completed three years later by Frank Mittelbach and Rainer Schöpf, together with Michael Downes of the $\mathcal{A}\mathcal{M}\mathcal{S}$. $\mathcal{A}\mathcal{M}\mathcal{S}$ - \LaTeX has been fully converted to $\text{\LaTeX} 2_\epsilon$ with version 1.2 in 1996.

The $\mathcal{A}\mathcal{M}\mathcal{S}$ - \LaTeX collection consists of three parts: packages for extending mathematical typesetting, extra classes for articles and books published by the $\mathcal{A}\mathcal{M}\mathcal{S}$, and supplemental fonts for additional symbols, math alphabets, and Cyrillic fonts.

In the next sections, we give an overview of the math extensions available in the package `amsmath`; a more detailed user's manual is delivered with the collection, in the file `ams1doc.tex`. How to invoke the additional fonts is described below in Section 12.4, or in the $\mathcal{A}\mathcal{M}\mathcal{S}$ -supplied manual found in the file `amsfndoc.tex`. The extra classes will not be described in this book; $\mathcal{A}\mathcal{M}\mathcal{S}$ authors should refer to the instructions in the document `instr-1.tex` provided with $\mathcal{A}\mathcal{M}\mathcal{S}$ - \LaTeX .

12.1 Invoking $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$

Package: `amsmath` If the `\documentclass` statement at the beginning of the $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ document selects one of the $\mathcal{A}\mathcal{M}\mathcal{S}$ classes `amsbook`, `amstart`, or `amsproc`, then most of the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ features are loaded automatically. These features may still be employed with other classes by including the main extension package `amsmath` by means of

$$\backslash\text{usepackage}[options]\{amsmath\}$$

in the document's preamble. The list of allowable options is described below in Section 12.2.8.

The `amsmath` package defines many of the new math typesetting features itself, but it also loads a number of other packages from the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ collection that contain further extensions, such as `amsofn`, `amstext`, and `amsbsy`. These packages could be loaded separately without `amsmath` if only their limited features are wanted. On the other hand, the packages `amscd` and `amsthm` are not included in `amsmath` and must be loaded explicitly if their features are desired. Simply add their names to the list of packages in `\usepackage`.

The following Section 12.2 describes the new commands and environments made available with `amsmath` and its associated packages. We call these the standard features of $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$. Further extensions added by other packages are explained afterwards.

! The examples in this chapter employ the user-defined commands `\mi`, `\me`, and `\dif` defined in Section 5.4.10 for printing upright *i*, *e*, and *d* in math mode.

12.2 Standard features of $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$

This relatively long section presents those standard features of $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ that are activated by loading the `amsmath` package, or by selecting one of the $\mathcal{A}\mathcal{M}\mathcal{S}$ classes `amstart`, `amsbook`, or `amsproc`.

12.2.1 Additional font switching commands

Package: `amsbsy` Standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ provides the math alphabet commands `\mathcal{a}`, `\mathrm`, `\mathbf`, `\mathsf`, `\mathit`, `\mathtt` for changing fonts within math mode (Section 5.4.2). With $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, one may also use the commands

$$\backslash\text{boldsymbol}\{symbol\} \quad \text{and} \quad \backslash\text{pmb}\{symbol\}$$

to print *symbol* in a bold face, provided there is an appropriate bold font for it. Whereas the command `\mathbf` sets only Latin letters, numbers, and Greek upper case letters in bold, these commands also affect math symbols and Greek lower case letters. Compare the result of $\mathbf{\nabla \times \mathbf{d}\sigma}$ with that

of $\boldsymbol{\nabla} \times \boldsymbol{V} \boldsymbol{d}\boldsymbol{\sigma}$. With the standard $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ command `\mathbf`, only the letters V and d appear bold, while the other characters remain in normal weight. Not only that, these letters are upright, and not italic as required by international standards. With `\boldsymbol`, all symbols are bold and italic.

Those symbols for which no bold face font exists will remain in normal weight with the `\boldsymbol` command. Such symbols are, for example, those that come in two sizes (Section 5.3.7) like \sum , \int , \cup , and so on. The command `\pmb` (poor man's bold) simulates a bold face even for these symbols by printing them several times slightly displaced. The result of `\pmb{\sum\;\int\;\cup}` is $\sum \int \cup$.

These commands are defined in the package `amsbsy`, which may be loaded separately without `amsmath`.

Package:
`amstext`

A short piece of normal text can be given within a formula with

`\text{short.text}`

In contrast to `\mbox{short.text}` for standard $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$, the `\text` command switches font size correctly when used as superscripts and subscripts. Thus `...{\text{Word}}` sets `Word` lower and changes to `\scriptstyle` font size. To achieve the same effect in standard $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$, the font size must be given explicitly, as `...{\mbox{\scriptstyle Word}}`. Furthermore, the name `\text` is more precise than `\mbox`.

This command is defined in the package `amstext`. Like `amsbsy`, it may be loaded on its own without `amsmath` if none of the other $\mathcal{AMS-L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ features are wanted.

Another command to insert normal text inside a displayed equation is

`\intertext{insert.text}`

The `insert.text` is inserted as a left-justified line of text between those of the formula. The alignment of the formula lines remains unaffected, something that is not guaranteed if one closes the displayed equation, inserts text and reopens the equation. For example:

$$\begin{aligned}(x + iy)(x - iy) &= x^2 - ixy + ixy - i^2y^2 \\ &= y^2 + y^2 \quad \text{since } i^2 = -1 \text{ is true.}\end{aligned}$$

On the other hand

$$\begin{aligned}(x + iy)^2 &= x^2 + 2ixy + i^2y^2 = x^2 + 2ixy - y^2 \\ (x - iy)^2 &= x^2 - 2ixy + i^2y^2 = x^2 - 2ixy - y^2\end{aligned}$$

```
\begin{align*}
(x+iy)(x-iy) &= x^2 - ixy + ixy - i^2y^2 \\
&= y^2 + y^2 \quad \text{\text{since} } i^2 = -1 \\
&\quad \text{\text{is true.}}\end{align*}
```

```

\intertext{On the other hand}
(x +\mi y)^2 & = x^2 + 2\mi xy +\mi ^2y^2 = x^2 + 2\mi xy-y^2\\
(x -\mi y)^2 & = x^2 - 2\mi xy +\mi ^2y^2 = x^2 - 2\mi xy-y^2
\end{align*}

```

The alignment of the lines on the first equals sign is maintained through the interruption with the line of text ‘On the other hand’. The environment `align` (Section 12.2.6) is one of several new ones provided by $\mathcal{A}_{\mathcal{M}}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ to replace the standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ environment `eqnarray`. Note that `\intertext` may only be issued immediately after the `\\` for starting a new line.

12.2.2 Multiple mathematical symbols

Mathematical formulas often require the same symbol to appear several times, such as multiple integral signs, or symbols and arrows to be stacked above or below a mathematical expression. Usually the distances between these symbols depends on the mathematical meaning, something that $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ cannot automatically recognize. $\mathcal{A}_{\mathcal{M}}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ provides a number of structures to help the user find the right spacing without tedious trial and error.

Multiple integrals

With $\mathcal{A}_{\mathcal{M}}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, the commands `\iint`, `\iiint`, `\iiiiint`, and `\idotsint` output multiple integrals, with upper and lower limits being added in the usual manner. In text formulas, they are printed as \iint , \iiint , \iiiiint , $\int \cdots \int$, while in displayed formulas, they appear as

$$\iint_S f(x,y) \, dS \quad \backslash [\iint \limits_S f(x,y) \backslash, \, dS \backslash]$$

$$\iiint_V f(x,y,z) \, dV \quad \backslash [\iiint \limits_V f(x,y,z) \backslash, \, dV \backslash]$$

$$\iiiiint_G f(x,y,z,t) \, dG \quad \backslash [\iiiiint \limits_G f(x,y,z,t) \backslash, \, dG \backslash]$$

$$\int \cdots \int_U f(x_1, \dots, x_k) \, dU \quad \backslash [\idotsint \limits_U f(x_1, \dots, x_k) \backslash, \, dU \backslash]$$

whereby the command `\limits` may be left off if the option `intlimits` has been specified when `amsmath` was loaded (see Section 12.2.8).

Multiline limits

One often needs multiline limits or indices for summations, as in the examples below.

$$\Delta_{\substack{p_1 p_2 \cdots p_{n-k} \\ q_1 q_2 \cdots q_{n-k}}} \sum_{\substack{k_0, k_1, \dots \geq 0 \\ k_0 + k_1 + \dots = 0}} a_{0k_0} a_{1k_1} \cdots$$

$\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ provides a command `\substack` for this purpose, with syntax

```
\substack{1st line\\2nd line\\...\\ last line}
```

where the command must immediately follow the `^` or `_` shifting commands, and be entirely enclosed in curly braces `{ }`. The index for the left-hand example above was generated with

```
\Delta_{\substack{p_1 p_2 \cdots p_{n-k} \\ q_1 q_2 \cdots q_{n-k}}}
```

The lines of text printed by `\substack` are centered horizontally, as is apparent in the right-hand example above. This was produced with

```
\[ \sum_{\substack{k_0, k_1, \dots \ge 0 \\ k_0 + k_1 + \dots = 0}} a_{0k_0} a_{1k_1} \cdots \]
```

On the other hand, the environment `subarray` offers more control over the horizontal alignment:

```
\begin{subarray}{pos} 1st line\\2nd line\\...\\ last line \\end{subarray}
```

The argument `pos` may be `c` for centered, or `l` for left-justified lines.

$$\sum_{\substack{i \in \Lambda \\ i < j < n}} P(i, j) \quad \backslash [\sum_{\substack{i \in \Lambda \\ i < j < n}} P(i, j) \backslash$$

Special limits

To add a differential prime sign to a summation symbol without a lower limit, like $\sum' E_n$, in a displayed formula, one can easily give

```
\[ \sum \nolimits' E_n \] \quad \sum' E_n
```

However, if there to be an upper limit as well, the prime can only be added with much fiddling. The `\sideset` command simplifies this task considerably.

$$\sum'_{n=0}^{\infty} (2n + 1) E_{2n+1} \quad \backslash [\sideset{}{\prime} \sum_{n=0}^{\infty} (2n+1) E_{2n+1} \backslash$$

The complete syntax for this command is:

$$\backslash\text{sideset}\{pre\}\{post\}\backslash\text{symbol}$$

where *pre* and *post* are the superscripts and subscript commands to be added before and after the $\backslash\text{symbol}$, respectively. They must contain raising and lowering operators $\hat{}$ and $_$.

The product symbol \prod is given daggers above and asterisks below with $\backslash\text{sideset}\{_\backslash\text{dag}^*\}\{_\backslash\text{dag}^*\}\backslash\text{prod}$, as shown $\dagger\prod\dagger$ at the right.

Additional shifting commands are

$$\backslash\text{overset}\{char\}\{\backslash\text{symbol}\} \quad \text{and} \quad \backslash\text{underset}\{char\}\{\backslash\text{symbol}\}$$

which place the arbitrary *char* above or below the $\backslash\text{symbol}$ in the size appropriate for superscripts and subscripts. Thus $\backslash\text{overset}\{*\}\{X\}$ produces $\overset{*}{X}$ and $\backslash\text{underset}\{*\}\{X\}$ yields $\underset{*}{X}$.

Extended arrows

The `amsmath` package provides a number of commands to produce extra long arrows for combining with mathematical expressions. The commands

$$\begin{array}{ll} \backslash\text{overleftarrow}\{expr\} & \backslash\text{underleftarrow}\{expr\} \\ \backslash\text{overrightarrow}\{expr\} & \backslash\text{underrightarrow}\{expr\} \\ \backslash\text{overleftrightharrow}\{expr\} & \backslash\text{underleftrightharrow}\{expr\} \end{array}$$

produce lengthened arrows pointing left and right, as well as double arrows above and below the mathematical expression *expr*.

$$\begin{array}{ll} \overrightarrow{ABCD} = \overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD} & \begin{array}{l} \backslash\text{begin}\{eqnarray*\} \\ \backslash\text{overrightarrow}\{ABCD\} \& = \& \\ \backslash\text{underrightarrow}\{AB\} + \\ \backslash\text{underrightarrow}\{BC\} + \\ \backslash\text{underrightarrow}\{CD\} \backslash \\ \backslash\text{overleftarrow}\{ABCD\} \& = \& \\ \backslash\text{underleftarrow}\{DC\} \dots \\ \backslash\text{end}\{eqnarray*\} \end{array} \\ \overleftarrow{ABCD} = \overleftarrow{DC} + \overleftarrow{CB} + \overleftarrow{BA} & \\ \overleftrightarrow{ABCD} = \overleftrightarrow{DCAB} & \end{array}$$

The lower arrows are actually too close to the expression, as is seen on the right-hand side of the last example. This should also be the case for all the other examples with a lower arrow, except that we have added a strut to push them down somewhat:

$$\begin{array}{l} \backslash\text{underrightarrow}\{\rule[-2pt]{0pt}{2pt}AB\} \dots \text{and} \\ \backslash\text{underleftarrow}\{\rule[-2pt]{0pt}{2pt}DC\} \dots \end{array}$$

A smaller font size will be used for the arrows when they appear in exponents, indices, superscripts, and subscripts:

$$\int_{0.2\pi} r d\varphi = 2\pi r \quad \int_{\overrightarrow{0.2\pi}} r \, d\varphi = 2\pi r$$

There are two more commands for horizontal arrows of variable length:

`\xleftarrow[below]{above}` `\xrightarrow[below]{above}`

which place the mandatory *above* in superscript size over the arrow, and the optional *below* in subscript size beneath it.

$$A \xleftarrow[n+\mu-1]{T} B \xrightarrow[n\pm i-1]{T} C \quad \int [A \xleftarrow{n+\mu-1} B \xrightarrow[n\pm i-1]{} C]$$

The package `amscd` (Section 12.3.2) offers further possibilities for combining arrows and text.

Stacked accents

Attempting to place multiple accents over a character with standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, say with `\hat{\hat{A}}`, results in a misplacement: $\hat{\hat{A}}$. The same applies to the other mathematical accents commands `\check`, `\breve`, `\acute`, `\grave`, `\tilde`, `\bar`, `\vec`, `\dot`, and `\ddot` (Section 5.3.9). The `amsmath` package provides a set of math accent commands with the same names but capitalized,

`\Hat` `\Breve` `\Grave` `\Bar` `\Dot`
`\Check` `\Acute` `\Tilde` `\Vec` `\Ddot`

which can be safely combined with one another for the expected results: `\Hat{\Hat{A}}`, `\Breve{\Bar{B}}` and `\Tilde{\Tilde{C}}` produce $\hat{\hat{A}}$, $\breve{\bar{B}}$, and $\tilde{\tilde{C}}$.

Three or four dots in a row over a symbol are often used for time derivatives of third and fourth order. They can be placed with the commands

`\dddot{sym}` and `\ddddot{sym}`

In this way \dddot{u} and \ddddot{u} are produced with `\dddot{u}` and `\ddddot{u}`.

Continuation dots

In standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, one has the commands `\l dots` and `\c dots` for printing three continuation dots, either on the baseline or raised to the center of the line. $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ offers a number of additional possibilities. The most general of these is the `\dots` command which adjusts the vertical height according to the symbol that follows it. If this is an equals sign or binary operator, such as `+` or `-`, the dots are raised, as with `\c dots`, otherwise they are on the baseline, as with `\l dots`.

$$\begin{aligned} \$a_0+a_1+\dots+a_n\$ &\Rightarrow a_0 + a_1 + \dots + a_n \\ \$a_0,a_1,\dots,a_n\$ &\Rightarrow a_0, a_1, \dots, a_n \end{aligned}$$

If the continuation dots come at the end of a formula, there is no following symbol to determine the height of the dots. In this case, one must manually indicate the height by means of one of the commands `\dotsc` (comma), `\dotsb` (binary), `\dotsm` (multiplication), or `\dotsi` (integral).

The `\dotsc` is to be used with commas, so `\$A_1,A_2,\dotsc\$` produces A_1, A_2, \dots ; the `\dotsb` sets them for a binary operator, thus `\$A_1+A_2+\dotsb\$` yields $A_1 + A_2 + \dots$; the command `\dotsm` is actually identical to `\dotsb`, but it is logically meant to be applied to multiplication, `\$A_1A_2\dotsm\$` makes $A_1 A_2 \dots$; finally `\dotsi` places the dots at the mean height of an adjacent integral sign.

$$\backslash [\backslash \text{int}_{A_1} \backslash \text{int}_{A_2} \backslash \text{dotsi} \backslash] \quad \int_{A_1} \int_{A_2} \dots$$

12.2.3 Fractions

The $\mathcal{T}\mathcal{E}\mathcal{X}$ fraction commands `\atop`, `\choose`, and others may be allowed in standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, but not in $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$. With the `amsmath` package, only those fraction commands described here may be used.

Basic fraction commands

In addition to the regular $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ command `\frac{over}{under}`, $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ provides the commands `\tfrac` and `\dffrac` with the same syntax. These are effectively the same as `\frac` but with the font set to `\textstyle` or `\displaystyle`, respectively (Section 5.5.2). We demonstrate their effects with some examples from the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ user's manual.

$$\begin{aligned} \backslash [\backslash \text{frac}\{1\}\{k\}\backslash \log_2 c(f)\backslash \text{quad} \\ \backslash \text{tfrac}\{1\}\{k\}\backslash \log_2 c(f)\backslash \text{quad} \\ \backslash \text{sqrt}\{\backslash \text{frac}\{1\}\{k\}\backslash \log_2 c(f)\}\backslash \text{quad} \\ \backslash \text{sqrt}\{\backslash \text{dffrac}\{1\}\{k\}\backslash \log_2 c(f)\} \backslash] \end{aligned}$$

$$\frac{1}{k} \log_2 c(f) \quad \frac{1}{k} \log_2 c(f) \quad \sqrt{\frac{1}{k} \log_2 c(f)} \quad \sqrt{\frac{1}{k} \log_2 c(f)}$$

Binomial expressions

A binomial expression looks something like a fraction, but is enclosed in round parentheses and is missing the horizontal rule. The basic command in the `amsmath` package is

$$\backslash \text{binom}\{over\}\{under\}$$

which functions in the same way as `\frac` and the other fraction commands.

$$\backslash[\ \backslash\binom{n+1}{k} = \backslash\binom{n}{k} + \backslash\binom{n}{k-1} \backslash] \quad \binom{n+1}{k} = \binom{n}{k} + \binom{n}{k-1}$$

Similarly there are the commands `\tbinom` and `\dbinom` analogous to `\tfrac` and `\dfrac`.

User-defined fractions

The `amsmath` package provides a powerful tool for defining fraction-like structures:

```
\genfrac{left_brk}{right_brk}{thickness}{mathsize}{over}{under}
```

where *left_brk* and *right_brk* are the parenthesis characters on the left and right, *thickness* is the thickness of the horizontal line, and *mathsize* is a number 0–3 representing the math sizes `\displaystyle`, `\textstyle`, `\scriptstyle`, and `\scriptscriptstyle`, respectively. The last two arguments, *over* and *under*, are the texts in the two parts of the fraction, the same arguments as in `\frac` and `\binom`.

If the *thickness* is left blank, the standard thickness for $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ fractions is used. If *mathsize* is empty, the font size is determined automatically by the normal rules in Section 5.5.2.

Rather than repeating `\genfrac` with the same first four arguments time and again, one should define new fraction commands with it. For example, the following definitions are given in `amsmath.sty`:

```
\newcommand{\frac}[2]{\genfrac{}{}{}{}{#1}{#2}}
\newcommand{\dfrac}[2]{\genfrac{}{}{0}{#1}{#2}}
\newcommand{\tfrac}[2]{\genfrac{}{}{1}{#1}{#2}}
\newcommand{\binom}[2]{\genfrac{({}{)}{0pt}{}{}{#1}{#2}}
```

As a further example, consider the redefinition of the command `\frac`

```
\renewcommand{\frac}[3][\genfrac{}{}{#1}{#2}{#3}]
```

in which the line thickness is now an optional first argument; without this optional argument, the command behaves as normal. Thus

$$\backslash[\ \backslash\binom{n}{m} = \backslashfrac[2pt]{n!}{M!(n-m)!} \backslash] \quad \text{yields} \quad \binom{n}{m} = \frac{n!}{M!(n-m)!}$$

Continued fractions

Continued fractions can be made in $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ with the command

```
\cfrac[pos]{over}{under}
```

whereby the denominator *under* may contain further `\cfrac` commands.

```
\[ a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3 + \cfrac{1}{a_4 + \dotsb}}}} \]
```

produces

$$a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4 + \dots}}}}$$

If the optional argument *pos* is missing, the numerator *over* is centered on the horizontal rule; otherwise it may take values of *l* or *r* to left or right justify the numerator.

12.2.4 Matrices

Standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ possesses the environment `array` for producing arrays and matrices. The `amsmath` package provides the additional environments `pmatrix`, `bmatrix`, `Bmatrix`, `vmatrix`, and `Vmatrix`, which automatically add the enclosing braces `()`, `[[`, `{}`, `||` and `|||` around the array, and in the right size. For completeness, there is also a `matrix` environment with no braces.

In contrast to the standard `array` environment (Section 4.8.1), these matrix environments do not require an explicit column specification as argument. By default, up to 10 centered columns may be used without any argument. (This maximum number may be changed by giving the special counter `MaxMatrixCols` a new value with either `\setcounter` or `\addtocounter`.) Otherwise the matrix environments are used in the same way as the `array` environment.

The following example is taken from Section 5.4.3 on page 134 and is recast here using $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ constructs.

$$\sum_{p_1 < p_2 < \dots < p_{n-k}}^{(1,2,\dots,n)} \Delta_{\substack{p_1 p_2 \dots p_{n-k} \\ p_1 p_2 \dots p_{n-k}}} \sum_{q_1 < q_2 < \dots < q_k} \begin{vmatrix} a_{q_1 q_1} & a_{q_1 q_2} & \dots & a_{q_1 q_k} \\ a_{q_2 q_1} & a_{q_2 q_2} & \dots & a_{q_2 q_k} \\ \dots & \dots & \dots & \dots \\ a_{q_k q_1} & a_{q_k q_2} & \dots & a_{q_k q_k} \end{vmatrix}$$

```
\[ \sum_{p_1 < p_2 < \dots < p_{n-k}}^{(1,2,\dots,n)} \Delta_{\substack{p_1 p_2 \dots p_{n-k} \\ p_1 p_2 \dots p_{n-k}}} \sum_{q_1 < q_2 < \dots < q_k} \begin{vmatrix} a_{q_1 q_1} & a_{q_1 q_2} & \dots & a_{q_1 q_k} \\ a_{q_2 q_1} & a_{q_2 q_2} & \dots & a_{q_2 q_k} \\ \dots & \dots & \dots & \dots \\ a_{q_k q_1} & a_{q_k q_2} & \dots & a_{q_k q_k} \end{vmatrix} \]
```

```

\hdotsfor[2.0]{4}\
a_{q_kq_1} & a_{q_kq_2} & \dots & a_{q_kq_k}
\end{vmatrix}

```

Comparing this input text with that on page 134, one sees that it is simpler and easier to follow. The only new command used here is `\hdotsfor` which has the syntax

```
\hdotsfor[stretch]{n}
```

and which prints a continuous line of dots through n columns. The optional argument *stretch* is a multiplicative number to increase the dot density, being 1.0 by default.

```

\[\begin{matrix} a & b & c & d & e \\ x & \hdotsfor{3} & & & z \end{matrix} \quad \begin{matrix} a & b & c & d & e \\ x & \dots\dots\dots & & & z \end{matrix}
\]

```

Compare the standard dot spacing above with that from `\hdotsfor[2.0]` in the previous example.

The initial letter of each of the `xmatrix` environments indicates the type of braces that enclose it: `pmatrix` for (round) parentheses, `bmatrix` for (square) brackets, `Bmatrix` for (curly) braces, `vmatrix` for vertical lines, and `Vmatrix` for double vertical lines. They appear as

$$\begin{matrix} r & s & t \\ u & v & w \\ x & y & z \end{matrix} \quad \begin{pmatrix} r & s & t \\ u & v & w \\ x & y & z \end{pmatrix} \quad \begin{bmatrix} r & s & t \\ u & v & w \\ x & y & z \end{bmatrix}$$

$$\left\{ \begin{matrix} r & s & t \\ u & v & w \\ x & y & z \end{matrix} \right\} \quad \left| \begin{matrix} r & s & t \\ u & v & w \\ x & y & z \end{matrix} \right| \quad \left\| \begin{matrix} r & s & t \\ u & v & w \\ x & y & z \end{matrix} \right\|$$

where each matrix has been produced with

```

\[\begin{xmatrix} r & s & t \\ u & v & w \\ x & y & z \end{xmatrix}
\]

```

where `xmatrix` is set to `matrix`, `pmatrix`, `bmatrix`, `Bmatrix`, `vmatrix`, and `Vmatrix` one after the other.

To generate a small array within a text formula, one can apply the `smallmatrix` environment. In this way $\left(\begin{smallmatrix} a & b & c \\ e & m & r \end{smallmatrix} \right)$ can be made with

```

\$ \bigl( \begin{smallmatrix} a & b & c \\ e & m & r \end{smallmatrix} \bigr) \$

```

12.2.5 User extensions and fine adjustments

Function names

Package: Standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ recognizes a number of preprogrammed function names (`amsopn`) (Section 5.3.8) that are printed in math made by placing a backslash in

front of that name: arccos, arcsin, arctan, arg, cos, cosh, cot, coth, csc, deg, det, dim, exp, gcd, hom, inf, ker, lg, lim, liminf, limsup, ln, log, max, min, Pr, sec, sin, sinh, sup, tan, tanh. Not only do these names appear in an upright font, as is required for function names, but the spacing with adjacent parts of the mathematical expression is adjusted automatically.

$\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ provides some more function names, as variations on the standard \lim name:

$$\begin{array}{ll} \backslash\varlimsup & \overline{\lim} \\ \backslash\varliminf & \underline{\lim} \end{array} \quad \begin{array}{ll} \backslash\varinjlim & \overleftarrow{\lim} \\ \backslash\varprojlim & \overrightarrow{\lim} \end{array}$$

These functions may take on limits with the raising and lowering operators \wedge and $_$; for example $\backslash\varliminf_{n\to\infty}$ for $\lim_{n\to\infty}$.

It is also possible to define new function names with the same font and spacing properties as the predefined ones. The command

$$\backslash\text{DeclareMathOperator}\{\backslash\text{cmd}\}\{\text{name}\}$$

which may only be issued in the preamble, before $\backslash\text{begin}\{\text{document}\}$, defines a command $\backslash\text{cmd}$ that prints the function name *name*. For example, to define a function name $\backslash\text{doit}$, give

$$\backslash\text{DeclareMathOperator}\{\backslash\text{doit}\}\{\text{doit}\}$$

and then $\$A=3\backslash\text{doit}^2(B)\$$ yields $A = 3 \text{doit}^2(B)$. Note that superscripts and subscripts are printed beside the operator; if they are to be printed as limits, that is, above and below the operator in displayed math mode, use the \ast -form to define them. For example:

$$\begin{array}{ll} \backslash\text{DeclareMathOperator}\ast\{\backslash\text{Lim}\}\{\text{lim}\} & \begin{array}{c} n\rightarrow+\infty \\ \text{lim} \\ n\rightarrow-\infty \end{array} \\ \backslash[\backslash\text{Lim}_{n\to-\infty}\wedge\{n\to+\infty\}\backslash] & \end{array}$$

The *name* text need not be identical to the command name. In particular, it may contain special characters not allowed in command names.

Modulo expressions are printed in standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ with $\backslash\text{bmod}$ and $\backslash\text{pmod}$ commands, and are complemented in $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ by $\backslash\text{mod}$ and $\backslash\text{pod}$. The possibilities are:

$$\begin{array}{ll} z \equiv x + y \text{ mod } n^2 & z \equiv x+y \backslash\text{bmod}\{n^2\} \\ z \equiv x + y \pmod{n^2} & z \equiv x+y \backslash\text{pmod}\{n^2\} \\ z \equiv x + y \text{ mod } n^2 & z \equiv x+y \backslash\text{mod}\{n^2\} \\ z \equiv x + y \pmod{n^2} & z \equiv x+y \backslash\text{pod}\{n^2\} \end{array}$$

The automatic parentheses are missing with $\backslash\text{mod}$, while with $\backslash\text{pod}$ the name ‘mod’ is omitted. Furthermore, $\backslash\text{pmod}$ is redefined for text formulas to reduce the preceding space: $\$y\backslash\text{pmod}\{a+b}\$$: $y \pmod{a + b}$.

The $\backslash\text{DeclareMathOperator}$ command and additional function names are defined in the *amsopn* package, which may be loaded on its own without *amsmath*.

Fine-tuning roots

The positioning of an index to a root sign is not always ideal under standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$. In $\sqrt[\beta]{k}$, for example, the β could be somewhat higher and shifted slightly to the right. The $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ commands

$$\backslash\leftroot\{shift\} \quad \backslashuproot\{shift\}$$

cause such manual displacements, where *shift* is a number specifying the size in small, internal units. Negative numbers represent a shift in the opposite direction. Compare the above standard result with that of $\$\sqrt[\beta]{k}\$$: $\sqrt[\beta]{k}$.

The size of the root sign depends on its contents. If they hang below the baseline, the root sign extends lower down than for contents that have no depth. Note the differences between \sqrt{x} , \sqrt{y} , and \sqrt{z} . Some publishers want all root signs be at the same height, as $\sqrt{x} + \sqrt{y} + \sqrt{z}$. This is accomplished with the $\mathcal{T}\mathcal{E}\mathcal{X}$ command \backslashsmash which places its argument in a box of zero height and depth. The $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ version of this command allows an optional argument *b* or *t* to zero only the depth or height, respectively. The above example is produced with $\$\sqrt[\beta]{\smash[b]{y}}\$$. The option *b* is taken because we want only the depth to be ignored, not the height of the letter *y*.

Spacing adjustment

With standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, there are a number of commands to fine-tune the spacing in a math formula (Section 5.5.1). These are \backslash , $\backslash:$, $\backslash;$, \backslashquad and \backslashqqquad for increasing amounts of positive spacing, and $\backslash!$ for negative spacing. With the *amsmath* package, the first three still exist, but may also be called with the more obvious names \backslashthinspace , \backslashmedspace , and \backslashthickspace . There is also \backslashnegthinspace as an alias for $\backslash!$.

The complete set of spacing commands are summarized in the table below taken from the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ manual.

Short form	Command name	Demo	Short form	Command name	Demo
\backslash ,	\backslashthinspace	\perp \perp	$\backslash!$	\backslashnegthinspace	\perp
$\backslash:$	\backslashmedspace	\perp \perp		\backslashnegmedspace	\perp
$\backslash;$	\backslashthickspace	\perp \perp		\backslashnegthickspace	\perp
	\backslashquad	\perp \perp			
	\backslashqqquad	\perp \perp \perp			

The general math spacing command is

$$\backslashmspace\{mu\}$$

which inserts space in mathematical spacing units ‘mu’ (=1/18 em). For example, $\backslashmspace\{-9mu\}$ puts in negative spacing of 1/2 em.

Vertical bars

In standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, the commands `|` and `\|` are used for single and double vertical bars, `|` and `||`. However, these symbols are often used as delimiters (that is, like braces) in which case different spacing requirements are needed. In particular, a distinction must be made between the left and right delimiter in expressions like $|a|$ and $\|v\|$. The $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ commands are only appropriate for single appearances, like $p|q$ or $f(t, x)|_{t=0}$.

The `amsmath` package defines the delimiter commands `\lvert`, `\rvert` for a single bar, and `\lVert`, `\rVert` for a double bar. They are useful for defining commands that set their arguments in such delimiters, as

```
\newcommand{\abs}[1]{\lvert#1\rvert}
\newcommand{\norm}[1]{\lVert#1\rVert}
```

Now $\$ \backslash \text{abs}\{a\} \$$ produces $|a|$, and $\$ \backslash \text{norm}\{v\} \$$ $\|v\|$.

A similar recommendation can be made for the standard commands `\langle` and `\rangle`. By defining

```
\newcommand{\mean}[1]{\langle#1\rangle}
```

one gives $\$ \backslash \text{mean}\{x\} \$$ to generate $\langle x \rangle$, rather than $\$ \langle x \rangle \$$ which produces $\langle x \rangle$.

Boxed formulas

A formula may be placed in a box with the command

```
\boxed{formula}
```

For example,

```
\[ \boxed{\int_0^\infty f(x) dx \approx \sum_{i=1}^n w_i e^{x_i} f(x_i)} \]
```

produces

$$\int_0^\infty f(x) dx \approx \sum_{i=1}^n w_i e^{x_i} f(x_i)$$

12.2.6 Multiline equations

Equations consisting of several lines which are horizontally aligned at set points, such as the equals sign, can be generated in standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ with the `eqnarray` and `eqnarray*` environments (Section 5.4.7). Many authors consider these to be far too limited for publications with complicated multiline equations. $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ therefore provides a range of further alignment environments for formulas extending over a single line:

```
align gather falign multiline alignat split
```

With the exception of `split`, all exist in a standard and a *-form. As for `eqnarray`, the standard form adds an automatic equation number to each line, while the *-form does not. The standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ `equation` environment for single line formulas is also available in $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ in a *-form. It may be used in combination with multiline environments.

Common features of alignment environments

All the alignment, or multiline, environments switch to math mode at the start and back to text mode at the end, except for `split` which must be called in math mode. A new line is forced in the formula with the `\\` command, as usual; an optional argument `\\[len]` can be added to increase the line spacing by *len*, again as usual.

The automatic numbering with the standard forms can be suppressed for single lines by adding `\notag` before the `\\` line break. Alternatively, the line can be given a desired marker with `\tag{mark}`. For example, with `\tag{\$\dag\$}`, the marker is (†). Using the *-form instead, the marker text is printed without the parentheses.

The vertical position of the equation number or marker can be adjusted with the command

```
\raisetag{len}
```

which moves the marker upwards by *len* for that line only. A negative value moves it downwards.

The `multiline` environment

The `multiline` environment is a variant of the `equation` environment for *single* formulas that are too long for one line. The line breaks occur where the user forces them with the `\\` command. The first line is left justified, the last right justified, and lines in between are centered. However, if the option `fleqn` has been given, all the lines appear left justified.

The equation number, if present, appears at the right of the *last* line by default or if the option `reqno` has been selected; if the option `leqno` has been chosen, the number is placed at the left of the *first* line. (See Section 12.2.8 for the `amsmath` options.)

It is possible to shift individual lines fully to the left or right with the commands `\shoveleft{formula}` and `\shoveright{formula}`. The entire formula text for that line, except the terminating `\\`, is placed in their arguments.

The left and right margins for the formula are set by the length parameter `\multlinegap` which is initially 10 pt. This may be altered by the user with the `\setlength` or `\addtolength` commands.

An equation with five lines could be broken to look as follows:

$$\begin{array}{c}
 \boxed{\text{First line — left justified}} \\
 \boxed{\text{Second line — horizontally centered}} \\
 \boxed{\text{Third line — pushed to the left}} \\
 \boxed{\text{Fourth line — pushed to the right}} \\
 \boxed{\text{Last line — right justified}}
 \end{array} \tag{12.1}$$

```

\begin{multline}
\framebox[.75\columnwidth]{First line --- left justified}\
\framebox[.6\columnwidth]{Second line --- horizontally
centered}\
\shoveleft{\framebox[.6\columnwidth]{Third line --- pushed
to the left}}\
\shoveright{\framebox[.6\columnwidth]{Fourth line --- pushed
to the right}}\
\framebox[.75\columnwidth]{Last line --- right justified}
\end{multline}

```

A real equation would contain mathematical expressions and not the `\framebox` commands in the above demonstration.

The `split` environment

Like `multline`, the `split` environment is meant for a single equation that does not fit on one line. Line breaks are again forced with the `\\` command; the difference is that in each line there is an alignment marker `&` such that the lines are horizontally positioned to line up the markers.

The `split` environment does not switch into math mode, nor does it produce an equation number. It is intended to be applied within another math environment, such as `equation` or `gather`. This is why there is an `equation*` environment in $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$.

The equation number, if present, is provided by the outer environment. It is applied to the entire multiline formula, which by default, or with the option `centertags`, is centered on the group of lines. With the option `tbtags`, it is placed either at the left of the last line, or at the right of the first line, depending on the further options `lqno` and `reqno`, respectively. (See Section 12.2.8.)

$$\begin{aligned}
 H_c = & \frac{1}{2n} \sum_{l=0}^n (-1)^l (k-l)^{p-2} \sum_{l_1+\dots+l_p=l} \prod_{i=1}^p \binom{n_i}{l_i} \\
 & \times [(k-l) - (k_i - l_i)]^{k_i - l_i} \times \left[(k-l)^2 - \sum_{j=1}^p (k_i - l_i)^2 \right]
 \end{aligned} \tag{12.2}$$

```
\begin{equation}\begin{split}
H_c&=\frac{1}{2n}\sum_{l=0}^n (-1)^l (k-l)^{p-2} \\
&\quad \sum_{l_1+\dots+l_p=l} \prod_{i=1}^p \binom{n_i}{l_i} \\
&\quad \&\quad \times [(k-l) - (k_i-l_i)]^{k_i-l_i} \times \\
&\quad \Bigl[(k-l)^2 - \sum_{j=1}^p (k_i-l_i)^2 \Bigl] \\
\end{split}\end{equation}
```

The alignment has been chosen to be just before the equals sign. The second line begins with the alignment marker & so that the equation continues below the = in the first line. A \quad has been inserted so that the × is not immediately below the equals sign. Alternatively, one could place the & after the = and dispense with \quad in the second line. However, the above is more suitable when there are continuation lines beginning with =. Note the centered equation number at the right.

The gather environment

The gather environment switches to math mode, centering each of its formula lines without any alignment. The formula lines are separated by \\ commands. Each line receives an equation number, unless the *-form has been used, or \notag has been issued in that line.

$$\frac{1}{2} + \left(\frac{2}{3}\right)^4 + \left(\frac{3}{4}\right)^9 + \dots + \left(\frac{n}{n+1}\right)^{n^2} + \dots = \sum_{n=1}^{\infty} \left(\frac{n}{n+1}\right)^{n^2} \quad (12.3)$$

converges since $\lim_{n \rightarrow \infty} \sqrt[n]{\left(\frac{n}{n+1}\right)^{n^2}} = \lim_{n \rightarrow \infty} \left(\frac{1}{1 + \frac{1}{n}}\right) = \frac{1}{e} < 1$ root condition

$$2 + \frac{3}{4} + \frac{4}{9} + \dots + \frac{n+1}{n^2} + \dots = \sum_{n=1}^{\infty} \frac{n+1}{n^2} \quad (12.4)$$

diverges since $\int_c^{\infty} \frac{x+1}{x^2} dx = \left[\ln x - \frac{1}{x} \right]_c^{\infty} = \infty$ (integral condition)

```
\begin{gather}
\frac{1}{2} + \left(\frac{2}{3}\right)^4 + \left(\frac{3}{4}\right)^9 + \dots + \left(\frac{n}{n+1}\right)^{n^2} + \dots \\
= \sum_{n=1}^{\infty} \left(\frac{n}{n+1}\right)^{n^2} \\
\text{converges since} \quad \lim_{n \rightarrow \infty} \sqrt[n]{\left(\frac{n}{n+1}\right)^{n^2}} = \lim_{n \rightarrow \infty} \left(\frac{1}{1 + \frac{1}{n}}\right) = \frac{1}{e} < 1 \\
\text{*root condition} \\
2 + \frac{3}{4} + \frac{4}{9} + \dots + \frac{n+1}{n^2} + \dots \\
= \sum_{n=1}^{\infty} \frac{n+1}{n^2} \\
\text{diverges since} \quad \int_c^{\infty} \frac{x+1}{x^2} dx,
\end{gather}
```

```

\def x = \left[ \ln x - \frac{1}{x} \right]_{c^{\infty}} = \infty
\tag{integral condition}
\end{gather}
    
```

Note the use of `\tag` and `\notag` (page 271) to add text as markers to the second and fourth lines.

The align environment

The `align` environment is intended for multiple equations with horizontal alignment, usually on an equals sign or equivalent. New lines are indicated with `\\` as usual. Each line is split into aligned columns such that the first column is right justified against the `&` character, the second left justified; the third column is right justified against the *third* `&`, the fourth column left justified again, and so on. This is the same as an `array` environment with column specification `{r l r l r l ...}`.

$(x^n)'$	$= nx^{n-1}$	$(e^x)'$	$= e^x$	$(\sin x)'$	$= \cos x$
$\left(\frac{1}{x^n}\right)'$	$= -\frac{n}{x^{n+1}}$	$(a^x)'$	$= a^x \ln a$	$(\cos x)'$	$= -\sin x$
$(\sqrt[n]{x})'$	$= \frac{1}{n \sqrt[n]{x^{n-1}}}$	$(\ln x)'$	$= \frac{1}{x}$	$(\tan x)'$	$= \frac{1}{\cos^2 x}$
		$(\log_a x)'$	$= \frac{1}{x \ln a}$	$(\cot x)'$	$= -\frac{1}{\sin^2 x}$

```

\begin{align*}
\left(x^n\right)' &= nx^{n-1} & \left(e^x\right)' &= e^x & & \\
\left(\frac{1}{x^n}\right)' &= -\frac{n}{x^{n+1}} & \left(a^x\right)' &= a^x \ln a & \left(\cos x\right)' &= -\sin x \\
\left(\sqrt[n]{x}\right)' &= \frac{1}{n\sqrt[n]{x^{n-1}}} & \left(\ln x\right)' &= \frac{1}{x} & \left(\tan x\right)' &= \frac{1}{\cos^2 x} \\
& & \left(\log_a x\right)' &= \frac{1}{x \ln a} & \left(\cot x\right)' &= -\frac{1}{\sin^2 x}
\end{align*}
    
```

The `align*` environment is used here to prevent the lines from being numbered, something that is not appropriate for such a collection of formulas. The alignment within each of the three column pairs is on the equals sign. The input for the last line begins with a double `&&` to produce an empty column pair.

Occasionally a set of formulas is to be aligned on several equals signs in one line, as in the equations below for the volume V , inertial moment I_z , and mass M of an arbitrary body, in Cartesian, cylindrical, and spherical coordinates. In this case, the second and third parts are separated by a

double `&&` so that the left-hand sides of these column pairs are empty: the equals signs are always on an odd-numbered alignment marker.

$$\begin{aligned} V = \int_V d\nu &= \iiint dx dy dz &= \iiint \rho dx d\rho d\phi \\ & &= \iiint r^2 \sin \theta dr d\theta d\phi \end{aligned} \quad (12.5)$$

$$\begin{aligned} I_z = \int_V \rho^2 d\nu &= \iiint (x^2 + y^2) dx dy dz = \iiint \rho^3 dz d\rho d\phi \\ & &= \iiint r^4 \sin^3 \theta dr d\theta d\phi \end{aligned} \quad (12.6)$$

$$\begin{aligned} M = \int_V \delta d\nu &= \iiint \delta dx dy dz &= \iiint \delta \rho dz d\rho d\phi \\ & &= \iiint \delta r^2 \sin \theta dr d\theta d\phi \end{aligned} \quad (12.7)$$

```
\begin{align}
V & \&= \int\limits_V \!d\nu & \&= \iiint \!dx \!dy \!dz \\
& \&= \iiint \rho \!dx \!d\rho \!d\phi \\
& \& \& \&= \iiint r^2 \sin\theta \!dr \!d\theta \!d\phi \\
I_z & \&= \int\limits_V \rho^2 \!d\nu & \&= \iiint (x^2 + y^2) \\
& & \!dx \!dy \!dz & \!dz \!d\rho \!d\phi \\
& & \&= \iiint r^4 \sin^3\theta \!dr \!d\theta \!d\phi \\
M & \&= \int\limits_V \delta \!d\nu & \&= \iiint \delta \\
& & \!dx \!dy \!dz & \!dz \!d\rho \!d\phi \\
& & \&= \iiint \delta r^2 \sin\theta \!dr \!d\theta \!d\phi \\
\end{align}
```

There are two variations on the `align` environment, `falign` and `alignat`. The first has exactly the same syntax as `align` but it inserts so much spacing between the column pairs that the entire line is filled out. The `alignat` environment is just the opposite: no spacing is inserted automatically between the column pairs. It must take the number of column pairs as a mandatory argument, but otherwise the syntax of the contents is the same as that for `align`. The example above with the volume, inertial moment, and mass of a body could just as well have been given with

```
\begin{alignat}{3} formula_text \end{alignat}
```

(In fact, this is precisely what was done in order to fit it within the line width of this book.)

If one or more columns are empty, as in this example, it is possible to control their widths precisely in the `alignat` environment by adding

explicit spacing between the two & characters in one of the lines. See Section 5.5.1 for spacing in math mode.

In summary, for the `align` environment and its variants, the first, third, fifth, etc. & characters are alignment markers, while the second, fourth, sixth, etc. are column pair separators.

Nested alignment environments

We have already pointed out on page 272 how the `split` environment is to be placed inside an `equation` environment. The same is true for the environments `aligned` and `gathered`, which may be used as building blocks within formulas. Their contents and behavior are otherwise the same as their related environments.

Both of these environments take an optional argument *pos*

```
\begin{aligned}[pos] lines \end{aligned}
\begin{gathered}[pos] lines \end{gathered}
```

which takes values of `t` or `b` to determine the vertical alignment (top or bottom) when they appear beside other elements. When no *pos* is given, they are centered. In this way

$\alpha = aa$		$s = x + y$
$\beta = bbbbbb$	versus	$d = u - v - w$
$\gamma = g$	versus	$p = x \circ y$
	$\delta = dd$	
	$\eta = eeeeeee$	
	$\varphi = f$	

is produced with

```
\begin{equation*}
\begin{aligned} \alpha&=aa\ \ \beta&=bbbbbb\ \ \gamma&=g \\
\end{aligned} \\
\quad\text{versus}\quad \\
\begin{aligned}[t] \delta&=dd\ \ \eta&=eeeeeee\ \ \varphi&=f \\
\end{aligned} \\
\quad\text{versus}\quad \\
\begin{gathered}[b] s= x+y\ \ d= u - v - w\ \ p = x\circ y \\
\end{gathered} \\
\end{equation*}
```

The cases environment

Although it is possible with standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ to produce structures of the form

$$P_{r-j} = \begin{cases} 0 & \text{if } r-j \text{ is odd,} \\ r!(-1)^{(r-j)/2} & \text{if } r-j \text{ is even.} \end{cases} \quad (12.8)$$

as demonstrated by a similar example in Section 5.4.1 on page 132, the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ `cases` environment allows a simpler input:

```
\begin{equation}
P_{r-j}=\begin{cases} 0 & \text{if } r-j \text{ is odd,} \\
r! \cdot (-1)^{(r-j)/2} & \text{if } r-j \text{ is even.} \end{cases} \\
\end{equation}
```

There may be more than two cases in the environment, as in the example reproduced here from page 132:

$$y = \begin{cases} -1 & : x < 0 \\ 0 & : x = 0 \\ +1 & : x > 0 \end{cases} \quad \left[\begin{array}{l} y = \begin{cases} -1 & \text{if } x < 0 \\ \hfill 0 & \text{if } x = 0 \\ +1 & \text{if } x > 0 \end{cases} \end{array} \right]$$

12.2.7 Equation numbering

Numbering hierarchy

With the standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ classes `book` and `report`, equations are given a double number with the chapter designation and then a sequential number starting at 1 for each new chapter. For the `article` class, the equations are numbered sequentially throughout the work.

With the `amsmath` package, it is possible to alter this hierarchy. For example, if an article is to have the equations numbered within each section, with the section number, give

```
\numberwithin{equation}{section}
```

to redefine the equation numbers to include the section number and to make the `equation` counter reset every time the `section` counter is incremented. This is as though the `equation` counter had been created with `\newcounter{equation}[section]` (Section 8.1.2), something which the user cannot normally bring about. Furthermore, `\theequation` is redefined to be `\thesection.\arabic{equation}`, something that is in the user's power but which is not much use if the `equation` counter is never reset.

Subnumbering equations

On page 190 we give an example of how equations may be subnumbered, that is, the main equation number stays the same and a letter is appended to it, as 1.8a, 1.8b, 1.8c The `amsmath` package provides this feature with the `subequations` environment. Numbered equations appearing within

```
\begin{subequations} ... \end{subequations}
```

will all have the same main number which is one more than that of the previous one, with sequential, lower case letters attached.

Within the environment, the `equation` counter refers to the subnumber, that is, to the letters, while the main number is to be found in the `parentequation` counter. To change the format of the subnumber, say to 1.8-A, 1.8-B, . . . , give

```
\begin{subequations}
\renewcommand{\theequation}
{\theparentequation-\Alph{equation}}
. . .
\end{subequations}
```

Referencing equation numbers

The $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ cross-reference system is described in Section 9.2.1 and works exactly the same way with $\mathcal{A}\mathcal{M}\mathcal{S}$ - $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$: when `\label{marker}` is issued in a mathematical formula that receives an automatic equation number, that number can be printed anywhere in the text with `\ref{marker}`, where *marker* is arbitrary text to identify that equation.

The `amsmath` package adds a command `\eqref{marker}` to print the equation number in parentheses, as it appears beside the math formula. For example, the cases equation on page 276 is referred to as equation 12.8 with `\ref`, or as equation (12.8) with `\eqref`.

If `\label` is given immediately after the start of a `subequations` environment, the corresponding `\ref` commands will print the main equation number without the extra letter. In this way one can refer to the entire group of equations. Later `\label` commands are associated with individual equation lines and reference them with the letters.

Page breaks within multiline formulas

Unlike the standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ `eqnarray` environment, the $\mathcal{A}\mathcal{M}\mathcal{S}$ - $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ multiline math environments do not normally allow any page breaks to occur within them. The idea is that the author should have more control over where such breaks may occur. To allow or force a page break within a multiline equation, one gives

```
\displaybreak[num]
```

just before the line breaking command `\`. Here the optional *num* has the same meaning as for the standard `\pagebreak` command (page 33): without it, a new page is forced, but it may take values of 0–4 to allow a break with increasing degree of encouragement, whereby 4 also forces the page break.

Alternatively, one can issue `\allowdisplaybreaks` in the document preamble to allow $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ to break pages automatically within multiline

formulas as necessary. This command too takes an optional argument *num* with possible values between 0 and 4 which make it progressively easier for automatic page breaks to occur.

Once `\allowdisplaybreaks` has been given in the preamble, it is still possible to suppress page breaks within a formula by ending an equation line with `*` instead of with `\\`.

12.2.8 Package options for `amsmath`

The main `amsmath` package for $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ recognizes a number of options that may be given when it is loaded with

```
\usepackage[options]{amsmath}
```

They are listed here as pairs with opposing effects. The member of each pair that is assumed if neither is given, the default, is indicated by underlining.

centertags | tbtags The equation number for a `split` environment (page 272) is centered vertically by default. With `tbtags`, it is placed either to the left of the first line or to the right of the last line, depending on the side on which numbers are to appear.

sumlimits | nosumlimits In displayed formulas, initial and final limits appear below and above the \sum sign with the `sumlimits` option. With `nosumlimits`, they are placed beside the sign, raised and lowered with the usual `^` and `_` characters.

Other symbols that are affected by these options are \sum \prod \coprod \cup \uplus \cap \sqcup \vee \wedge \odot \otimes and \oplus . On the other hand, integral signs are not influenced by them.

$$\begin{array}{l} \text{sumlimits} \\ \sum_{n=0}^{\infty} \frac{1}{2^n} = 2; \quad \prod_{i=0}^{m-1} n - i = \frac{n!}{(n-m)!} \end{array} \qquad \begin{array}{l} \text{nosumlimits} \\ \sum_{n=0}^{\infty} \frac{1}{2^n} = 2; \quad \prod_{i=0}^{m-1} n - i = \frac{n!}{(n-m)!} \end{array}$$

The input text is the same for both of the above cases.

intlimits | nointlimits Integral signs normally have their limits at the side; these options allow them to be placed above and below as for summations.

$$\text{intlimits} \quad \int_0^a \sqrt{a^2 - x^2} dx = \int_0^1 a^2 \sqrt{1 - \sin^2 t} d \sin t = a^2 \int_0^{\pi/2} \cos^2 t dt = \frac{\pi a^2}{4}$$

`nointlimits`

$$\int_0^a \sqrt{a^2 - x^2} dx = \int_0^1 a^2 \sqrt{1 - \sin^2 t} d \sin t = a^2 \int_0^{\pi/2} \cos^2 t dt = \frac{\pi a^2}{4}$$

where again the input text is the same for both cases. As a reminder, the standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ treatment of limits on integral signs is the same as for `nointlimits`.

`namelimits` | `nonamelimits` The function names `\det`, `\gcd`, `\inf`, `\lim`, `\liminf`, `\limsup`, `\max`, `\min`, `\Pr`, and `\sup` frequently take lower limits which normally appear below the name in displayed formulas. With `nonamelimits`, they are placed at the lower right.

<code>namelimits</code>	<code>nonamelimits</code>
$\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x = e = 2.7182\dots$	$\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x = e = 2.7182\dots$

The above options determine the standard placement of limits for the entire document. It is still possible to change the behavior in any particular case with the `\limits` and `\nolimits` commands, as in normal $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$.

The remaining package options select the side for equation numbers and the horizontal positioning of equations.

`leqno` | `reqno` The standard location for equation numbers is on the right side, at the margin; with `leqno`, they are placed on the left side of the equation.

`fleqn` With this option, all displayed equations are printed flush left, set off from the left margin by an amount `\mathindent`. Without this option, equations are centered. (This is like the `fleqn` class option for the standard classes, page 39.)

12.3 Further $\mathcal{A}\mathcal{M}\mathcal{S}$ - $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ packages

The $\mathcal{A}\mathcal{M}\mathcal{S}$ - $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ packages described in this section must be loaded explicitly if their features are to be exploited. Unlike the `amsbsy` and `amstext` packages, they are not loaded automatically with `amsmath`. They may, however, be used on their own, independently of the main package.

12.3.1 Extended theorem declarations

Package: `amsthm` The `amsthm` package offers many additional possibilities for generating theorem-like declarations described for standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ in Section 4.5.

As for standard $\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$, a new theorem declaration is created with a statement like

```
\newtheorem{com}{Comment}
```

where the first argument is the name of the theorem type (here `com`) and the second is the title that is printed when the theorem declaration is invoked. For example,

```
\begin{com}
  Theorem declarations can have any name.
\end{com}
```

produces the declaratory text

Comment 1. *Theorem declarations can have any name.*

In addition to the two mandatory arguments, the `\newtheorem` command may have one of two optional ones. The complete syntax is

```
\newtheorem{type}[num_like]{title}
or
\newtheorem{type}{title}[in_counter]
```

where *num.like* is the name of an existing theorem-like declaration which is to be numbered in the same sequence as *type*, and *in_counter* is a counter name like `chapter` or `section` to reset the numbers of the *type* declarations.

All this is standard $\mathcal{L}\mathcal{T}\mathcal{E}\mathcal{X}$ so far. The `amsthm` package adds the following features.

- A `\newtheorem*` is provided that defines an unnumbered theorem structure.
- Three predefined theorem styles are available:

`plain` in which the title and number are in bold face and the text italic;

`definition` with title and number in bold face and the text in normal font;

`remark` for title and number in italic and the text normal.

The desired style is activated by first issuing `\theoremstyle{style}`; all subsequent `\newtheorem` statements will have this style until a new one is activated.

- A `\swapnumbers` can be issued to cause all following new theorem types to have the numbers appear before the title, as **1 Comment**.
- New theorem styles may be defined by the user by means of a `\newtheoremstyle` command, or additional predefined styles may be loaded with package options. Since this is fairly specialized and complex, it is best to examine the example file `thmtest.tex` or read the documentation in `amsthm.dtx`.

- A `proof` environment is available for presenting short proofs. It is an unnumbered structure with the title *Proof*. The text is terminated automatically with the Q.E.D. symbol \square . This symbol may be altered by redefining the command `\qedsymbol`; it may be printed at any time by issuing `\qed`.

The `amsthm` package has much in common with Frank Mittelbach's `theorem` package in the `tools` collection of Section B.5.4.

12.3.2 Commutative diagrams

Package:
`amscd`

The extra $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ package `amscd` makes it easier to generate commutative diagrams like the one here at the right.

$$\begin{array}{ccc}
 S^{\mathcal{W}\Lambda} \otimes T & \xrightarrow{j} & T \\
 \downarrow & & \downarrow_{\text{End } P} \\
 (S \otimes T)/I & \longequal{\quad} & (Z \otimes T)/J
 \end{array}$$

These diagrams are created within the `CD` environment using some additional arrow commands. These bear the rather unusual names `@>>>`, `@<<<`, `@AAA` and `@VVV` for arrows pointing right, left, upwards, and downwards, respectively. The command `@=` draws a horizontal double rule, a lengthened equals sign.

Any text or symbols between the first and second `>` or `<` characters will appear above the horizontal arrow in `\scriptstyle` font. Similarly, any text or symbols between the second and third characters will be printed below the arrow.

For vertical arrows, text or symbols between the first and second `A` or `V` are placed to the left; those between the second and third to the right, again in `\scriptstyle`.

The above example diagram, which is taken from the $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ manual `amsl.doc.tex`, was produced with

```

\[\begin{CD}
S^{\mathcal{W}\Lambda} \otimes T @>j>> T \\
@VVV @VVV{\text{End } P} \\
(S \otimes T)/I @= (Z \otimes T)/J
\end{CD}\]

```

The command `\End` to print the function name 'End' is not standard. It must be previously defined with `\DeclareMathOperator{\End}{End}` (see page 268).

12.3.3 References with `upref` package

Package:
`upref`

Normally the numbers printed with the `\ref` and `\pageref` commands are in the current font, whether that be bold, italic, or upright. In order to ensure that the numbers are always upright, load the extra $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ package `upref`.

12.4 The $\mathcal{A}\mathcal{M}\mathcal{S}$ fonts

The $\mathcal{A}\mathcal{M}\mathcal{S}$ makes a number of fonts available to complement the regular Computer Modern fonts provided with the standard $\text{T}\text{E}\text{X}/\text{L}\text{A}\text{T}\text{E}\text{X}$ installation. They include extra math alphabets, supplemental CM bold math italic and symbol fonts in smaller sizes than 10 pt, Cyrillic fonts, and additional symbol fonts.

In the next sections we describe these various fonts and how to take advantage of them.

12.4.1 Extra CM math fonts

Standard TEX installations of Computer Modern fonts provide bold math italic `cmmib10`, the bold symbols `cmbsy10`, and math extensions `cmex10` fonts only in 10 pt size, as indicated by the suffix 10 to their names. The $\mathcal{A}\mathcal{M}\mathcal{S}$ has supplemented these with versions in sizes 5–9 pt.

<code>cmmib5</code>	<code>cmmib6</code>	<code>cmmib7</code>	<code>cmmib8</code>	<code>cmmib9</code>
<code>cmbsy5</code>	<code>cmbsy6</code>	<code>cmbsy7</code>	<code>cmbsy8</code>	<code>cmbsy9</code>
		<code>cmex7</code>	<code>cmex8</code>	<code>cmex9</code>

The small caps font `cmcsc10` is also given companions `cmcsc8` and `cmcsc9`.

The normal $\text{L}\text{A}\text{T}\text{E}\text{X}$ installation automatically assumes that these fonts are on the system and incorporates them into the necessary NFSS font definition files. Substitutions will be made if they are missing.

12.4.2 Cyrillic fonts

The $\mathcal{A}\mathcal{M}\mathcal{S}$ Cyrillic fonts were originally used in reviews of books published in Russian and other Slavic languages in which the titles were to be rendered in the original language. In 1988, the Humanities and Arts Computing Center of the University of Washington redesigned them for general purpose Slavic studies, adding the pre-Revolutionary and accented letters. The overall appearance was also greatly enhanced (see Layout 8 on page 497).

These fonts all bear the prefix `wncy`, followed by the style designation `r` (upright), `b` (bold), `i` (italic), `sc` (small caps), or `ss` (upright sans serif), and the design size in points.

The best way to enable the Cyrillic fonts is simply to select font encoding OT2 under NFSS, as illustrated in Section A.2 on page 371. The `.fd` (font definition) files for the Cyrillic fonts have been so set up that the other font attributes fully parallel those of the Latin fonts. This means `wncyr10` has all the same attributes as `cmr10`, except for the encoding: family `cmr`, shape `n`, series `m`. (Of course, if the CM fonts are not the

current standard ones, it will require more than just selecting the OT2 encoding to activate these Cyrillic fonts.)

The layout of the Cyrillic fonts has been chosen in such a way that the input text may be entered following the regular English transliteration scheme. Thus Cyrillic *C* is in position 83 where Latin *S* is normally situated. Typing *S* when a Cyrillic font is active outputs the correct equivalent *C*. Numerals and punctuation are to be found in the standard locations and so may be typed in as usual. ‘Санкт-Петербург 10?’ is thus generated by `{\cyr Sankt-Peterburg 10?}`.

Since the Cyrillic alphabet possesses more letters than the Latin, many of them must be transliterated with multi-letter combinations. These are automatically programmed into the fonts using \TeX 's ligature system. For example, *Ch* is treated as a ligature for symbol 81 Ч just as *fi* is for *fi* in a Latin font. This means that multi-letter transliterations are simply typed in. The input for ‘Хрущёв’ is `{\cyr Khrushchev}`, where *Kh* → *X* and *shch* → *ш*. The transliteration scheme is that for English; other languages have their own systems to reproduce the original pronunciation. For example, ‘Горбачёв’ is *Gorbatschow* in German, *Gorbaciov* in Italian, and *Gorbachev* in English. These other schemes do *not* work with these fonts.

Not all letters can be produced so automatically (for example, the *ë* in Горбачёв) and for this reason the $\mathcal{A}\mathcal{M}\mathcal{S}$ provides a file `cyracc.def` containing macro definitions for accented letters and other special features, such as the hard and soft signs. When these macros are given in a Latin font, additional transliteration symbols appear.

12.4.3 Euler fonts

The fonts known as the *Euler* collection, named after the eighteenth-century mathematician Leonhard Euler, have been collected from various sources by the $\mathcal{A}\mathcal{M}\mathcal{S}$. They include a ‘blackboard’ font, representing a professor’s handwriting on a blackboard, a Fraktur or Gothic font, and a script font. Their main purpose in mathematics is to be a substitute for the CM calligraphic math alphabets.

Package: `amsfonts` To use the blackboard characters, one must load the package `amsfonts` (which is included automatically with the `amssymb` package) and then employ the math alphabet command `\mathbb`. Thus `\mathbb{A B C ...}` produces

A B C D E F G H I J K L N M O P Q R S T U V W X Y Z

Package: `euca1` The package `euca1` redefines the `\mathcal` command to use the Euler script characters in place of the CM calligraphic letters. If this package is loaded with the option `mathscr`, the command `\mathcal` is left unchanged and instead `\mathscr` is defined to invoke these letters. In this case, `\mathscr{A B C ...}` produces

A B C D E F G H I J K L N M O P Q R S T U V W X Y Z

Package: Finally, the package `eufrak` defines the math alphabet command
eufrak `\mathfrak`, with which `\mathfrak{A B C . . .}` yields

Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓝ Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ Ⓤ Ⓥ Ⓦ Ⓧ Ⓨ Ⓩ

This math alphabet is also enabled with the `amsfonts` package.

12.4.4 Extra math symbols

The set of symbols in the CM math symbol fonts by no means exhausts the fantasies of active mathematicians. To overcome this deficiency, the \mathcal{AMS} has produced two fonts, `msam10` and `msbm10`, containing only symbols, arrows, and the blackboard characters. They are also available in sizes 5–9 pt. Since these fonts originated in the days when $\text{T}_\text{E}\text{X}$ could only handle 128 characters in any font, that is exactly how many they contain. Today, they could be combined into one font of 256 characters.

Two packages permit access to this treasure trove of hieroglyphs:

`amsfonts` enables the `\mathbb` math alphabet command for the blackboard characters, and defines those symbol names which are otherwise only provided in the `latexsym` package (Section 5.3.3).

`amssymb` is the more convenient package, which loads `amsfonts` and then defines names for all the symbols in the two fonts.

For example,

```
\[ \circlearrowright \Cup \lessapprox \lll \varpropto \because
\circeq \vDash \blacktriangle \sphericalangle \]
⊂ ⊃ ≈ ≪ ∞ ∴ ≐ ≠ ▲ ✕
```

All the symbols and their associated names from the `amssymb` package are to be found in Tables H.20–H.26 on pages 599–601.

The inclusion of graphical material from other programs is treated in Chapter 6. Such ‘foreign’ files do add some complications (which are greatly reduced today with L^AT_EX 2_ε) and can cause portability problems. What would be desirable is a means to do graphics with L^AT_EX itself so that the source text file is fully self-contained.

Standard L^AT_EX does contain the means to make somewhat primitive drawings on its own. The word ‘primitive’ should not be considered derogatory, for simple building blocks are the basic units for constructing very complicated, sophisticated structures. They are also useful for superimposing imported graphics or for adding embellishments to them, as demonstrated in Section 6.1.5.

This chapter describes the intrinsic L^AT_EX drawing capabilities, and then explains some extensions that are available to enhance them.

Many more possibilities exist for adding specialized diagrams, from chemistry, to music, to chess positions. These are described in detail in *The L^AT_EX Graphics Companion* by Goossens *et al.* (1997).

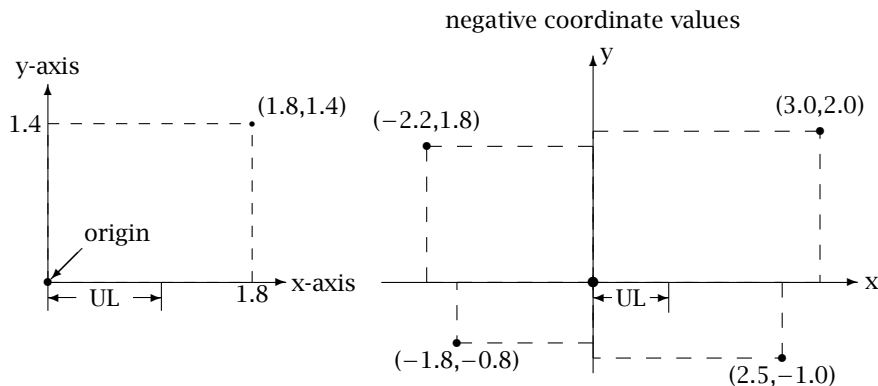
13.1 The picture environment

13.1.1 Picture coordinates

The picture building blocks can only be put in place once a *coordinate system* has been established for that picture. This consists of a *reference point* or *origin*, and two mutually perpendicular *coordinate axes*, as well as a *length unit* for the coordinates. The origin is the lower left corner of the picture and the axes are its lower and left edges. These edges are referred to as the *x-axis* (lower) and *y-axis* (left).

Once the unit of length (UL) has been specified, every point within the picture area can be uniquely referred to with two decimal numbers: the first is the number of length units along the x-axis, the second the number along the y-axis.

The coordinate numbers are generally positive, meaning that the point lies to the right and above the reference point. Since this point is the lower left corner of the picture, all other points should be more to the right and higher than it. However, negative values are also possible. A negative x value (a negative number for the first member of a coordinate pair) defines a point *left* of the origin, while a negative y value (the second member of the pair is negative) specifies a point below the reference point.



The unit length is selected with the command

```
\setlength{\unitlength}{length}
```

In the left-hand example above, the unit length was set to a value of 1.5 cm with the command `\setlength{\unitlength}{1.5cm}`. The point (1.8,1.4) then lies 1.8 times the unit length (= 2.7 cm) to the right, and 1.4 times (= 2.1 cm) above the origin. In the right-hand example, the unit length is set to 1 cm.

The unit of length is normally set to a convenient size such as 1 cm, 1 mm, or 1 in and the picture is built up accordingly. Once it has been completed, it is possible to rescale the whole thing simply by changing the value of the length unit. A picture that was originally designed with `\unitlength` set to 1 cm can be enlarged by a factor 1.2 by redefining its length unit to be 1.2 cm.

13.1.2 The picture environment

Pictures are constructed within the `picture` environment which is started with

```
\begin{picture}(x_dimen,y_dimen)
  picture_commands
\end{picture}
```

where (x_dimen, y_dimen) is a pair of numbers that specifies the size (dimensions) of the picture in the x -direction (horizontal) and y -direction (vertical). This pair of numbers is enclosed in *round* parentheses! The unit of length is that previously selected by `\unitlength`.

```
\setlength{\unitlength}{1.5cm}
\begin{picture}(4,5) ... .. \end{picture}
```

produces a picture that is 4 length units wide and 5 units high. Since the length unit has been set to 1.5 cm, the actual size is 6 cm wide and 7.5 cm high.

Picture commands are those commands described below that are used to produce and position the individual picture elements. These are the only commands that are allowed within the `picture` environment, other than font style and size declarations (Section 4.1) and the line thickness commands `\thicklines` and `\thinlines`. These last determine which of the two available line thicknesses will become current for drawing lines: one may switch back and forth as one pleases. Initially *thin* lines are active.

The value of the parameter `\unitlength` must not be altered within the `picture` environment, for it must remain the same for the entire picture. It may, however, be changed between pictures.

If the `\unitlength` specification together with the `picture` environment are enclosed within another environment, such as `\begin{center} ... \end{center}`, then that value of `\unitlength` is valid only until the end of the environment. A `picture` environment without a preceding `\unitlength` command uses the standard value of 1 pt.

13.1.3 The positioning commands

Picture elements are generated and positioned by means of the two commands `\put` and `\multiput`, which have the syntaxes:

```
\put(x,y){pic_elem}
\multiput(x,y)(\Delta x,\Delta y){num}{pic_elem}
```

The *pic_elem* is one of the picture element commands described in the next section. The arguments (x, y) are the *placement coordinates*, designating the location of the picture element within the picture coordinate system, in units of `\unitlength`. If this is 1 cm, then (2.5,3.6) means that the element is to be positioned 2.5 cm to the right and 3.6 cm above the lower left corner of the picture.

The `\multiput` command generates the same picture element *num* times, moving it $(\Delta x, \Delta y)$ each time. Thus the element is drawn at

```
(x, y), (x + \Delta x, y + \Delta y),
(x + 2\Delta x, y + 2\Delta y), ... up to
(x + [num - 1]\Delta x, y + [num - 1]\Delta y)
```

The coordinate pair (x, y) is incremented by $(\Delta x, \Delta y)$ for each successive placement. The values of the incrementing pair may be positive or negative.

Thus `\multiput(2.5,3.6)(0.5,-0.6){5}{pic_elem}` produces the *pic_elem* a total of five times, first at the location (2.5,3.6) and then at (3.0,3.0), (3.5,2.4), (4.0,1.8), and finally (4.5,1.2).

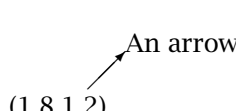
Note that the numbers for the *coordinate* and *increment* pairs are given in round parentheses (,) and that the two numbers within each pair are separated by a comma. The *num* and *pic_elem* entries, on the other hand, are enclosed in curly brackets { } as usual.

Warning: Since the comma separates the two numbers in a coordinate pair, it may *not* be used in place of a decimal point. *For coordinate entries, decimal numbers must be written with a period, not a comma.*

13.1.4 Picture element commands

Text within pictures

The simplest picture element of all is a piece of text, positioned at the desired location within the picture. This is accomplished by putting text in place of *pic_elem* in the `\put` or `\multiput` command.

 (1.8,1.2) An arrow

The arrow points to the location (1.8,1.2). The command `\put(1.8,1.2){An arrow}` inserts the text 'An arrow' so that its lower left corner is at the specified position.

The text as picture element may also be packed into a `\parbox` or a `minipage` environment, and the reference point for the coordinate entry in the `\put` command depends on the positioning arguments of that box:

<code>\parbox[b]{...}{...}</code> Reference point is the lower left corner of the last line in the parbox.	<code>\parbox{32mm}{...}</code> For a standard parbox, the reference point is the vertical center of the left edge.	<code>\parbox[t]{...}{...}</code> Reference point is the lower left corner of the top line in the parbox.
---	--	--

Exercise 13.1: Produce a picture 100 mm wide and 50 mm high with `\unitlength` equal to 1 mm. Place the given texts at the following locations: (0,0) 'The First Picture', (90,47) 'upper left', (70,40) 'somewhere upper right', and put a parbox of width 60 mm at (25,25) containing 'A separate exercise file with the name picture.tex should be created for the exercises in this Chapter.'

Exercise 13.2: Repeat the picture processing with a value of 1.5 mm for `\unitlength`, and with positioning arguments *t* and *b* for the parbox.

Picture boxes—rectangles

The box commands `\framebox`, `\makebox`, and `\savebox` (Section 4.7.1) are available in the `picture` environment but with an extended syntax. In addition, there is another box command `\dashbox`:

```
\makebox(x_dimen,y_dimen)[pos]{text}
\framebox(x_dimen,y_dimen)[pos]{text}
\dashbox{dash_len}(x_dimen,y_dimen)[pos]{text}
```

The *dimensional* pair (x_dimen, y_dimen) defines the width and height of the rectangular box in units of `\unitlength`. The positioning argument *pos* determines how the *text* is located within the box. It may take on values:

- [t] *top* The input text appears—centered horizontally—*below* the *upper* edge of the box.
- [b] *bottom* The input text appears—centered horizontally—*above* the *lower* edge of the box.
- [l] *left* The input text *begins*—centered vertically—at the *left* edge of the box.
- [r] *right* The input text *ends*—centered vertically—at the *right* edge of the box.
- [s] *stretch* The input text is stretched horizontally to fill up the box, and centered vertically.

Without the optional argument *pos*, the input text is centered vertically and horizontally within the box.

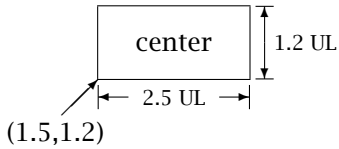
These positional values may be combined two at a time:

- [tl] *top left* The text appears at the *upper left*.
- [tr] *top right* The text appears at the *upper right*.
- [bl] *bottom left* The text appears at the *lower left*.
- [br] *bottom right* The text appears at the *lower right*.

The order of the values is unimportant: `tl` has the same effect as `lt`.

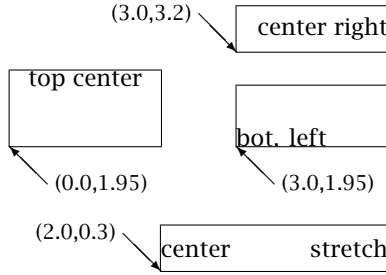
These box commands are to be used as *pic_elem* in the placement commands `\put` and `\multiput`. The box is so placed that its lower left corner is at the position given by the coordinate pair in the placement command.

```
\put(1.5,1.2){\framebox(2.5,1.2){center}}
```



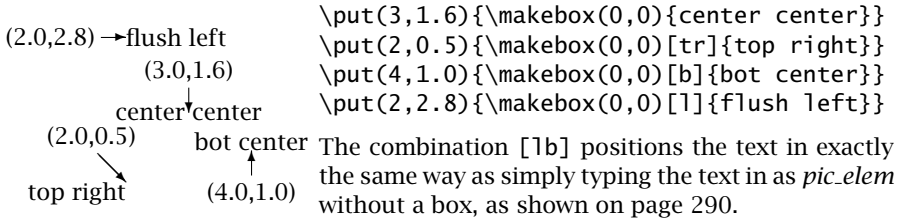
The arrow indicates the point (1.5,1.2) which is the position of the lower left corner of the rectangle with width 2.5 units and height 1.2 units. The text 'center' is centered both horizontally and vertically. UL = 0.8 cm.

The effect of the text positioning argument is made clear with the following examples (UL = 1 cm):



```
\put(0.0,1.95){\framebox(2,1.0)
[t]{top center}}
\put(3.0,1.95){\framebox(2,0.8)
[lb]{bot. left}}
\put(3.0,3.2){\framebox(2,0.6)
[r]{center right}}
\put(2.0,0.3){\framebox(2,0.6)
[s]{stretch\hfill center}}
```

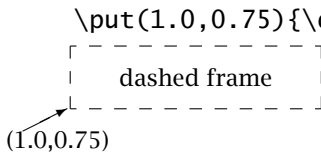
The picture element `\makebox` is exactly the same as the `\framebox` command but without the rectangular frame. It is most often employed with the dimensional pair (0,0) in order to place text at a desired location. (See Section 4.7.1 for the effect of *zero* width boxes on the enclosed text.)



```
\put(3,1.6){\makebox(0,0){center center}}
\put(2,0.5){\makebox(0,0)[tr]{top right}}
\put(4,1.0){\makebox(0,0)[b]{bot center}}
\put(2,2.8){\makebox(0,0)[l]{flush left}}
```

The combination `[lb]` positions the text in exactly the same way as simply typing the text in as *pic.elem* without a box, as shown on page 290.

The picture element `\dashbox` also produces a framed box, but with a *dashed* line around it. The argument *dash_len* specifies the *dash length*.



```
\put(1.0,0.75){\dashbox{0.2}(4,1){dashed frame}}
```

A dashed frame looks best when both the height and width are a multiple of the dash length.

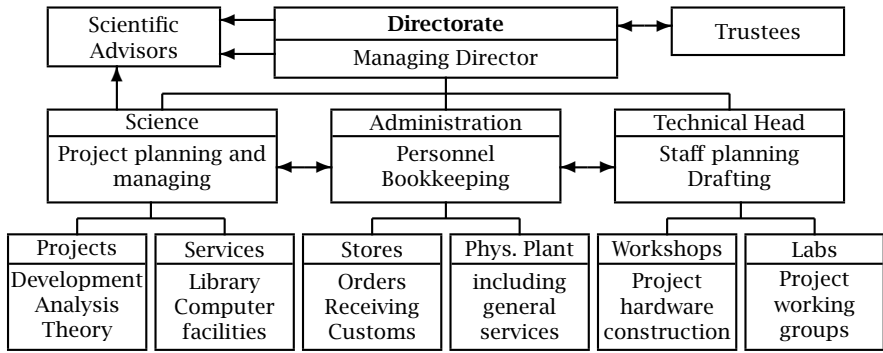
Even in the above picture box commands, the entered *text* may be put into a vertical box (`\parbox` or `\minipage`). Since vertical boxes themselves possess an optional positioning argument `b` or `t`, which must not conflict with that of the picture box, the following rule must be observed:

If a picture box command contains the positioning argument `b` or `t`, then the same value must be applied to the enclosed vertical box. If the picture box command has no positioning argument or only `r` or `l`, then the vertical box must be used in the standard (no argument) form.

The positioning argument of a picture box has the same effect on the enclosed vertical box as it does on a line of text, in that the whole box is treated as a single unit.

Exercise 13.3: Reproduce the organization table below with the boxes and included text but without the horizontal and vertical lines and arrows. These will be part of the next exercise.

Hint: first draw the boxes on a piece of squared paper so that the edges of the boxes lie on the printed rules. Select the unit of length to be the rule spacing of the paper. Take as the origin the lower left corner of an imaginary frame surrounding the entire diagram.

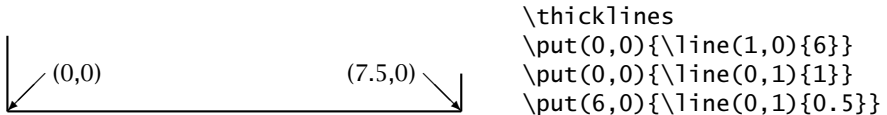


Straight lines

In the `picture` environment, \LaTeX can draw straight lines of any length, horizontally and vertically as well as at a limited number of angles. The syntax for this picture element reads

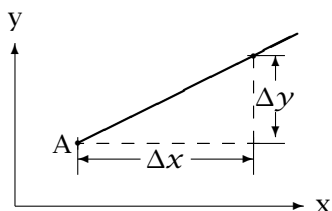
```
\line( $\Delta x$ ,  $\Delta y$ ) {length}
```

For horizontal and vertical lines, *length* specifies how long the line is to be in length units. For lines at an angle, it has a somewhat more complicated meaning, as is explained below. The line begins at that spot given by the placement coordinates in the `\put` or `\multiput` command.



The angle at which the line is drawn is given by the *slope pair* $(\Delta x, \Delta y)$. The slope pair $(1, 0)$, in which $\Delta x = 1$ and $\Delta y = 0$, produces a *horizontal* line, while the pair $(0, 1)$ leads to a *vertical* line. This is illustrated in the above example.

In general $(\Delta x, \Delta y)$ has the following meaning:



Beginning at a point A on the line and moving a distance Δx in the x direction (horizontally), Δy is the distance one must move in the y direction (vertically) in order to rejoin the line.

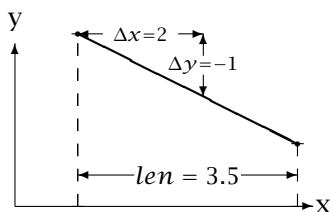
By specifying a slope pair $(\Delta x, \Delta y)$, a line is drawn at just that angle to fulfill the above conditions.

As mentioned already, the number of different slopes available is limited. This is because Δx and Δy may only take on values according to certain rules:

1. The number must be a whole integer (negative or positive).
2. Only the values 0, 1, . . . , 6 are allowed.
3. The two numbers in the pair may not contain a common divisor.

Pairs such as (3.5, 1.2) (rule 1) and (7, 0) (rule 2) are thus forbidden. Similarly (2, 2) and (3, 6) are invalid pairs by rule 3, since both numbers in the first pair are divisible by 2, and those in the second by 3. The same angles are achieved with the pairs (1, 1) and (1, 2) respectively. In all there are 25 allowed slope pairs, including (1, 0) for horizontal and (0, 1) for vertical lines, as one can verify by writing down all the possibilities.

In addition, the numbers in the slope pair may be positive or negative, for example, (0, -1), (-2, -5). A negative Δx in the above diagram means motion to the left, and a negative Δy is for motion downwards. Thus `\put(2,3){\line(0,-1){2.5}}` draws a line starting at point (2,3) and going 2.5 length units vertically downwards.



For lines at an angle, the argument *length* determines the projected distance along the x-axis. This is made clearer with the help of the diagram on the left.

`\put(1.0,2.75){\line(2,-1){3.5}}`

If one draws dashed lines straight down from the two end points, then that part of the x-axis between them is the projection of the line on to the x-axis.

Sloping lines must have a minimum length of about 10 pt or 3.5 mm, otherwise a warning is issued and no line is drawn.

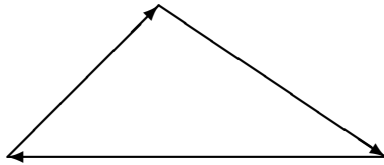
Arrows

The *arrow* picture element is made with the command

`\vector(Δx , Δy){length}`

which functions exactly the same as the `\line` command as far as the arguments and their limitations are concerned. The command draws a line from the placement location given in the `\put` or `\multiput` command and places an arrow head at the end.

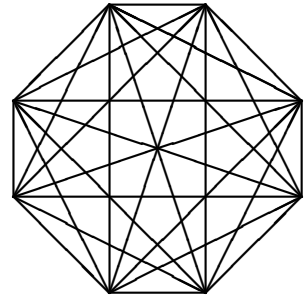
Just as for lines, arrows too must have a length of at least 10 pt or 3.5 mm. Rules 1–3 apply to Δx and Δy as well, with the further restriction that the allowed numbers are limited to 0, 1, \dots , 4. This makes a total of 13 possible angles for arrows, not counting changes in sign.



```
\begin{picture}(5,2)\thicklines
\put(5,0){\vector(-1,0){5}}
\put(0,0){\vector(1,1){2}}
\put(2,2){\vector(3,-2){3}}
\end{picture}
```

Exercise 13.4: Complete the diagram in Exercise 13.3 by including the missing horizontal and vertical lines and arrows.

Exercise 13.5: Generate the figure at the right. The corner points are (0,5), (0,10), (5,15), (10,15), (15,10), (15,5), (10,0), and (5,0) and the length unit is 0.1 inch.

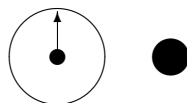


Circles

The *circle* picture element is produced with the commands

```
\circle{diameter}
\circle*{diameter}
```

With the *-form of the command, a solid filled-in circle is printed rather than just an outline as for the standard form. Only certain sizes are available so \LaTeX selects the one closest to the specified *diameter* entry. If the size is too small, a warning is output to the monitor and no circle is printed.



```
\begin{picture}(3,1.6)
\put(1,1){\circle*{0.2}}
\put(1,1){\circle{1.2}}
\put(1,1){\vector(0,1){0.6}}
\put(2.5,1){\circle*{0.5}}
\end{picture}
```

The placement location in the corresponding `\put` command refers to the center of the circle.

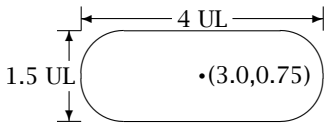
Ovals and rounded corners

The term *oval* is used here to mean a rectangle whose corners have been replaced by quarter circles; the largest possible radius is chosen for the circles such that the sides join together smoothly. The command to produce them is

```
\oval(x_dimen,y_dimen)[part]
```

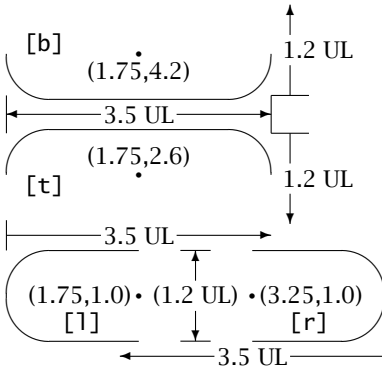
The placement location in the corresponding `\put` command refers to the center of the oval.

```
\put(3.0,0.75){\oval(4.0,1.5)}
```



Here we have set the values $x_dimen=4.0$ UL and $y_dimen=1.5$ UL, whereby the unit length UL has been selected to be 0.8 cm. The center of the oval is at the placement coordinates in the `\put` command, at (3.0,0.75).

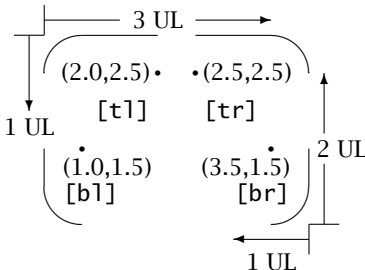
The optional argument *part* takes on values `t`, `b`, `l`, or `r`, for making half ovals.



```
\put(1.75,4.2){\oval(3.5,1.2)[b]}
\put(1.75,2.6){\oval(3.5,1.2)[t]}
\put(1.75,1.0){\oval(3.5,1.2)[l]}
\put(3.25,1.2){\oval(3.5,1.2)[r]}
```

The width and height specifications for half ovals are always those of the *entire* figure even though only part of it is being drawn. Similarly, the placement coordinates in the corresponding `\put` command refer to the center of the complete oval. (Unit length here is UL = 1 cm.)

The argument *part* may also be one of the combinations `tl`, `tr`, `bl`, or `br` to generate a quarter oval. The order of the two letters is unimportant, so that `lt`, `rt`, `lb`, and `rb` are equally valid.

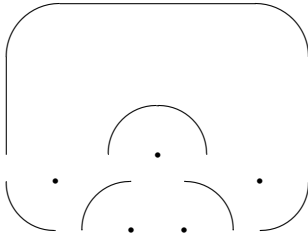


```
\put(2.0,2.5){\oval(3.0,1.0)[tl]}
\put(2.5,2.5){\oval(3.0,1.0)[tr]}
\put(1.0,1.5){\oval(1.0,2.0)[bl]}
\put(3.5,1.5){\oval(1.0,2.0)[br]}
```

Once again the size specifications refer to the *entire* oval and not just to the part that is drawn, and the placement coordinates in the `\put` command refer to the center of the complete oval.

Quarter and half circles may also be drawn as partial ovals with equal width and height, but only up to a certain size. The following examples

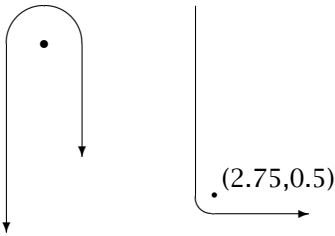
demonstrate that sections of circles are possible up to a size of about 1.5 cm.



```
\put(2.0,1.0){\oval(4.0,4.0)[t]}
\put(2.0,1.0){\oval(1.5,1.5)[t]}

\put(0.75,0.75){\oval(1.5,1.5)[b1]}
\put(1.75,0.0){\oval(1.5,1.5)[t1]}
\put(2.25,0.0){\oval(1.5,1.5)[tr]}
\put(3.25,0.75){\oval(1.5,1.5)[br]}
```

Sections of ovals may be combined with other picture elements. The placement coordinates in the `\put` command, however, require some serious consideration to get them positioned properly.



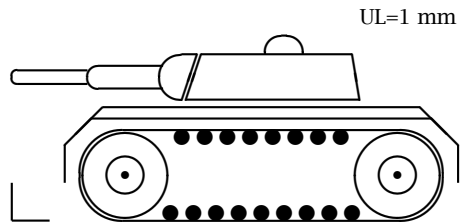
```
\put(0.5,2.5){\oval(1.0,1.0)[t]}
\put(0.0,2.5){\vector(0,-1){2.5}}
\put(1.0,2.5){\vector(0,-1){1.5}}
\put(0.5,2.5){\circle*{0.1}}

\put(2.5,0.5){\line(0,1){2.5}}
\put(2.75,0.5){\oval(0.5,0.5)[b1]}
\put(2.75,0.25){\vector(1,0){1.25}}
```

In all the above examples, the centers of the ovals have been marked with a black dot to indicate where they are. They are not normally a part of the `\oval` picture element.

Exercise 13.6: *Although the object pictured here is very offensive, it does make an excellent exercise for the picture environment.*

Hint: sizing and positioning can be worked out best by overlaying the illustration with transparent graph paper.



Vertically stacked text

It is sometimes necessary to write text vertically in a diagram, as in the example here at the right. This is carried out with the command

```
\shortstack[pos]{col}
```

The positioning argument can take on values `l`, `r`, or `c`. The standard is `c` for centered. The command is similar to a `tabular` environment with only one column. The text is entered as `col`, each row being separated from the next by `\\`.

The `\shortstack` command is most frequently implemented for placing short lines of text inside a framed box, or for stacking single letters

y
-
a
x
i
s

vertically. The individual rows are separated from each other with the smallest possible vertical spacing. This means that rows with letters sticking up or down (like *h* and *y*) will have larger apparent gaps between them than rows without such letters. Adding `\strut` to each line, as in the third example, equalizes the vertical spacing.

The placement coordinates of the corresponding `\put` command refer to the lower left corner of an imaginary box that contains the vertically stacked text. The first of the above texts is left justified, the second centered, and the third right justified. The last two on the right are centered. They were entered with

```
\put(1.0,0.5){\shortstack[1]{This\spacing\leaves\some\...}}
\put(3.0,0.5){\shortstack{Not\really\the\best\...}}
\put(5.0,0.5){\shortstack[r]{A strut\strut\in each\strut\...}}
\put(8.0,0.8){\shortstack{L\l\l\l\l\l\l\l\l}}
\put(9.0,1.2){\shortstack{b\l\l\l\l}}
```

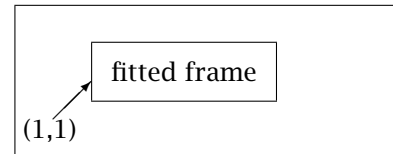
The `\shortstack` command may also be used outside of the `picture` environment within normal text. One possible application is for marginal notes, as in Section 4.10.5.

Framed text

The `\framebox` command generates a frame of a predetermined size in which text may be inserted at various positions (page 291). In text mode, there is the command `\fbox` for drawing a frame around text that fits it exactly (Section 4.7.1). This command is also available in the `picture` environment.

The amount of spacing between the box frame and the enclosed text is given by the parameter `\fboxsep`. The placement of an `\fbox` by means of the `\put` command occurs in an unexpected manner, as shown below:

```
\begin{picture}(5,2)
\setlength{\fboxsep}{0.25cm}
\put(0,0){\framebox(5,2){}}
\put(1,1){\fbox{fitted frame}}
\end{picture}
```




The additional frame spacing is often unwanted in a diagram, especially if the frame surrounds a picture object rather than text. In this case, the command

`\frame{pic_elem}`

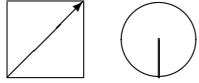
is used instead. The placement coordinate of the `\put` command then refers to the lower left corner as usual.

```
\put(0.0,0.5){\frame{TEXT}}
\put(1.5,0.0){\frame{\shortstack{W\0\R\D}}
```



The contents of the `\frame` command can be any of the previous picture elements, and need not be merely text. However, in many cases the output comes out wrong.

```
\put(0,0){\frame{\vector(1,1){1.0}}}
\put(2,0){\frame{\circle{1.0}}}
```



The first example produces the correct result, while the second has failed. In such cases, one can try putting the picture object inside a `\makebox` of suitable size and positioning as argument for the `\frame` command. However, it would then make more sense to use the `\framebox` command itself in place of `\frame{\makebox...}`.

Curved lines

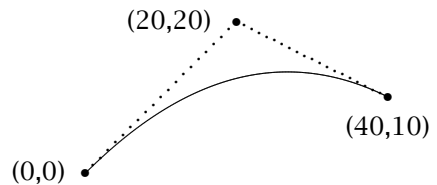
Curved lines may be drawn in the `picture` environment with the commands

```
\qbezier[num](x_1,y_1)(x_2,y_2)(x_3,y_3)
```

which draw a quadratic *Bézier* curve from point (x_1, y_1) to (x_3, y_3) with (x_2, y_2) as the extra Bézier point. The curve is actually drawn as $num + 1$ dots. The number of points num is an optional argument; if it is omitted, its value will be calculated to produce a solid-looking line.

The meaning of the extra point can be illustrated with the example at the right. The input is

```
\begin{picture}(40,20)
\qbezier(0,0)(20,20)(40,10)
\end{picture}
```



The curve is drawn from $(0,0)$ to $(40,10)$ such that the tangents at the endpoints (the dotted lines) intersect at the extra Bézier point $(20,20)$. Another way of stating this is that, as one moves from the first to the third point, one begins by heading directly towards the second point, and on arrival at the destination, one is moving directly away from that second point again. The dotted lines in the above example, which are not drawn by the `\bezier` functions, illustrate this.

A dotted curve may be drawn by specifying the number of points num ; some experimentation may be required to get just the right effect.

Line thickness

There is a choice of two line thicknesses for the picture elements `\circle`, `\oval`, and `\vector`, as well as for sloping lines. These may be selected with

```
\thicklines or \thinlines
```

Each of these declarations remains in effect until countermanded by a call to the other one, or until the end of the environment in which it was invoked. Initially, `\thinlines` is in effect.

The thickness of the horizontal and vertical lines may be set with the declaration

```
\linethickness{thickness}
```

to any desired size. The argument *thickness* is a positive length specification. With `\linethickness{1.5mm}`, all subsequent horizontal and vertical lines will have a thickness of 1.5 mm.

Since frame boxes are constructed out of horizontal and vertical lines, the command `\linethickness` also affects the `\framebox` and `\dashbox` commands.

Saving parts of pictures

It is possible to store a combination of picture elements as a sub-picture under a certain name, and to recall the whole set as often as one wants without having to reissue the individual commands every time.

First each sub-picture must have a name reserved for it with

```
\newsavebox{\sub_pic_name}
```

which creates a box with the name `\sub_pic_name` for storing the picture. Afterwards, the sub-picture is saved with

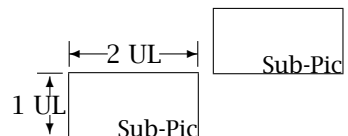
```
\savebox{\sub_pic_name}(x_dimen,y_dimen)[pos]{sub_pic}
```

where the arguments (x_dimen, y_dimen) and *pos* have the same meaning as for `\makebox` on page 291.

If the picture commands *sub_pic* are simply a piece of text, this command is exactly the same as the `\makebox` command except that the text is not printed but stored under the name `\sub_pic_name`. The *sub_pic* may be set down anywhere within the main picture as a separate picture element.

```
\usebox{\sub_pic_name}
```

```
\newsavebox{\sub}
\savebox{\sub}(2,1)[br]{\small Sub-Pic}
....
\put(0.7,0.0){\frame{\usebox{\sub}}}
\put(3.0,1.0){\frame{\usebox{\sub}}}
```



This example may not seem very practical, since the `\savebox` and `\usebox` commands could have been replaced by a `\framebox` together with `\multinput` to achieve the same result with even less effort. However, the main advantage of these two commands is not for multiple setting of text, but rather for more complex *sub.pic* compositions.

It should be pointed out that a `\savebox` command may be given outside of the `picture` environment, and even within the preamble. Such a sub-picture is then available in all `picture` environments throughout the document. However, if a `\savebox` is defined within an environment, it keeps its contents only until that environment comes to an end.

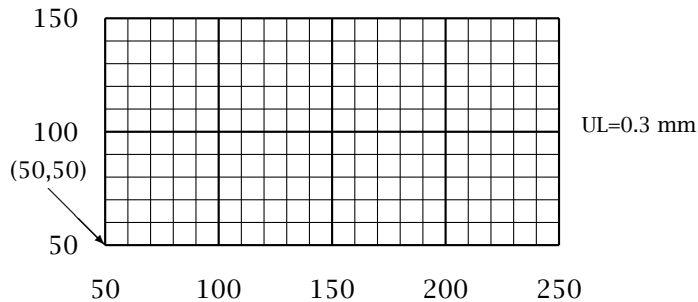
The picture elements inside a `\savebox` will be sized according to the value of `\unitlength` in effect at the time that the box is constructed. It will not be rescaled by a later change in `\unitlength`.

13.1.5 Making graph paper

Package: The package `graphpap` adds a new command for drawing gridded paper:
`graphpap`

`\graphpaper[num](x,y)(lx,ly)`

which places a grid with its lower left corner at (x,y) , which is lx units wide and ly units high. Grid lines are drawn for every num units, with every fifth one thicker and labeled. If num is not specified, it is assumed to be 10. All arguments must be integers, not decimal fractions. For example, `\graphpaper(50,50)(200,100)` produces



Exercise 13.7: Produce a sheet of graph paper 10 cm by 15 cm with 2 mm separation between the lines. This sheet may be used to determine the positioning of picture elements when planning a new diagram.

13.1.6 Shifting a picture environment

The generalized syntax of the `picture` environment contains a further coordinate pair as an optional argument

```
\begin{picture}(x_dimen,y_dimen)(x_offset,y_offset)
picture_commands \end{picture}
```

In this form, (x_offset, y_offset) specifies the coordinates of the lower left corner. This means that for all `\put` commands in the environment, the amounts x_offset and y_offset are effectively subtracted from the placement coordinates, so that the entire picture is shifted by x_offset to the left and by y_offset downwards.

13.2 Extended pictures

13.2.1 The epic package

Package: With the intention of adding some higher level commands and creating a more user-friendly interface to the `picture` environment, Sunil Podar released his `epic` package, adding new features and enhancements. One idea is to be able to draw multiple objects relative to each other, with only a limited number of absolute coordinates, making reuse and shifting much easier. Another goal is to simplify the drawing of lines.

This code was originally written for L^AT_EX 2.09, but functions just as well as a L^AT_EX 2_ε package. Thus it is implemented with

```
\usepackage{epic}
```

It makes the following new commands available to the user:

```
\multiputlist      \matrixput      \grid
\dottedline        \dashline      \drawline
\jput              \picsquare     \putfile
```

as well as the environments:

```
dottedjoin dashjoin drawjoin
```

The `\multiputlist` command is a variation on the regular `\multiput` command; rather than placing the same element in several locations, it puts *different* elements at regularly spaced intervals.

```
\multiputlist(x,y)(Δx,Δy)[pos]{Obj1, Obj2, ..., ObjN}
```

places the N picture elements $Obj1, \dots, ObjN$ at (x, y) , $(x+\Delta x, y+\Delta y)$, and so on. They are actually put into a series of `\makebox(0,0)[pos]{}`, so that the optional pos argument specifies the location of the element relative to the plotted point (Section 13.1.4). The elements in the list are separated by commas, so they must be enclosed in `{}` if they themselves contain commas.

The `\matrixput` command is the 2-D equivalent of `\multiput`, creating an array of a single picture element. Its syntax is:

`\matrixput(x,y)(\Delta x_1,\Delta y_1)\{n_1\}(\Delta x_2,\Delta y_2)\{n_2\}\{Obj\}`

Thus, `\matrixput(0,0)(3,5)\{3\}(10,0)\{5\}\{\circle{1.5}\}` produces



The `\grid` command is similar to the `\graphpaper` command, but it will also optionally label the axes.

`\grid(width,height)(\Delta width,\Delta height)[X_0,Y_0]`

draws a grid of size $width \times height$, with grid lines at intervals $\Delta width$ and $\Delta height$. If the optional argument is given, the grid lines are labeled starting at X_0, Y_0 , which must be integers, incremented by $\Delta width$ and $\Delta height$, which must also be integers in this case. The `\grid` command must be placed inside a `\put` command to specify its lower left corner: `\put(0,0)\{\grid...\}`.

A set of points can be joined by a dotted line with the command

`\dottedline[dot_char]\{dot_gap\}(x_1,y_1)(x_2,y_2)\dots(x_n,y_n)`

where *dot_gap* is the spacing (in `\unitlength` units) between the dots and *dot_char* is the character used for the dot; if it not specified, the `\picsquare` (see below) is used by default, a small square. A near solid line can be achieved by making *dot_gap* very small, but this could cause \TeX to run out of memory.

To join a set of points with a dashed line, one uses

`\dashline[stretch]\{dash_len\}\{dot_gap\}(x_1,y_1)(x_2,y_2)\dots(x_n,y_n)`

where *dash_len* is the length of the dashes (in `\unitlength` units), which are constructed as a series of dots to produce a solid looking dash. If the optional *dot_gap* is given, then the dashes are made as a series of dots with that separation. The optional *stretch* is a number between -100 and infinity. If it is 0 or missing, the number of dashes is chosen so that the gaps between them are the same length as the dashes; if *stretch* is positive, the number of dashes is increased by *stretch* percent; if negative, it is reduced by that amount. With various combinations of *stretch* and *dot_gap*, different dash patterns can be produced.

To draw a solid-looking line through a set of points, one uses

`\drawline[stretch](x_1,y_1)(x_2,y_2)\dots(x_n,y_n)`

which draws the lines as a series of line segments using the \LaTeX line fonts. Since these have a limited number of angles, the result can appear fairly jagged. By increasing the optional *stretch* factor (again a percent), more segments are used and the appearance is improved; by decreasing it, the line can begin to look dashed.

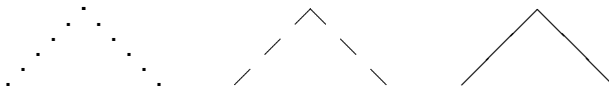
As an example of these three line drawing commands,

```

\begin{picture}(100,13)
  \dottedline[.]{3}(0,0)(10,10)(20,0)
  \dashline{3}(30,0)(40,10)(50,0)
  \drawline(60,0)(70,10)(80,0)
\end{picture}

```

produces



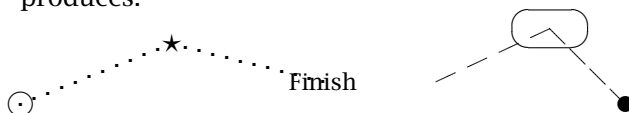
For each of the three line drawing commands, there is a corresponding environment, named `dottedjoin`, `dashjoin`, and `drawjoin`, each taking the same set of optional and mandatory arguments as the commands, except for the set of coordinates. Within these environments, one gives a set of `\jput` commands, which behaves exactly like the regular `\put`, except that all its elements are joined by the selected line type. For example,

```

\begin{picture}(100,13)
  \begin{dottedjoin}{2}
    \jput(0,0){\circle{3}}
    \jput(20,8){\makebox(0,0){\Large$star$}}
    \jput(40,3){\makebox(0,0){\small Finish}}
  \end{dottedjoin}
  \begin{dashjoin}[20]{3}
    \jput(55,3){}
    \jput(70,10){\oval(10,5)}
    \jput(80,0){\circle*{2}}
  \end{dashjoin}
\end{picture}

```

produces:



Real life data curves are generated by other software programs. These results can be imported into the `picture` environment by storing them in a data file, named say `mycurve.put` and then issuing

```

\putfile{mycurve.put}{\picsquare}

```

The data file contains a list of $x y$ coordinates, one pair per line, with possible comments beginning with `%` as usual. The `\putfile` command places its second argument at all the points listed in the data file.

The default dot character for plotting all lines is the `\picsquare`, a black square that scales with the current line thickness. A different dot character may be used with `\putfile` if one wishes. It is also possible to specify the dot character for `\dottedline`, but the default is `\picsquare`.

The default values for the optional *stretch* argument in `\dashline` and `\drawline` are initially 0, but may be changed at any time by redefining (with `\renewcommand`) `\dashlinestretch` and `\drawlinestretch`, respectively. This makes it possible to revise a whole set of curves with one command, rather than manually changing each one.

13.2.2 The `epic` package

Package: `epic` The `epic` commands are still subject to many of the limitations of the `picture` environment: limited number of slopes for lines, limited line thicknesses, restrictions on circle sizes. This is because the `picture` environment uses L^AT_EX fonts to ‘draw’ inclined lines and circles, making the results portable to all output devices.

The `epic` package, by Conrad Kwok repairs these problems by employing graphic commands executed by the DVI driver itself. They are transmitted to the `.dvi` file by `\special` commands, which are driver-specific. Thus greater flexibility is achieved, but at the price of loss of portability. The package is therefore most suitable for use with the PostScript `dvips` driver, as well as with the previewers `xdvi` and `windvi`. It does not work with `pdfTEX`, unfortunately; on the other hand, it has no problems with `dvipdfm`.

However, `epic` not only recodes the features of `epic`, it also adds some additional functionality. If one wishes to invoke these extra features with a driver that does not recognize the graphics `\specials`, one can use the emulation package `eepicemu` instead. A comparison of the results with these two packages is shown in Figure 13.1 on the next page.

In either case, one must load `epic` with one of `eepic` or `eepicemu`:

```
\usepackage{epic,eepic} or \usepackage{epic,eepicemu}
```

The following standard `picture` elements are modified by the `eepic` package:

`\line(Δx , Δy){length}` (page 293) where Δx and Δy may take on any positive or negative integer values, and not just those between ± 6 .

`\circle{diameter}` (page 295) may have any value for *diameter*; the same for `\circle*`.

`\oval` (page 296) may have the maximum diameter of the corners set to any value; this is stored in the length `\maxovaldiam` which the user may change; the default value is 40 pt.

Similarly, all the extra commands from `epic` package are also revised internally. The restrictions on slopes never apply directly to them, but lines of arbitrary slope are drawn with little segments at the nearest available slope, or as series of dots, requiring much computer time and

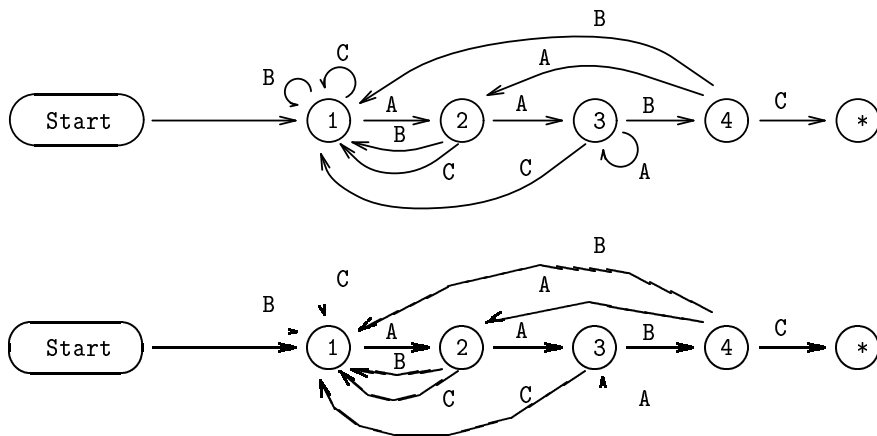


Figure 13.1: Comparison of results using the true eepic drawing functions (top) and those with the emulation in eepicemu (bottom). (This example is taken from the eepic user’s manual.)

overloading the output file. With eepic, these lines are drawn more efficiently.

Additional features added by eepic (and eepicemu, even if they do not work very well):

`\allinethickness{dimen}`

sets the line thickness to *dimen* for *all* picture elements, including circles, ovals, splines, not just for straight lines;

`\Thicklines`

sets thickness of straight lines to 1.5 times that of `\thicklines`;

`\path(x1, y1)(x2, y2)... (xn, yn)`

is a fast version of `\drawline`, without the *stretch* option; a solid line is always drawn;

`\spline(x1, y1)(x2, y2)... (xn, yn)`

draws a curve from the first to last point, with intermediate points as control points;

`\ellipse(x.diam, y.diam)`

draws an ellipse with horizontal and vertical sizes *x.diam*, *y.diam* respectively; there is also ***-form to produce a solid ellipse;

`\arc{diameter}{start}{end}`

draws the arc of a circle with *diameter* (in `\unitlength` units) from angle *start* to *end*, in radians, clockwise from 0 pointing to the right; *start* must be from 0 to 2π , and *end* from *start* to $start+2\pi$.

13.3 Other drawing packages

13.3.1 The Xy-pic package

As indicated at the beginning of this chapter, an exhaustive description of many other specialized packages, for drawing or using METAFONT fonts, can be found in *The L^AT_EX Graphics Companion* by Goossens *et al.* (1997). Most of these are designed for T_EX in general, but will also work with L^AT_EX. We mention two of these here just to show the possibilities.

The Xy-pic package can carry out general drawing entirely with extra METAFONT fonts, making it fully portable among all output drivers. The fonts are also available in type 1 coding (Section G.6) so that the package works just as well with PDF output. It was created by Kristoffer H. Rose and then extended by Ross Moore and others.

Even an overview of Xy-pic is beyond the scope of this book. We recommend the supplied *User's Guide* and more extensive *Reference Manual* both to be found in `texmf/doc/generic/xy-pic`. The descriptions and illustrations in Chapter 5 of Goossens *et al.* (1997) are especially helpful.

To give a flavor of the syntax in Xy-pic, we give the following examples:

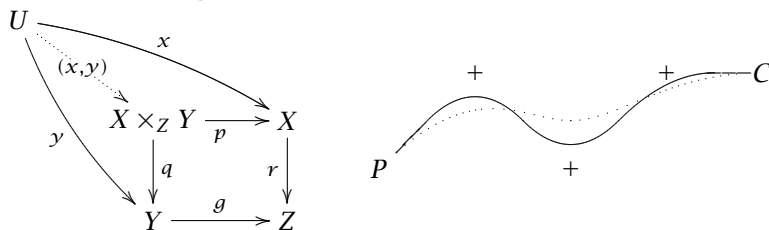
```
\xymatrix{
U \ar@/_/[ddr]_y \ar@/^/[drr]^x \ar@{.}>[dr]|-{(x,y)} \\
& X \times_Z Y \ar[d]^q \ar[r]_p & X \ar[d]_r \\
& Y \ar[r]_g & Z}

```

```
\xy /r1.5pc/: ,+<5pc,3pc>*+{P};p
@(+,(2,2)*{+}@+ , +(2,-2)*{+}@+
 ,+(2,2)*{+}@+ , +(2,0)*+{C}="C"
 ,*\qspline{ , "C" ,**\crvs{.}
 ,@i @)\endxy

```

that produce the diagrams:



The first example, with `\xymatrix`, organizes its contents in rows and columns, not dissimilar to the `tabular` environment. In this case, the first row contains `U` in the first column, and the rest are empty; the second row has an empty first column (starts with `&`, the column separator) while the next two columns contain `X \times_Z Y` and `X`; the third row also has an empty first column, with entries `Y` and `Z` in the remaining columns. Everything else describes how these nodes are connected. For example,

`\ar@/_/[ddr]_y` means ‘draw an arrow, curving down to the node located two down and one right, and subscript it with γ .’ And so on for the other connections.

The second example, with `\xy... \endxy` gives more complicated drawing instructions, placing objects at given coordinates, joining them with arrows, lines, curves. As can be seen from both of these examples, it takes some practice to learn the syntax and to exploit X_Ypic fully.

13.3.2 PSTricks

In Chapter 10 we describe how the PostScript language plays a very important role in T_EX and L^AT_EX by making a wide spectrum of fonts available to complement the original Computer Modern fonts. But PostScript is also a powerful plotting language. It was in order to exploit the PostScript possibilities directly that Timothy van Zandt wrote the PSTricks package for direct use within T_EX, and thus within L^AT_EX.

Actually PSTricks consists of over a dozen packages. The complete functionality may be loaded with the package `pstricks`, or the individual packages may loaded singly. (Since PSTricks is really a T_EX utility, the L^AT_EX package `pstricks.sty` does nothing more than load the `pstricks.tex` file containing the actual code.) Some of these packages are:

<code>pst-3d</code>	3-D drawing
<code>pst-blur</code>	adding blurred shadows
<code>pst-char</code>	stroking and filling character paths
<code>pst-coil</code>	coil and zigzag objects
<code>pst-eps</code>	export objects to EPS files
<code>pst-fill</code>	adds <code>\psboxfill</code> command
<code>pst-gr3d</code>	drawing 3-D grids
<code>pst-grad</code>	gradient color fills
<code>pst-lens</code>	simulating effect of a lens
<code>pst-node</code>	placing and joining nodes
<code>pst-osci</code>	emulating oscilloscopes
<code>pst-plot</code>	plotting data
<code>pst-poly</code>	drawing polygrams
<code>pst-slope</code>	improvement on <code>pst-grad</code>
<code>pst-text</code>	setting text along a path
<code>pst-tree</code>	tree commands

As with X_Ypic, it is beyond the scope of this book on document production with L^AT_EX to describe the extensive plotting features of PSTricks. We refer to Goossens *et al.* (1997), Chapter 4 for a description of most of these packages (some have been added since then) and otherwise to the supplied manuals and documentation to be found in `texmf\generic\source\pstricks`.

Bibliographic Databases and BIBTEX

In academic publications, a bibliography or list of references is standard procedure. In Section 9.3 we describe how a bibliography can be formatted with the `thebibliography` environment and how its entries are referred to within the text. Often authors find that they are constantly referring to the same publications in most of their own papers. Similarly, researchers working in the same field will frequently be referring to the same set of papers. This means that many of the entries in the `thebibliography` environment will be repeated from one work to the next, or even among co-workers at one institute.

It would be very useful if the bibliographic entries could be stored in one database file once and for all to be available for all documents with a list of references in that field. Such a database system is possible with the `BIBTEX` program supplied with the `LATEX` installation. The information about the various publications is stored in one or more files with the extension `.bib`. For each publication there is a *key* that identifies it, and which may be used in the text document to refer to it. Such a file is called a *bibliographic database*.

14.1 The BIBTEX program

`BIBTEX` is an auxiliary program to `LATEX` that automatically constructs a bibliography for a `LATEX` document by searching one or more databases. To this end, the `LATEX` file must contain the command

```
\bibliography{database1, database2, ...}
```

at that point in the text where the bibliography is to appear. Here the argument `database1, database2, ...` is a list of root names, separated by commas, of the bibliographic database files that are to be searched. The extension `.bib` is not explicitly written.

Reference can be made to a publication in one of the databases at any place in the text with the commands

```

\cite{key}
\citep{key}
\citet{key}

```

as is explained in Sections 9.3.3 and 9.3.4. The *key* is the database identifier for that publication, which of course the user must know beforehand. After the first L^AT_EX processing, the BibTeX program must be run either by clicking the appropriate icon in the editor shell, or from a command line with `bibtex` plus the root name of the L^AT_EX file. Supposing this source file name is `comets.tex`, the call

```
bibtex comets
```

produces a new file with the name `comets.bbl`, containing the extracted information for those publications for which there was a `\cite` reference, packaged in a thebibliography environment to be input into the document on the next L^AT_EX run.

Occasionally the bibliography is to include publications that were *not* referenced in the text. These may be added with the command

```
\nocite{key}
```

given anywhere within the main document. It produces no text at all but simply informs BibTeX that this reference is also to be put into the bibliography. With `\nocite{*}`, *every* entry in all the databases will be included, something that is useful when producing a list of all entries and their keys.

After running BibTeX to make up the `.bbl` file, it is necessary to process L^AT_EX *at least twice* to establish both the bibliography and the in-text reference labels. The bibliography will be printed where the `\bibliography` command is issued; it in fact inputs the `.bbl` file.

The formatting of the bibliography may be selected with the declaration

```
\bibliographystyle{style}
```

which may be issued anywhere in the document. Its only function is to inform BibTeX what bibliography style file (`.bst`) is to be loaded to determine the resulting format. Many contributed `.bst` files exist, designed for specific journals and publishing houses, and it is possible to create one's own (Section 14.3). However, the supplied standard ones for numerical citation only are:

- `plain` The entries in the bibliography are ordered alphabetically; each is assigned a running number in square brackets as the in-text reference marker, printed where the `\cite` commands are issued.
- `unsrt` The entries are ordered according to their first references by the `\cite` and `\nocite` commands. The entry for the first `\cite`

receives the number 1, that of the next `\cite` with a different key the number 2, and so on. The markings and listings are otherwise the same as for `plain`.

- `alpha` The ordering in the bibliography is the same as for `plain` but the markers are an abbreviation of the author's name plus year of publication. A reference to Smith (1987) would appear as [Smi87] instead.
- `abbrv` The ordering and marking are the same as for `plain`, but the bibliographic listing is shortened by abbreviating first names, months, and journal names.

For author-year citations and the `natbib` package (Section 9.3.4), there exist the bibliographic styles `plainnat`, `unsrnat`, and `abbrvnat`, producing the same bibliography format as the corresponding standard styles, but with `natbib` compatibility.

14.2 Creating a bibliographic database

Creating a bibliographic database might seem like more work than typing up a list of references with the `thebibliography` environment; the great advantage is that the entries need to be included in the database once and only once and are then available for all future publications. Even if a different bibliography style is demanded in later works, all the information is already on hand in the database for `BIBTEX` to write a new `thebibliography` environment in another format. In fact, we feel that even for a single document, it is simpler to make an entry into the database than to adhere to the very precise and fiddly requirements of a literature list, especially regarding punctuation and positioning of the authors' initials. The database entry proceeds very quickly and easily if one has a generalized template, as illustrated in Section 14.2.6.

The entries in a bibliographic database are of the form

```
@BOOK{knuth:86a,
  AUTHOR = "Donald E. Knuth",
  TITLE = {The \TeX{}book},
  EDITION = "third",
  PUBLISHER = "Addison--Wesley",
  ADDRESS = {Reading, Massachusetts},
  YEAR = 1986
}
```

The first word, prefixed with `@`, determines the *entry.type*, as explained in the next section. The *entry.type* is followed by the reference information for that entry enclosed in curly braces `{ }`. The very first entry is the *key*

for the whole reference by which it is referred to in the `\cite` command. In the above example this is `knuth:86a`. The *key* may be any combination of letters, numerals, and symbols, except commas. The actual reference information is then entered in various *fields*, separated from one another by commas. Each *field* consists of a *field.name*, an = sign, with optional spaces on either side, and the *field text*. The *field.names* shown above are AUTHOR, TITLE, PUBLISHER, ADDRESS, and YEAR. The *field text* must be enclosed either in curly braces or in double quotation marks. However, if the text consists solely of a number, as for YEAR above, the braces or quotation marks may be left off.

For each entry type, certain fields are *required*, others are *optional*, and the rest are *ignored*. These are listed with the descriptions of the various entry types below. If a required field is omitted, an error message will occur during the BibTeX run. Optional fields will have their information included in the bibliography if they are present, but they need not be there. Ignored fields are useful for including extra information in the database that will not be output, such as a comment or an abstract of the paper. Ignored fields might also be ones that are used by other database programs.

The general syntax for entries in the bibliographic database reads

```
@entry_type{key,
  field_name = {field text},
  ....
  field_name = {field text} }
```

The names of the *entry_types* as well as the *field_names* may be written in capitals or lower case letters, or in a combination of both. Thus `@BOOK`, `@book`, and `@b00k` are all acceptable variations.

The outermost pair of braces for the entire entry may be either curly braces `{ }`, as illustrated, or parentheses `()`. In the latter case, the general syntax reads

```
@entry_type(key, ... .. )
```

However, the *field text* may only be enclosed within curly braces `{ ... }` or double quotation marks `" ... "` as shown in the example above.

14.2.1 The entry types

The following is a list of the standard entry types in alphabetical order, with a brief description of the types of works for which they are applicable, together with the required and optional fields that they take. The meanings of the fields are explained in the next section.

`@article` Entry for an article from a journal or magazine.

required fields author, title, journal, year.

optional fields volume, number, pages, month, note.

- @book** Entry for a book with a definite publisher.
required fields author or editor, title, publisher, year.
optional fields volume or number, series, address, edition, month, note.
- @booklet** Entry for a printed and bound work without the name of a publisher or sponsoring organization.
required fields title.
optional fields author, howpublished, address, month, year, note.
- @conference** Is the same as @inproceedings below.
- @inbook** Entry for a part (chapter, section, certain pages) of a book.
required fields author or editor, title, chapter and/or pages, publisher, year.
optional fields volume or number, series, type, address, edition, month, note.
- @incollection** Entry for part of a book that has its own title.
required fields author, title, booktitle, publisher, year.
optional fields editor, volume or number, series, type, chapter, pages, address, edition, month, note.
- @inproceedings** Entry for an article in conference proceedings.
required fields author, title, booktitle, year.
optional fields editor, volume or number, series, pages, address, month, organization, publisher, note.
- @manual** Entry for technical documentation.
required fields title.
optional fields author, organization, address, edition, month, year, note.
- @mastersthesis** Entry for a Master's thesis.
required fields author, title, school, year.
optional fields type, address, month, note.
- @misc** Entry for a work that does not fit under any of the others.
required fields none.
optional fields author, title, howpublished, month, year, note.
- @phdthesis** Entry for a PhD thesis.
required fields author, title, school, year.
optional fields type, address, month, note.

- @proceedings** Entry for conference proceedings.
required fields title, year.
optional fields editor, volume or number, series, address, month, organization, publisher, note.
- @techreport** Entry for a report published by a school or other institution, usually as part of a series.
required fields author, title, institution, year.
optional fields type, number, address, month, note.
- @unpublished** Entry for an unpublished work with an author and title.
required fields author, title, note.
optional fields month, year.

Each entry type may also have the optional fields `key` and `crossref`. The former provides additional information for alphabetizing the entries, especially when the author information is missing. The author information is normally found in the `author` field but may also be in the `editor` or even `organization` fields. This `key` field has nothing to do with the `key` for identifying the entry in the `\cite` command. The `crossref` field gives the `key` for another entry in the database that shares many of the information fields, as illustrated in Section 14.2.3.

14.2.2 The fields

The fields that may be used within a bibliographic entry are listed below together with their meanings. They are always given in the form:

field_name = {*field text*} or
field_name = "*field text*"

address

The address of the publisher or other institution. For major publishing houses, it is sufficient to give just the city. For smaller publishers, giving the full address is recommended.

annotate An annotation that may be used by non-standard bibliography styles to produce an annotated bibliography. The standard BibTeX styles ignore it.

author The name(s) of the author(s) as described in Section 14.2.4.

booktitle

The title of a book when only part of it is being cited. See Section 14.2.4 for special considerations on capitalization.

chapter

A chapter or section number.

- crossref** The key of another entry in the database that shares many of the same field entries. See Section 14.2.3.
- edition** The edition of a book, usually written in full and capitalized, as 'Second'. The standard styles will change it to lower case as necessary.
- editor** The name(s) of the editor(s) as described in Section 14.2.4. If there is also an author field, then this gives the editor of the book or collection in which the citation appears.
- howpublished** States anything unusual about the method of publishing. Should be capitalized. Example: 'Privately published'.
- institution** The name of the sponsoring institution for a technical report.
- journal** The name of a journal or magazine. Abbreviations are provided for the most common ones (see Section 14.2.5).
- key** An addition for alphabetizing purposes when the author information is missing. This is not the same as the *key* for identifying the entry to a `\cite` command.
- month** The month in which the work was published or, if unpublished, when it was written. Abbreviations exist in the form of the first three letters of the (English) names.
- note** Any additional information that should be added. Capitalize the first letter.
- number** The number of a journal, magazine, technical report, or work in a series. Journals are usually identified by volume and number; technical reports are issued a number by the institution; books in series sometimes have a number given to them.
- organization** The sponsoring organization for a conference or a manual.
- pages** A page number or a range of pages, in the form 32, 41, 58 or 87--101 or 68+. The last form indicates page 68 and following pages. A single hyphen given for a range will be converted by the standard styles to the double hyphen to produce a dash, as '87-101'.
- publisher** The publisher's name.

- `school` The name of the academic institution where a thesis was written.
- `series` The name of a series or set of books. When citing a book from a series, the `title` field gives the name of the book itself while the optional `series` specifies the title of whole set.
- `title` The title of the work, obeying the capitalization rules listed in Section 14.2.4.
- `type` The type of technical report, for example, 'Research Note'.
- `url` The *universal resource locator*, or Internet address, for online documents; this is not standard but supplied by more modern bibliography styles.
- `volume` The volume number of a journal or multi-volume book.
- `year` The year in which the work was published or, if unpublished, in which it was written. It should normally consist of four numerals, such as 1993.

Additional field names may be included, which BibTeX will simply ignore. For example, to add the abstract of an article in the database,

```
abstract = {text of an abstract}
```

This can be of use in other applications as well as for database management.

14.2.3 Cross-referencing fields

If many entries in the bibliographic database share a common set of field information, such as for a number of works all appearing in the same conference proceedings, it is possible to refer to another entry containing that common set with the `crossref` field. For example,

```
@INPROCEEDINGS{xyz-1,
  crossref = {xyz-proceedings},
  author = {J. S. Jones},
  title = {The First Results from the {Appleville Experiment}},
  pages = {34--38} }
. . . . .
@PROCEEDINGS{xyz-proceedings,
  editor = {C. H. Kelvin},
  title = {Proceedings of the First Conference on the
           {Appleville Experiment}},
  booktitle = {Proceedings of the First Conference on the
              {Appleville Experiment}}
  year = 1991 }
```


The first entry, with key `xyz-1`, is to obtain all its missing fields from the second entry, by means of the `crossref` field referring to the entry with key `xyz-proceedings`. The missing fields are `editor`, `booktitle`, and `year`, those that are common to all articles in the conference proceedings. Note that `booktitle` is an ignored field for `@PROCEEDINGS` but needs to be included here since it is required for `@INPROCEEDINGS`.

If an entry is referred to by two or more other entries, then it too will be included in the bibliography, even though its key never appeared as the argument of a `\cite` or `\nocite` command.

In order for this system to function properly, the entry that is referred to must appear in the database(s) *after* all those that refer to it. It is therefore recommended to put all such referenced entries at the end of the database. Cross-references may not be nested.

14.2.4 Special field formats

There are some special rules for entering the texts to the fields `author`, `editor`, `title`, and `booktitle`. `BIBTEX` will process names, putting surnames first, abbreviating given names with initials, and so on, according to the instructions in the style file. Thus it is important that the program knows what is a given name and what a surname. Similarly for titles, capitalization may change depending on style and/or entry type, so `BIBTEX` must know what words are always capitalized.

Names

The names in the `author` and `editor` fields may be typed in either in the form `{Given Names Surname}` or as `{Surname, Given Names}`. That is, `BIBTEX` assumes that if there is no comma the last capitalized name is the surname, or family name; otherwise what comes before the comma is taken to be the surname. Thus the name texts "John George Harrison" and "Harrison, John George" are equivalent for Mr J. G. Harrison. However, if a person has a double surname, without a separating hyphen, the second form must be employed, or the double name must be enclosed in braces, as

"San Martino, Maria" *or* "Maria {San Martino}"

for Ms M. San Martino.

Auxiliary words to a surname that are not capitalized, such as *von* or *de*, may be entered in either form:

"Richard von Mannheim" *or* "von Mannheim, Richard"

"Walter de la Maire" *or* "de la Maire, Walter"

Anything enclosed in braces will be treated as a single item, something that is used in ambiguous cases, or when the name contains a comma or the word *and*. An example is

```
"{Harvey and Sons, Ltd}"
```

If the name contains a *Junior* or some other addition, it must be entered *{Surname, Junior, Given Name}*, for example as

```
"Ford, Jr, Henry" or "Ford, III, Henry"
```

However, if there is to be no comma, then the *Jr* must be treated as part of a double surname, *something that is not recommended at all*:

```
"{Filmore Jr}, Charles" or "Charles {Filmore Jr}"
```

Accents within a name formed with a backslash command should be enclosed in braces *with the backslash as the first character after the opening brace*. In this way, the alphabetization and the formation of labels with the alpha bibliography style will function properly. For example,

```
author = "Kurt G{"o}del",
year = 1931
```

will produce the label [Göd31] as desired. The accent text must not be enclosed any deeper than shown here.

Accents should be formed with the backslash command for most generality. Some language modifications have shorthands for accented letters (like "a instead of *a* for German) but these should be avoided in the database to ensure that the results will be universally understood.

Hyphenated first names are properly abbreviated. Thus "Jean-Paul Sartre" becomes 'J.-P. Sartre'.

If an author or editor field is to contain more than one name, the names are separated by the word *and*. For example,

```
author = "Helmut Kopka and Daly, Patrick William" or
AUTHOR = {Peter C. Barnes and Tolman, Paul and Mary Smith}
```

If the *and* is actually part of the name, the whole name must be enclosed in braces, as pointed out above.

Do not insert any ~ characters between names or initials; BibTeX will do this automatically as it deems fit.

If only initials are given for the authors given names, insert a blank between them, as P. W. Daly, not P.W. Daly. The latter will be interpreted as a single given name and will be abbreviated as 'P. Daly'

If the author list is too long to type in all the names, it may be terminated with *and others*. This will be converted to the form of *et al.* prescribed in the style file.

Titles

The capitalization of the title depends on the bibliography style: usually book titles are capitalized while article titles are not. The text in the fields

`title` and `booktitle` should be written in the capitalized form so that Bib_{TEX} can change to lower case as required.

The general rules for capitalizing titles in English state that the first word of the title, the first word after a colon, and all other words are capitalized except articles and unstressed prepositions and conjunctions. For example:

```
title="The Right Way to Learn: A Short-Cut to a Successful Life"
```

Words that are always to be capitalized, such as proper nouns, must be enclosed in braces. It is sufficient to enclose only the letter that must be capitalized. The two following examples are equivalent:

```
title = "The {Giotto} Mission to Comet {Halley}" or
TITLE = {The {G}iotto Mission to Comet {H}alley}
```

14.2.5 Abbreviations

It is always possible to use an abbreviation in the field text in place of actual text. Some abbreviations, such as the names of the months and some standard journal names, are already available, and the user is free to define new ones for his or her personal use.

The name of an abbreviation consists of any combination of letters, numbers, and symbols except

```
" # % ' ( ) , = { }
```

An abbreviation is defined with the command

```
@string{abbrev_name = {text}} or
@string(abbrev_name = {text})
```

where *abbrev_name* stands for the name of the abbreviation and *text* is the replacement text. For example, if the abbreviation

```
@string{JGR = {Journal of Geophysical Research}}
```

has been defined, the following two field statements are identical:

```
journal = JGR
journal = {Journal of Geophysical Research}
```

The name of the abbreviation is *not* enclosed in braces or double quotes, otherwise the name itself will be interpreted literally as the field text. In both the `@string` command and the name of the abbreviation, the case of the letters is unimportant. The above abbreviation could just as well be defined as

```
@STRING{jgr = {Journal of Geophysical Research}}
or @StrinG{jGr = {Journal of Geophysical Research}}
```

and it may be referred to in the fields as JGR, JGr, JgR, Jgr, jGR, jGr, jgR or jgr.

Abbreviations may be concatenated with the symbol # between them. Thus after giving

```
@string{yrbk = {Institute Yearbook}}
```

this abbreviation may be combined with other abbreviations and text, as in

```
title = "Max-Planck~" # yrbk # 2000
```

to produce 'Max-Planck Institute Yearbook 2000'.

Standard abbreviations exist for the months of the year, the names consisting of the first three letters of the name, as `jan`, `feb`, etc. These are actually included within the `.bst` file, and can change their definition for styles intended for other languages. However, the name of the abbreviation remains the same, the first 3 letters of the English name.

Further predefined abbreviations are available (in the `.bst` file) for some standard journal names. Those produced with `custom-bib` are especially extensive. See Section 14.3.

The `@string` commands may be issued anywhere in the database between two bibliographic entries, but must already be defined before they are used. Therefore, it makes most sense to insert all the abbreviation definitions at the beginning of the database file.

14.2.6 Using a template

Typing in the text for bibliographic entries into a database might seem to be rather complicated since there are so many things to remember, such as which fields are required and which are optional, what their formats are, and so on. One way to simplify this task is to make up *templates* for the most common entry types that you use. A template is basically a complete entry with all the fields left blank. It is stored in a separate file on its own, to be inserted into the database file whenever a new entry of that type is to be made. Then the field texts are written in.

An appropriate template for the entry type `@article` could be

```
@ARTICLE{<key>,
  AUTHOR   = {},
  TITLE    = {},
  YEAR     = {},
  JOURNAL  = {},
  volume   = {},
  number   = {},
  month    = {},
  pages    = {},
```

```

    note      = {}
}

```

in which the `<key>` is a reminder that the keyword is to go here, the required fields come first and are capitalized, while the optional fields are in lower case.

Finally, we mention that `BIBTEX` has been written by Oren Patashnik, Stanford University, in close association with Leslie Lamport. The `BIBTEX` installation should contain the two files `btXdoc.tex` and `btXhak.tex` for additional information about `BIBTEX`. In particular, `btXhak.tex` contains instructions for writing bibliographic style files. Process these files with `LATEX`, if the resulting `.dvi` or `.pdf` files are not already there.

14.3 Customizing bibliography styles

It seems that every journal and publishing house has its own set of rules for formatting bibliographies. The differences are really minor, such as whether to use commas or colons here, or to put volume numbers in bold or italic typeface. Nevertheless, in spite of this triviality, the rules are rigid for each house.

Standard `LATEX` provides only four bibliography styles, and their differences have more to do with sorting and labeling than with such fussy details. It is possible to design one's own `.bst` file, by modifying existing ones; however, this requires a knowledge of the peculiar `BIBTEX` programming language, something that puzzles even experienced `LATEX` users. There are some 50 `.bst` files in the `BIBTEX` directories of the `TEX` file servers, and probably many more in contributed `LATEX` directories. Each is designed for a specific journal and there is no guarantee that it would be accepted by another one. What is a user to do if his or her publisher demands a certain format that just is not to be found? How can one seek a given format anyway among those offered?

Some help can be found in the `custom-bib` application written by Patrick W. Daly. The heart of this package is a generic (or master) bibliography style `merlin.mbs` containing alternative coding for a multitude of different bibliographic features or options. It is processed with the `DocStrip` program which is capable of including alternative coding according to selected options (see Section D.7.1).

Because of the large number of options offered (well over 100), a menu-guided interface is provided, called `makebst.tex`. When processed under `TEX` or `LATEX`, this 'program' first asks which `.mbs` file is to be read, and then interactively constructs a `DocStrip` batch job to produce the selected bibliographic features according to menu information contained in the `.mbs` file itself. This means that there could be a number of `.mbs` files

to choose from, each one explaining its set of options to the user via `makebst`.

Support for other languages is provided by means of additional `.mbs` files, one for each language, which contain the translations for such words as *volume*, *editor*, *edition*, and so on.

Some of the features provided by the supplied generic bibliographic style file are:

- numerical or author-year citations; in the latter case, one may also choose which `\bibitem` style is to be used;
- order of references: by citation order, alphabetical by all authors, alphabetic by author-year label;
- format of authors' names: first name plus surname, initials plus surname, surname plus initials, reversed initials only for first author, and more;
- number of author names to include before giving *et al.*;
- typeface to be used for the author names;
- position of date, parentheses or brackets around the year;
- format of volume, number, and pages for journals;
- capitalization of article titles as sentence or title style;
- whether to use the word *and* or an ampersand &;
- placement of commas with the word *and*;
- whether to abbreviate *editor*, *volume*, *chapter*, etc.;
- first and last page numbers or only first;
- optional addition of shorthand designations of common journal names;
- and much more.

Abbreviations for many journal names in physics, optics, and geophysics can be provided in those `.bst` files produced by `custom-bib`, which then may be used in BibTeX databases. It is unfortunate that these are to be found in the `.bst` files themselves, which means that they may not be universally present. Which ones are present depends on the options chosen by the producer of the style file. The file `shorthnd.tex` in the `custom-bib` installation lists all the current possible abbreviations. (Actually, it is generated by running L^AT_EX on `shorthnd.ins`, which then produces the most current list from the existing `.mbs` files.) To check what any particular `.bst` file contains, open it and look for the MACRO commands.

Presentation Material

So far we have been assuming that the output of a \LaTeX project is to be printed paper or an electronic document looking like printed paper displayed on the computer monitor.

Another important type of output is *presentation material*, the visual support displayed in front of an audience during an oral presentation. Traditionally, this consisted of a set of slides to be projected onto a screen, but in more recent times this has been replaced by viewgraphs (or transparencies) and an overhead projector, giving the speaker much more interactive control over the presentation. However, the truly modern presentation is done electronically, with the entire presentation stored in a computer directly connected to the projector; there are no slides to fall out of the cassette, or be inserted the wrong way around, no viewgraphs to spill out onto the floor. The only thing that can go wrong is that the computer refuses the connection, needs rebooting, or the necessary display program is missing. Such teething problems are occurring less frequently now that this form of presentation is becoming standard.

In spite of the change in medium away from the $2'' \times 2''$ pieces of film, a computer presentation is still called a *slide show*, a term which today presupposes the electronic medium. We will use the word *slide* more generally to mean a page of text and/or graphics for presentation, whether it is to be printed on paper and then photographically rendered to film or transparency, or to be directly projected from the computer. The preparation of such a slide with \LaTeX is much the same regardless of the final projection method; direct projection does offer additional features which we also address.

We start this chapter with the standard \LaTeX method for slide preparation, the `slides` class, and then describe the far more advanced `seminar` class (Section 15.2). The latter is especially suitable for interesting PDF electronic presentations. We then illustrate `pdfscreen` (Section 15.3), a package designed more for documents meant for electronic viewing but which can also produce slides. Finally we show in Section 15.4 how PDF presentations may be enhanced with the help of an additional program.

15.1 Slide production with `SLiTeX`

The term `SLiTeX` was used in the old `LATEX 2.09` system to indicate a separate specialized version of `LATEX` for producing projection material. This awkward and cumbersome device was needed then because of the way fonts were hardwired into the formats. With `LATEX 2ε`, this is no longer necessary, and the entire functionality is now found within the `slides` class, considerably streamlined over the obsolete version, running under regular `LATEX`, or `pdfLATEX`. The word `SLiTeX` therefore should be retired, but since it is a nifty expression, we will continue to use it to distinguish the `slides` class, which is considerably different from `article` and the other standard classes.

15.1.1 The `slides` class

A slide is meant to be projected before an audience and is therefore something quite different from a sheet of paper to be read held in the hand. One could of course make up the text for slides with the normal `LATEX` commands, but there would be problems getting the font size right, arranging overlays, making sure that the text does not change pages unexpectedly, and the question of whether book-style fonts are suitable for projection. The `LATEX` class `slides` attempts to solve these.

A different set of fonts is used by this class, ones in which the lower case letters are relatively larger than in the normal fonts, and with a much bigger base size. This has the effect of limiting the amount of text that fits on one page/slide, but this is in fact very good practice for presentation material. The text really should be restricted to keywords and abbreviated sentences. A full page of normal text projected on to a screen will not be read by the audience.

One is not obliged to use the built-in fonts; one may still select other (sans serif) font packages, such as `helvet` for Helvetica (Section 10.1.2) as one pleases. They will be used in larger sizes than usual.

Slides should also make use of color. The original `SLiTeX` had a complicated method for producing color overlays (in black and white, to be copied in color) which now is totally eliminated from the `slides` class. Instead, one simply makes use of the `color` package of Section 6.2.

Most of the formatting commands of regular `LATEX` may be used with `slides`, except for the page breaking and sectioning commands. The special features that are unique to this class are described in the next sections.

15.1.2 The slide environments

The source file for producing slides is structured much the same as that for a normal document, except that it is the `slides` class that is invoked

as

```
\documentclass{slides}
  preamble text
\begin{document}
  slide text
\end{document}
```

If colors are wanted the `color` package of Section 6.2 must be added, for example as

```
\usepackage[pdftex]{color}
```

(You will have to specify your own driver as the option here, or rely on the local configuration to give it automatically, as is usually the case.)

The preamble may contain global specifications, for changing the paper size or selecting a page style, as usual. It may not contain any printable material.

Any text that appears after `\begin{document}` but before the special slide environments described below is output to an unnumbered *leading page* that comes before any slides. This may serve as a cover page for the slides.

There are three environments available for organizing different parts of a slide: the main *slide* itself, possible *overlays*, and additional *notes* to the slide.

Slides

A slide or viewgraph is created by means of the environment

```
\begin{slide} text and commands \end{slide}
```

The contents of a `slide` environment may be any text that one pleases. Note that the `slides` class makes use of its own set of character fonts. The standard font in the normal size is roughly equivalent to the L^AT_EX sans serif font `\sffamily` in the size `\LARGE`. All the regular font commands and declarations of Section 4.1 are available, along with the other display and list environments of Chapter 4. However, there can be no page breaks within the environment, for the entire text is expected to fit on one page (slide or viewgraph). The successive `slide` environments will be numbered consecutively. If the page should overflow, a warning message is printed.

Any color commands from the `color` package may be employed, if that package has been loaded.

Overlays

An *overlay* is an addition to a slide that can be laid on top of it to fill in certain gaps. The idea is to create suspense during a presentation, by

filling in some key words a few minutes later, or to be able to replace some text by alternatives.

The `slides` class generates overlays with the `overlay` environment, which functions exactly the same as the `slide` environment, except that the numbering is done as a sub-number of the last slide. Thus the overlays following slide 6 are numbered 6-a, 6-b, and so on.

```
\begin{overlay} text and commands \end{overlay}
```

The `slide` environment for a viewgraph that is to have overlays must come before the `overlay` environments that go with it. Both the `slide` and `overlay` should contain identical texts, except that certain parts are printed in ‘invisible’ ink by means of the two declarations

```
\invisible and \visible
```

These two commands function just like font declarations. They may be set within curly braces `{}` to limit their scope, or used to apply to the whole environment. Normally, in the `slide`, a few words might be made invisible, while in the corresponding `overlay`, `\invisible` is declared at the start and only those words that were blanked out in the slide are made visible. This may be seen in the sample on page 329.

Note: the `\invisible` command does not work with fonts other than the default ones, nor with pdf \TeX . However, for pdf \TeX , there are better methods to achieve the same results (Section 15.4.1).

One application for overlays is to present alternative text. One might, for example, show a table of cost estimates, with the figures on an overlay. By exchanging this overlay for another, new numbers that can be achieved by certain procedural changes may be fitted into the same table.

Notes

During a presentation, it is often necessary to refer to a list of keywords or other notes between the actual projected slides. The `slides` class has the `note` environment for producing such reminders for the speaker.

```
\begin{note} text \end{note}
```

Like the overlays, notes are sub-numbered with respect to the previous slide, but with numbers instead of letters. Following slide 4, notes are numbered 4-1, 4-2, and so on.

15.1.3 Further features

Page styles

The \LaTeX command `\pagestyle{style}` may also be used with the `slides` class. The following styles are available:

`plain` All slides, overlays, and notes have their number at the lower right corner.

`headings`

The same as `plain` except that if the `clock` option is selected (see below), a time marker is printed in the lower left corner of the notes. This is the default page style.

`empty` The sheets are printed with no page numbers.

In normal L^AT_EX, the command `\pagestyle` is issued in the preamble and is valid for the whole document. Individual pages may be given a different style by means of the `\thispagestyle` command which remains in effect for only one page. This command should not be employed within one of the environments, but rather a new `\pagestyle` command may be given *outside* of the `slide`, `overlay`, and `note` environments.

Timing notes

The option `clock` can be selected with `\documentclass`; it activates two additional commands:

```
\settime{secs}
\addtime{secs}
```

and prints the time in minutes at the bottom of each note. In this way, the notes contain a reminder of how far advanced the presentation should be at that point. The value of the time marker is set and incremented with the above two commands, which take a number in seconds as argument. The initial value of the timer is 0.

Selective slide processing

During the construction of a slide show, one is likely to spend considerable time working on individual slides, ignoring the others for the time being. Complicated slides need to be corrected, processed, and viewed. One can speed this up by selecting only a few slides for processing, by placing the command

```
\onlyslides{slide_list}
```

in the preamble. The *slide_list* stands for a list of slide numbers in ascending order, for example, `2,5,9-12,15`, specifying the slides, or range of slides, that are to be processed.

Non-existent slide numbers may also appear in the *slide_list*. If the slide file contains, say, 20 slides, the command `\onlyslides{1,18-999}` will allow only slides 1 and 18-20 to be processed. Any overlays that belong to these slides will also be output.

Finally, the command

```
\onlynotes{note_list}
```

in the preamble limits the notes that are output to those listed in *note_list*. Supposing that slide 5 has three `note` environments associated with it, `\onlynotes{5}` arranges that only the note pages 5-1, 5-2, and 5-3 are printed.

The `\onlyslides` and `\onlynotes` commands function similarly to the command `\includeonly` described in Section 9.1.2. An interactive means of selecting slides and notes to process may be set up exactly as illustrated in Section 9.1.3 with the `\typein` command:

```
\typein[\slides]{Which slides to do?}
\onlyslides{\slides}
```

During processing, the message ‘Which slides to do?’ is typed to the monitor, and the user replies with the desired slide numbers. A similar scheme may be set up for `\onlynotes`.

A sample slide file

An example of input text with the `slides` class, with a leading page, overlay, and note, and using the `clock` option, is given here. The four-page result is shown on the opposite page.

```
\documentclass[a4paper,clock]{slides}
\begin{document}
\begin{center}\Large\bfseries
Sample Viewgraphs
\end{center}

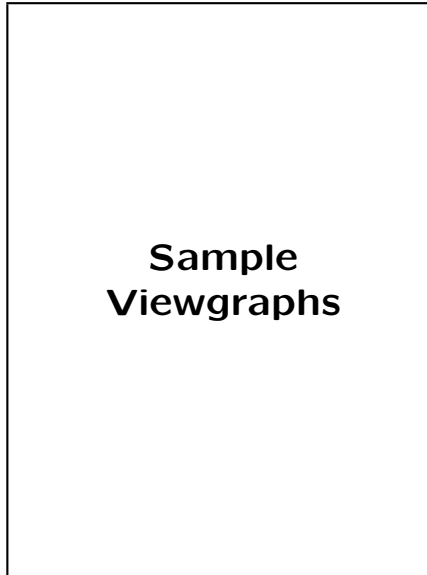
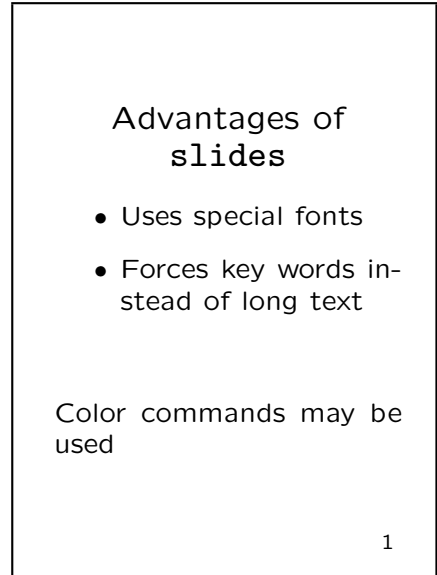
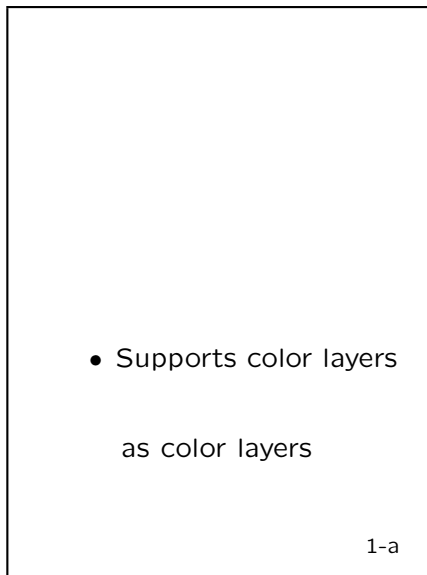
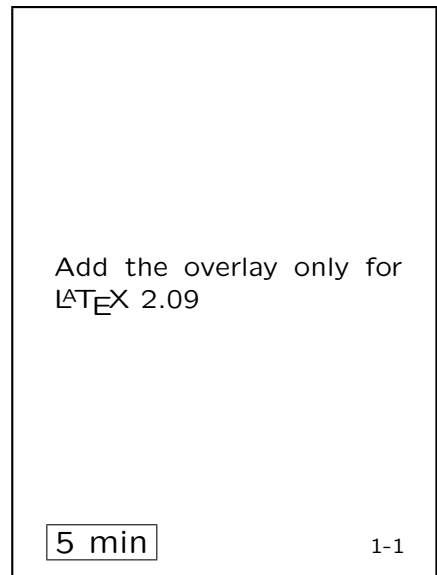
\begin{slide}
\begin{center}\large Advantages of \texttt{slides}\end{center}

\begin{itemize}
\item Uses special fonts
\item Forces key words instead of long text
\invisible
\item Supports color layers
\visible
\end{itemize}

Color commands may be used {\invisible as color layers}

\end{slide}

\begin{overlay}
\invisible
\begin{center}\large Advantages of \texttt{slides}\end{center}
```

The Leading Page**The Slide Page****The Overlay Page****The Note Page**

```

\begin{itemize}
\item Uses special fonts
\item Forces key words instead of long text
\visible
\item Supports color layers
\invisible
\end{itemize}

Color commands may be used {\visible as color layers}
\end{overlay}

\addtime{300}
\begin{note}
Add the overlay only for \LaTeX~2.09
\end{note}

\end{document}

```

15.2 Slide production with seminar

The `slides` class of the previous section some basic support for the production of presentation material. To improve on this, Timothy van Zandt has written the `seminar` class with many additional features. This was originally meant as a ‘main style’ for \LaTeX 2.09, but has been upgraded to a $\LaTeX 2_{\epsilon}$ class file by Sebastian Rahtz with fixes by David Carlisle and Denis Girou. They only changed the interfacing so that it would work as a class file, leaving the functionality untouched.

Unfortunately, the supplied manual for `seminar` (`sem-user.tex`) has not been updated, and is still couched in the language of \LaTeX 2.09; in particular it confuses packages and ‘style options’. We will try to correct this here.

If `seminar` is being used for PDF output, as for an electronic presentation, it is vital to include Sebastian Rahtz’ `hyperref` package (Section 10.2.4), which detects the presence of `seminar` and adjusts the PDF page sizes accordingly. This should be done even if no other `hyperref` features are utilized. There are some other refinements to make `seminar` function smoothly with `pdf \LaTeX` , explained in Section 15.2.7.

15.2.1 Overview

The `seminar` class is loaded as usual with

```
\documentclass[options]{seminar}
```

Here we summarize its main features which differ from `Sl \LaTeX` .

- The slide material is put into the `slide` environment, for landscape slides, and in `slide*` for portrait slides.
- Regular Roman fonts are used, but this can be changed. The options `semhelv` and `semcmss` switch to sans serif family with the PostScript Helvetica and the standard L^AT_EX fonts, respectively.
- Regular font sizes are used, with default 10 pt as usual. However, the slide text is magnified on output to make it more suitable for projection; the magnification factor can be set, but the default is a factor of 2, so the effective default font size is 20 pt.
- A slide is started automatically when the current one is full, or may be forced with the `\newslide` command; the entire slide show could therefore be contained within a single `slide` environment.
- There is a choice of framing style for the slide text; the framing may be turned off with `\slideframe{none}` in the preamble.
- Everything outside of the `slide` or `slide*` environments counts as note text. The notes are printed on separate pages, numbered *n.1*, *n.2*, . . . , for those following slide number *n*.
- The options `slidesonly`, `notes`, and `notesonly` control whether only the slides, both slides and notes, or only the notes are printed. By default, both are printed.
- With the `article` option (not to be confused with the class of the same name), the slide show is printed in miniature form, 2 per page, appropriate for reviewing or as a handout. There is a `notesonly*` option to be used with `article` to indicate the missing slides.

We now explain these features in more detail.

15.2.2 Magnification and lengths

Rather than using enlarged fonts as does L^AT_EX, `seminar` works with ‘normal’ sizes, which are then magnified at output. One can set the magnification step with `\slidesmag{num}` in the preamble, where *num* is an integer between -5 and 9 . Step 0 is one-to-one, and each step indicates an additional factor of 1.2 . The default is step 4 (factor 2).

By default, the basic font size is 10 pt, but this may be altered with the usual options `11pt` and `12pt`. All these are magnified on output. The font size can be changed at any point in the document with `\ptsize{pt}`, where *pt* can be one of 8 , 9 , 10 , 11 , 12 , 14 , or 17 . If this is given within a `slide` environment, it applies only within that environment.

The `article` option produces a handout, with 2 slides per page, using a separate magnification which is set with `\articlemag{num}`; the default step is 0, no magnification.

The output magnification applies to *all* sizes and lengths. This means, any lines drawn with `\rule` or spaces inserted with `\hspace` or `\vspace` are also magnified if they specify absolute units like `pt` or `in`. The size of the slide itself remains unchanged by the magnification, since the purpose is only to increase the size of the contents relative to the slide. To set lengths to values that remain fixed relative to the slide dimensions, use `\setslide length` and `\addtoslide length` in place of `\set length` and `\addto length`. For example,

```
\newlength{\fixed}
\setslide length{\fixed}{3in}
\addtoslide length{\fixed}{1cm}
\rule{1pt}{\fixed}
```

draws a line of height $1\text{ pt} \times \text{magnification}$ and of fixed length $3\text{ in} + 1\text{ cm}$.

For the `article` output, there are also the corresponding commands `\setart length` and `\addtoart length`

The following length commands are slide lengths (do not magnify) and may be used wherever a length is required:

<code>\semcm</code>	1 centimeter
<code>\semin</code>	1 inch
<code>\textwidth</code>	width of the text area
<code>\textheight</code>	height of the text area
<code>\linewidth</code>	current width of text

These are particularly useful with the `\includegraphics` command and its options `width=` and `height=`.

15.2.3 Landscape and portrait slides

In contrast to `SlTeX`, the `seminar` class allows landscape and portrait slides to be mixed. However, there are several aspects that need to be considered.

The `slide` and `slide*` environments determine whether the contents should be in landscape or portrait slides, but the actual placement will only be correct when it agrees with the orientation of the entire document, as specified by the options `landscape` and `portrait`. That means, when the `landscape` option is chosen, the landscape slides will be properly formatted, but the portrait ones not. The reverse applies with the `portrait` option. What one must do is to print the landscape and portrait slides separately, each with the appropriate option, and with the `\landscapeonly` or `\portraitonly` command in the preamble.

When using the `dvips` driver, one can print the landscape and portrait slides together by including the option `semrot`, which ensures that the portrait slides are rotated into the landscape orientation. The entire document (slide show) can be printed in one go. The portrait sheets are then manually rotated to the correct orientation. This would not be acceptable for a PDF electronic presentation, where one wants the two orientations to be mixed in one file, with the text always upright. Another solution for pdf \TeX is given in Section 15.2.7.

When printing both orientations together with the `semrot` option, the head and footlines will not normally be rotated with the text for portrait slides. This can be corrected by issuing `\rotateheaderstrue`. In this way, the output is the same as when one prints landscape and portrait slides separately.

Selecting landscape orientation in itself does not force the output printer to go into landscape mode; it only sets the page dimensions so that the text is written along the longer side. The printer is informed about the landscape intentions either by a switch when the file is sent to it, or by an option to the DVI driver. Again, `dvips` can get around this, as explained on page 232. Using `seminar` and `dvips`, one should define

```
\renewcommand{\printlandscape}{\special{landscape}}
```

to allow the class to instruct the printer to go landscape *when necessary*. This also avoids the warning message on processing that the output must be printed in landscape mode.

15.2.4 Slide formatting

Here we describe the various ways to control the size, layout, and other formatting aspects of the slides.

Slide size

By default, the paper size is American letter size, 11×8.5 in, and the slide dimensions (slide writing area) are 8.5×6.3 in. By specifying the `a4` option the paper size becomes 29.7×21 cm and the slide dimensions 22.2×15.2 cm. (The `a4paper` option exists, but may cause an error.)

The slide size may be altered temporarily as optional arguments to the `slide` and `slide*` environments, as for example,

```
\begin{slide}[10cm,7cm]
\begin{slide*}[7cm,10cm]
```

Both of the above produce a slide 10 cm wide and 7 cm high.

Margins

Normally the material within a slide is centered vertically. The declaration commands

```
\centerslidefalse and \centerslidetrue
```

turns this centering off and on, respectively. Without centering, the text is pushed to the top of the slide.

The text is left justified by default, with a ragged right margin. This can be changed with

```
\raggedslides[len]
```

where *len* is the maximum space between the end of the line and the right margin. Omitting *len* produces a ragged right margin, while a value of 0 pt yields right justification; giving 2 em, say, creates a semi-ragged margin.

The margins between the slide area and the edge of the page are set with the commands

```
\slideleftmargin \sliderightmargin
\slidetopmargin  \slidebottommargin
```

which are all set initially to 0.6 in. Since these are commands, not lengths, they must be changed with `\renewcommand`.

Framing

The slide area can be framed, the default being a rectangular box like that produced by `\fbox` (which is exactly what it is). The frame style can be chosen with

```
\slideframe[cmds]{style}
```

The possible values for *style* are `plain` (the default) or `none`. The optional *cmds* are settings to adjust the frame parameters, such as `\fboxrule` and `\fboxsep`. By including the `fancybox` package, one also has `shadow`, `double`, `oval`, and `Oval` as allowed values for *style*, with their corresponding parameters (Section 4.7.9).

All frames make use of the lengths

```
\slideframewidth and \slideframesep
```

for the frame thickness and separation from text. These may only be altered (with `\setlength`) outside the `\slideframe` command; in the optional *cmds*, one must alter `\fboxrule` and `\fboxsep` directly.

It is possible to define one's own frame style with

```
\newslideframe{new_style}[cmds]{\box_cmd{#1}}
```

where *new_style* is the name of the new style (for use with `\slideframe`), *cmds* are box parameter settings, and *\box_cmd* is a box command, like `\fbox` or `\shadowbox`.

There is a `semcolor` option for `seminar`, but this is not based on the \LaTeX `color` package, but depends on PostScript and the `dvips` driver. With the `color` package, one can make use of the `\color` and `\textcolor` commands for setting text in color, as well as `\colorbox` and `\fcolorbox` for colored boxes and `\pagecolor` to color the whole page (page 167). Two examples for defining color frame styles are

```
\newslideframe{gplain}{\fcolorbox{green}{white}{#1}}
\newslideframe{rshadow}[\color{red}]%
    {\shadowbox{\color{black}#1\color{red}}}
```

The first makes use of the color frame box command `\fcolorbox`, while the second shows a trick to combine color commands with `\shadowbox`, which normally prints a black shadow box. The two `\color{red}` commands ensure all sides of the box are in red, while the `\color{black}#1` puts the box's contents in black.

Page styles

Page styles determine how the running head and footlines appear on each page, just as in normal text. The regular \LaTeX page style of Section 3.2 (`plain`, `empty`, `myheadings`, and `headings`) are all available, and the default is `plain`, with the page/slide number centered in the footline. A different page style may be selected with `\pagestyle{style}` at any time, or with `\thispagestyle{style}` for just the current page.

There is also an additional page style `align` that puts `+` marks at the four corners.

You can define your own page styles with

```
\newpagestyle{style}{headline}{footline}
\renewpagestyle{style}{headline}{footline}
```

which is preferable to using the styles in the `fancyhdr` package of Section 3.2.2 since that cannot handle the magnified lengths correctly. For example, to define a page style with a centered text in the head, and a footline with a text at the left and the slide number at the right, give

```
\newpagestyle{mystyle}%
    {\hfill Report\hfill}%
    {March 20, 2004\hfill\thepage}
```

Note here that `\thepage` prints the number for the current page, whereas `\theslide` and `\thenote` refer to the latest slide and note numbers respectively; `\thepage` is always set to whichever of them is being printed.

Font commands can be included in the new definitions, but one should be aware that the commands `\slideheadfont` and `\slidefootfont` are always inserted into the head and footlines. These are defined to be `\scriptsize`, but may be redefined by the user.

It is possible to select different page styles for the slides and notes. The `\pagestyle` command sets the style for both (as well as for the `article` output) while `\slidepagestyle` applies only to slides.

Page breaking

Unlike `SLiTeX` where each `slide` environment generates a single slide (and warnings if it is too big), the `seminar` package allows the text to break naturally into multiple slides just as normal text does into pages. A new slide may be forced with `\newslide`.

You can add some extra tolerance for the page breaking by specifying

```
\extraslidesheight{len}
```

where *len* is the additional height allowed before a break is automatically inserted. By setting this to be large, automatic page breaks never occur, and the user has full control, either with `\newslide` or by ending the environment. Setting it to 0 pt causes pages to be broken as for regular text. The default is 10 pt.

15.2.5 Selective output

One can select to output just the slides, or just the notes, or both, by adding one of the options `slidesonly`, `notesonly`, or `notes` to the `\documentclass` command. There is also a `notesonly*` option to print the notes alone in `article` output but with indicators for the slides.

A problem arises if `slidesonly` has been selected. Any global specifications issued after `\begin{document}` and outside of a `slide` environment will be ignored. One might want to redefine parameters in this way; including them inside the `slide` environment makes the changes local to that one environment. To avoid this, such global commands should be placed inside a `allversions*` environment. (If you actually want to include text and not just non-printing specifications, use the `allversions` environment instead.)

Just as for `SLiTeX`, one can output selected slides or notes. This is useful during development of the slide show, when one may spend much time designing a complicated slide and is constantly processing it to see the results; this can become tediously slow if the other, completed, slides are also complicated or include large graphics files. As for `SLiTeX` (page 327), the `\onlyslides{list}` command in the preamble ensures that only those slides whose numbers are included in *list* are processed. However, there is also a `\notslides{list}` command to exclude those slides in *list*.

The *list* a set of numbers in any order, separated by commas, or a range with a hyphen. It is even possible to include `\ref` commands for slides containing the corresponding `\label`, something that is very useful during development when the slide numbers are yet finalized. For example,

```
\onlyslides{4,2,\ref{sum},10-999}
```

outputs slides 2, 4, the slide containing `\label{sum}`, and all from 10 to 999. Non-existent numbers are ignored, so 10-999 really means ‘10 to the end’, unless there really are so many slides in this show.

15.2.6 Additional features

Counters

The `seminar` class provides all the standard L^AT_EX counters (Section 8.1) as well as `slide` and `note` counters, the values of which are printed with `\theslide` and `\thenote`. The page number is printed with `\thepage`, which is set to whichever of the others is current, or to the true page number for `article` output.

The `footnote` counter is the only one that is reset to 1 for each new slide. If you want other counters to be reset too, say `equation`, specify this with

```
\slidereset{list} or \addtoslidereset{list}
```

where *list* is a comma-separated list of counters. The first command overwrites the existing list of counters, the second adds to it.

The note environment

As an alternative to note pages being generated by all text outside of the `slide` environment, one can issue `\noxcomment` in the preamble, or select option `noxcomment` in `\documentclass`, and then place all the notes in `\begin{note} ... \end{note}` environments.

Overlays

Overlays for slides can be produced by including the options `semlyayer` and `semcolor`. These make use of PostScript coding and therefore only work with the `dvips` driver or equivalent.

The `\overlay{n}` indicates that the following text is to appear on overlay *n*; it remains in effect until the current scope is ended, at the end of the environment or `{. .}` group, or when another `\overlay` command is issued.

Overlays are not so useful for a PDF electronic presentation. Instead, one creates the same effect by building the page successively. A method of doing this is explained in Section 15.4.1.

Adding a background image

Slide shows are made more effective with the use of color, and with a background pattern or picture. A background color can be added with the `\pagecolor` command from the `color` package.

However, even more effective is a background image. If this is a graphics file named `mybg.png`, one can insert it as a background to all slides with the following trick. This does require the `fancybox` package for the `\fancyput` command.

```

\newlength\bgwidth
\newlength\bgheight
\ifportrait
  \setslide\length{\bgwidth}{\paperwidth}
  \setslide\length{\bgheight}{\paperheight}
\else
  \setslide\length{\bgwidth}{\paperheight}
  \setslide\length{\bgheight}{\paperwidth}
\fi
\ifarticle\else
  \fancyput(-1\semin,1\semin){\raisebox{-\bgheight}
    {\includegraphics[totalheight=\bgheight,
      width=\bgwidth]{mybg.png}}}
\fi

```

What this does is first to define and set two new lengths, `\bgwidth` and `\bgheight`, to be the non-magnified size of the full page, for the current orientation. The `\fancyput` command places its contents on each page, relative to a point 1 in from the upper left corner; with the above coordinates, it is shifted exactly to the upper left corner. The graphics is inserted here, shifted down by the page height, and expanded/shrunk to fit the page exactly. One must design the graphics correctly so that any distortion is minimal. The `\ifarticle` construction prevents the background image from being included with `article` output.

This should work with any type of output, PostScript or PDF or other. Of course, the type of graphics file must conform to those allowed by the DVI driver. For PostScript, it must be an `.eps` file, not `.png`.

See also page 345 for an alternative means of adding background images.

Local configuration

The `seminar` class reads in the file `seminar.con` if it exists. This gives the user the chance to write all the specifications and new definitions that he or she always employs to this file, to have them automatically included in every `seminar` source file.

15.2.7 Using pdfT_EX with seminar

Although the `seminar` class originated in the pre- $\text{\LaTeX}2\epsilon$ days, and many of its extra features are coded for PostScript and the `dvips` driver without the modern `graphics` and `color` packages, there is no problem using it with today's \LaTeX and those packages. This is particularly true for PDF output.

However, with pdfT_EX itself, there are some extra length parameters `\pdfpagewidth` and `\pdfpageheight` which need to be properly set to get the output right. This is most simply guaranteed by including the `hyperref` package (Section 10.2.4) even if no other of its features is needed.

Another difficulty arises if landscape and portrait slides are mixed. If the goal is only to print to paper or transparencies, then the two orientations may be processed and output separately, as explained above. However, for an electronic presentation, this would be most inconvenient. Certainly the ability to mix the two orientations is highly desirable.

The following code makes this possible. It revises the `slide*` environment to interchange the PDF page dimensions, so that a true portrait page is produced. (This is not possible with printed output where a single print job must have a fixed orientation.)

```
\@ifundefined{pdfoutput}{\endinput}{%
  \ifcase\pdfoutput \endinput \fi}
\newcommand*{\pdf@revpage}{%
  \@tempdima=\pdfpagewidth
  \pdfpagewidth=\pdfpageheight
  \pdfpageheight=\@tempdima
  \@tempdima=\paperwidth
  \paperwidth=\paperheight
  \paperheight=\@tempdima
}
\ifarticle \pdf@revpage \fi
\renewcommand{\printlandscape}{}

\expandafter\let\expandafter\slide@str
  \csname slide*\endcsname
\@namedef{slide*}{\pdf@revpage\slide@str}
```

Store this in a file named `sempdftx.sty`, which can then be loaded with `\usepackage`. It is programmed to do nothing if `pdfTeX` is not being used. Alternatively, add a line `\RequirePackage{sempdftx}` to the local configuration file `seminar.con` to load it on every `seminar` run.

Note: This file can be copied from the enclosed CD in the directory `\books\Kopka_and_DaLy\`, where a version of `seminar.con` is also available.

15.3 Electronic documents for screen viewing

Strictly speaking, this section is not about presentation material that is to be projected before an audience, but rather about documents that are deliberately intended to be read from a computer monitor. These have other requirements from printable documents: the page shape should be more like a monitor (that is, landscape instead of portrait) and navigation aids should be included especially if the viewer's regular tool bars have been switched off. And of course, internal links should be present, as well as links to external web sites and documents.

Package:
pdf-
screen

The `pdfscreen` package by C. V. Radhakrishnan is an effort to fulfill these requirements. But it is more flexible than that, for it also allows the entire document to be output in traditional print format. And it even contains a `slide` environment for making projection material, so it does indeed belong to this chapter.

The supplied manual can be found in `texmf\doc\latex\pdfscreen`, in print and screen versions. The source file `manual.tex` can serve as a good example of how to use the package. Figure 15.2 on the opposite page demonstrates what a title page can look like, complete with navigation panel which appears on every page.

Parameters for `pdfscreen`

This package should be loaded with the `article` class and with the `hyperref` package. In fact, it should be considered to be an extension to `hyperref`. And it should be loaded last, right after `hyperref`.

The options that may be invoked with the `\usepackage` command are

`screen` to generate the output in the screen version, for online reading;

`print` to generate the print version of the output;

`panelleft`

to place the navigation panel at the left;

`panelright`

to place the navigation panel at the right;



Figure 15.2: Title page of a pdfscreen document

- `nopanel`
to suppress the navigation panel;
- `paneltoc`
to include a table of contents in the navigation panel;
- `nocfg` to ignore any local configuration file;
- `sectionbreak`
to insert a new page at the start of sections.

In addition one can specify various color schemes for the panel and its buttons. Possible color options are `blue1ace`, `blue`, `gray`, `orange`, `pa1egreen`, and `chocolate`. Also all the `babel` language options (Chapter 11) are recognized, for labeling the navigation buttons, although only 15 are actually supported; the others default to English.

There are additional parameters that must be set by declarations:

- `\emblem{image}`
to set the name of the graphics file used for the logo in the navigation panel;

`\urlid{url}`

to set the web address (URL) of the home page button in the navigation panel;

`\screensize{height}{width}`

to set the dimensions of the screen; since there are no defaults, this must be given;

`\margins{left}{right}{top}{bottom}`

to set the margins for the document; again there are no defaults, so this must be given.

The navigation panel

The navigation panel appears on each page and contains the buttons for changing pages and linking to the author's home page. A default panel is provided, but the user may redesign it as he or she pleases, by redefining the `\panel` command. For example,

```
\renewcommand{\panel}{\colorbox{panelbackground}
{\begin{minipage}[t][\paperheight][b]{\panelwidth}
. . . . .
\Acrobatmenu{FirstPage}
{\addButton{.2in}{$\blacktriangleleft$}}
. . . . .
\end{minipage}}}
```

Here the `\Acrobatmenu` command is from the `hyperref` package (see page 247) while `\panelwidth` and `\addButton` are from `pdfscreen`. The `\panelwidth` length is by default 15% of the screen width, and can be redefined. The `\addButton{wth}{text}` creates a button of width *wth* containing *text*. In the above example, clicking the button executes the viewer command to go to the first page.

There is also a command

```
\imageButton{wth}{ht}{image}
```

to insert the graphics file *image* as a button of width *wth* and height *ht*.

A row of small navigation buttons can be turned on at the bottom of the page with `\bottombuttons` and turned off with `\nobottombuttons`.

Background image

A graphics file can be inserted as background for the whole page with `\overlay{image}`, or a uniform background color can be selected with `\backgroundcolor{color}`.

The navigation panel has as background that color previously defined as `panelbackground`, which the user may alter. Otherwise, the graphics

file *image* may be inserted as the panel background with the command `\paneloverlay{image}`.

Making slides

There is a `slide` environment that places its contents centered vertically within a box the full size of the text area.

Local configuration

Any settings that you want to use for all documents with `pdfscreen` may be written to a file named `pdfscreen.cfg`, which is read in on loading if present.

Controlling print or screen output

The entire file can be processed either as a document to be printed in the traditional way, or as an electronic document for reading on a monitor. This is switched by the options `print` and `screen` when loading the package.

Text and specifications that are meant exclusively for one output version must be enclosed in `print` or `screen` environments. This is especially important for the `\screensize` and `\margins` commands, which are inappropriate in print mode.

Other packages loaded

The `pdfscreen` package makes heavy use of several other packages, which it loads automatically. These must then also be installed on the system:

<code>hyperref</code>	<code>graphicx</code>	<code>calc</code>	<code>shortvrb</code>
<code>comment</code>	<code>color</code>	<code>amssymb</code>	<code>fancybox</code>
<code>truncate</code>	<code>colortbl</code>	<code>amsbsy</code>	

15.4 Special effects with PDF

There are many fancy features that one expects today from an electronic presentation: sounds and animation, text dancing in from the sides, fade overs, and possibly fireworks. A PDF file can include many of these.

The `pdfTeX` program cannot (yet) generate these directly, but there is an auxiliary program called *PPower4*, written in Java by Klaus Guntermann and Christian Spannagel. This is a post-processor designed to take as input a PDF file specially prepared with `pdfTeX` with some extra packages, and to create a new PDF file with the additional tricks.

For example, in order to build up a page containing an itemized list, such that each item should pop up one at a time, one adds a `\pause` command after each item, runs `pdfTeX`, and processes the output with `PPower4`. It splits the page up into several pages, each one containing the text up to the next `\pause`. By stepping through these pages, the presenter ‘constructs’ the one slide before the eyes of the audience. In fact, `PPower4` can do much more, making a very sophisticated electronic slide show from pure `LATEX` input.

The `PPower4` program and the necessary `LATEX` support packages are on the `TEXLive` CD, but the latest versions can be obtained from <http://www-sp.iti.informatik.tu-darmstadt.de/software/ppower4/>. At the time of writing, it is still under development, but is already very impressive.

15.4.1 The `PPower4` packages

The `PPower4` post-processor is run with only two parameters: the names of the input and output files. There are no additional adjustments, controls, or options at processing time. Everything of that sort has already been placed in the `LATEX` source text itself with the help of supplied packages. These instructional commands add comments to the resulting PDF file, which may be viewed and printed as normal. It is the post-processor that reads these comments and uses them as instructions for making up the new output file.

Here we describe these packages and the marker commands that they enable. The use of the `hyperref` package is presupposed, since many effects can be achieved directly with it.

Page transitions

Transitions from one page to another can be done in various ways to catch attention. The simplest is the plain replacement: the old page vanishes, the new one appears. Others involve effects that look like blinds opening, or like a box opening from or towards the center, or dissolving from one to the other. These can be set with the `hyperref` package with the option `pdfpagetransition` (page 245) or set to a different effect anywhere in the document by giving

```
\hypersetup{pdfpagetransition={pars}}
```

where *pars* are the required parameters for the desired transition.

Marc van Dongen has prepared a file `pagetrans.tex`, available with the `PPower4` collection, that defines simpler commands to execute the above. (If this were renamed `pagetrans.sty`, it would be a package and could be loaded with `\usepackage` but as is, it must be included with the `\input` command.) These commands are:

`\Replace` pages are simply replaced, the default;

`\Dissolve` one page ‘dissolves’ into the other in a mosaic fashion;

`\VBlinds` several horizontal lines sweep vertically across the screen, like Venetian blinds;

`\HBlinds` same as `\VBlinds`, but vertical lines move horizontally;

`\HOSplit` two vertical lines sweep horizontally out from the center;

`\HISplit` as above, but the lines move into the center;

`\VOSplit` two horizontal lines sweep vertically out from the center;

`\VISplit` as above, but the lines move into the center;

`\OBox` a box opens out from the center;

`\IBox` a box sweeps into the center;

`\Wipe{angle}` a single line sweeps across the screen in the direction given by *angle*, which can be 0 (left to right), 90 (bottom to top), 180 (right to left), 270 (top to bottom);

`\pageTransitionGlitter{angle}` like `\Dissolve` but in a band that moves across the screen in the direction *angle*, which can be 0 (left to right), 270 (bottom to top), 315 (upper left to lower right).

We stress again, these declarations are simplifications of the `hyperref` commands, and function without `PPower4` post-processing. Once given, they remain in effect for all pages until a new transition command is declared.

Adding a background

We have already seen in Section 15.2.6 how a background image may be added with the help of the `fancybox` package, and how a solid background color can be set with the `color` package.

Package: back-ground These and other effects can also be achieved with the `background` package supplied with `PPower4`. This package provides the commands

```
\hpagecolor[color1]{color2} and
\vpagecolor[color1]{color2}
```

that cause the background color to blend from *color1* to *color2* horizontally or vertically. If the optional *color1* is omitted, it is the intensity of *color2* that changes across the page. Both colors must be defined by the `color` package command `\definicolor`, or be one of the predefined colors. *This effect requires post-processing with PPower4!*

The package can also add background images, *without PPower4 post-processing*, if it is loaded with the option `bgadd`. This then includes the commands

```
\bgadd{image} and \bgaddcenter{image}
```

to place *image* at the upper left corner or centered on the page. The *image* is an `\includegraphics` command with appropriate scaling to fit the page. These commands may be issued more than once to add further elements to the background. They may all be removed with `\bgclear`.

Note: The addition of background elements to the pages requires that the package `eso-pic` also be installed.

Building a page successively

Package: `pause` The electronic equivalent to overlays is the successive building of a page of text. The `PPower4` `pause` package introduces the `\pause` command that places markers in the PDF output which `PPower4` then uses to break the page at that point, and to start a new page containing the previous contents plus whatever comes up to the next `\pause` or end of page. This works for both `pdfTeX` and `dvipdfm`.

For example, we could build a numbered list with

```
We proceed as follows:
\begin{enumerate}
  \item We write the list source text.\pause
  \item We add the pause markers.\pause
  \item We run pdfTeX.\pause
  \item We run PPower4.\pause
\end{enumerate}
And there we have it!
```

The first PDF file generated will have a single page with a small colored block where each `\pause` command appears. (This may be suppressed if the package is loaded with the `nomarkers` option.) The resulting PDF file after post-processing will have 5 pages in place of this one, each one with an additional item. As the presenter steps through the pages, each new line appears to be added to a single page, until the full page is complete.

Building with transitions

Rather than having the new line simply popping up out of nowhere, one can select the type of page transition at any step by giving a modified `\pause` with the name of one of the transition declarations from page 344. For example `\pauseHBlinds` is the same as `\pause` plus `\HBlinds` except that the transitions between main pages are not affected. Note that

`\pauseReplace` is the default, causing the new text simply to appear. These remain in effect for the following `\pause` breaks until countermanded.

There is a `\pauseGlitter{angle}` command as the equivalent to `\pageTransitionGlitter{angle}`, but all others just attach the declaration name to `\pause`.

Building with levels

Even more sophistication can be added by assigning level numbers to the chunks of text between the `\pause` markers. In this way the page can be built up in any order, parts can be made to disappear or to be replaced, and the footline text at the bottom of the page can be visible from the beginning.

The level number corresponds to the sequence number of the views of the built-up page. Thus a chunk of text (that which comes between `\pause` commands) with level n will first appear in view n . By default, the level number starts at 1 and increases by 1 for each `\pause`. To ensure that the page footline is at level 1, we can write the last line of the above example as

```
And there we have it!\pause\pauselevel{=1}
```

The `\pauselevel` command sets the level number for the chunk in which it is located. There are several possibilities for its argument.

`{=n}` sets the level number absolutely to n ;

`{=+n}` increases it by n ; bear in mind that the preceding `\pause` has already incremented it by 1;

`{=-n}` decreases it by n ;

`{=n -d}` sets level number to n and makes the change in level number with `\pause` to be $-d$; this would be done with say `{=10 -1}` to make the chunks numbered backwards from 10, causing the page to be built from the bottom up;

`{:m}` sets the maximum level to m ; at higher levels, the text vanishes; with `{=3 :4}` the chunk is visible only at levels 3 and 4; the `:m` may also be set relatively as `{:+m}` or `{:-m}`.

It is also possible to give multiple level specifications, as

```
\pause\pauselevel{=2 :2, =5 :6}Text\pause
```

to cause ‘Text’ to appear at level 2, to vanish for 3 and 4, and to reappear only for 5 and 6.

The level number may not be less than 1. Zero and negative numbers are treated as 1.

With some tricky playing around with level numbers and with the \TeX overlap commands `\rlap` and `\llap`, it is possible to get text or images to be replaced. The two must be made to overlap, but at different level numbers. For example:

```
We now \rlap{alter}change this word
We now
\pause\pauselevel{=1 :1}\rlap{alter}\pause
change\pause\pauselevel{=1}
this word
```

The first line shows the text without the `\pause` markers, in which ‘alter’ overlaps to the right over ‘change’. The next lines show the same text with levels inserted: ‘alter’ belongs to level 1, and disappears after 1; ‘change’ belongs to 2 (automatic increment), and the remaining text is set back to level 1.

Highlighting instead of building

An alternative to building the page by pieces is to highlight the section of text being discussed. In this mode, the entire page is visible, but printed in a dull color, like gray, while the chunk of text at the current level is in a bright color. When switching to the next view (level), that text becomes dull, and the next chunk brightens.

To get this to work, one must inform PPower4 what the normal and highlight colors are to be, and one must further indicate what text should actually change. Clearly certain parts of the page are to remain as they always are, at least the head and footlines, and possible titles. This is done with

```
\pausecolors{textclr}{dullclr}{highclr}
```

where *textclr* is a dummy color that is not otherwise being used. Only text indicated in this color will participate in the highlighting. For example

```
\pausecolors{cyan}{gray}{red} ...
This is the \textcolor{cyan}{text to be highlighted}
by the ...
```

The ‘text to be highlighted’ will normally appear in gray, but will turn red for that view corresponding to its level number. And only for that view! At the next view, it returns to gray. Note that the color cyan never appears; it is only a marker for PPower4. (Well, it does appear in the first PDF output, before post-processing.)

The highlighting mode is activated with `\pausehighlight` which makes all text at all levels visible, but with this color switching feature. The build mode can be reactivated with `\pausebuild`. In build mode, the

color switching still takes place, but the text does not appear until the right view is reached. It will be highlighted only for this first view.

One can add the word `highlight` to the argument of `\pauselevel` to indicate a chunk that should always be visible even in build mode, and which participates in the color switching. In highlight mode, this has no effect.

Linking to first view

Package: `pp4link` Making an internal link with the `hyperref` commands `\hypertarget` and `\hyperlink` (page 247) causes the target to be on the completed built up page, on the last view. However, one probably wants to link to the first view, before the page is built up. The `pp4link` package can assist here. It defines the commands

```
\toplink{name}{text} and \toptarget{name}
```

to establish *text* as a link to the target *name*.

This package tries to load `hyperref` on its own, without any options. If you try loading `hyperref` afterwards, with options, you will get a message about conflicting options and the options will be ignored. Therefore, load `pp4link` after `hyperref`.

In addition to the three standard L^AT_EX document classes, there is a fourth one named `letter` for formatting correspondence. As provided, this class is intended for private letters without any frills such as letterheads or business reference codes. However, local modifications are possible.

We first present the standard L^AT_EX `letter` class, and then demonstrate how a house style can be written using our own institute style as an example. As always, it is highly recommended that each of these modifications be given its own file name so that `letter.cls` refers only to the provided L^AT_EX version.

16.1 The L^AT_EX `letter` class

The `letter` document class is meant for writing letters. A single input file may contain the text for more than one letter and recipient, all from the same sender. Address labels may also be printed automatically if one wishes. Most of the normal L^AT_EX commands function as usual within the `letter` class. One exception, however, is the sectioning commands, which will lead to the error message `! Undefined control sequence` when issued. It actually makes little sense to try to divide a letter up into chapters, sections, etc. On the other hand, there are a number of special commands that may be applied only within this style.

The input text for a letter begins as for every L^AT_EX document with

```
\documentclass[options]{letter}
```

in which all the options listed in Section 3.1 may be given for *options* except for `twocolumn` and `titlepage` which hardly make any sense within a letter.

Every letter must contain the name and address of the sender, which are set for all the letters in one file by including the commands

```
\address{sender_address}  
\signature{sender_name} or \name{sender_name}
```

in the preamble. The *sender_address* normally consists of several lines, separated by `\\` commands, as in the example

```
\address{Max-Planck-Institut f\"ur Aeronomie\\
        Max-Planck-Str.\ 2\\
        D--37191 Katlenburg--Lindau\\Germany}
```

The entry in the `\name` command will be used in the return address in the letterhead, if such has been programmed. The entry in the `\signature` command will be printed at the end of the letter below the space left blank for the writer's signature. If `\signature` has not been specified, the `\name` entry is inserted here instead. This allows a more formal `\name` to be used for the return address and a different form, perhaps with multiple lines, for the signature, as in

```
\name{Prof.\ M.\ Ostmann}
\signature{Martin Ostmann\\Project Leader}
```

When the above commands are issued in the preamble, they remain valid for all the letters in the document, except for those letters that contain new versions of these commands. Thus one letter might have a different `\signature` from the others. The scope of these entries extends only to the end of the environment in which they were called (see Section 8.5.4).

Two other sender entries are possible in standard `LaTeX` `letter` class. They are intended to be employed in local modifications for a house style. The idea is that if `\address` is *not* called, the preprogrammed company letterhead which might also contain the sender's room and/or telephone number is generated. Thus the commands

```
\location{room_number} and \telephone{tel_number}
```

are provided. In the standard `letter` class, the entries *room_number* and *tel_number* are printed at the bottom of the first page *only if* `\address` is *not issued*.

The preamble may also contain the `\pagestyle` command with the usual entries `plain`, `empty`, or `headings`. The first is the default, putting the page number centered at the bottom of all pages after the first. The `headings` page style adds the recipient's name, the date, and page number in a line at the top of all pages after the first.

After the preamble commands, the actual text begins as in all `LaTeX` files with the command `\begin{document}`. The text consists of one or more letters, each enclosed in a `letter` environment with the syntax:

```
\begin{letter}{recipient} text of letter \end{letter}
```

where *recipient* stands for the name *and* address of the recipient, divided into several lines separated by `\\` commands.

```
\begin{letter}{Mr Donald J. Burns\\
                Ontario Institute of Physics\\}
```

```
41 Adelaide St.\\
London, Ontario\\Canada N4R 3X5}
```

The *text of letter* normally begins with the command `\opening` and ends with `\closing`, between which the body of the letter appears, mixed with whatever L^AT_EX commands are desired. The syntax of these two commands is

```
\opening{dear}
\closing{regards}
```

where *dear* is the salutation, such as `Dear Mr Tibs`, and *regards* stands for the terminating text, for example `Yours sincerely,`. The `\opening` command could also contain other text, for example a subject entry line, with the true salutation as part of the following body text.

L^AT_EX places the *sender's* name and address in the upper right corner of the first page with the current date set right justified below it. Then the *recipient's* name and address appear at the left margin, followed by the *salutation* and the body of the letter. The letter ends with the *terminating text* and the sender's *name* or *signature* left justified from the center of the line with sufficient vertical space between them for the handwritten signature.

After the `\closing`, a number of other commands may appear as part of the letter. One is `\cc` to produce a copy distribution list:

```
\cc{name1 \\ name2 \\ ... }
```

The text 'cc:' (or more correctly, the text defined in `\ccname`) is printed at the left margin, followed by an indented list of names of the copy recipients.

The second additional command is `\encl` for making a list of enclosures:

```
\encl{enclosure1 \\ enclosure2 \\ ... }
```

The word 'encl:' (actually the text in `\enclname`) is printed at the left margin and then the list of enclosures.

Finally, the command `\ps` may be used to add a postscript after the signature. The command itself does not generate any text, nor does it take an argument. The postscript text is everything located between the `\ps` and `\end{letter}` commands.

Normally the letter is dated automatically with the current date. However, if it is desired that the letter be back-dated, or that the date be otherwise fixed in the text, it may be set with

```
\date{date_text}
```

in which case *date_text* appears where the current date would be placed.

A letter file may contain any number of `letter` environments, one per letter. As stated already, when `\address`, `\name`, and `\signature` have

A sample letter produced with the standard `letter` class.

Max-Planck-Institut für Aeronomie
Max-Planck-Str. 2
D-37191 Katlenburg-Lindau
Germany

September 8, 2003

T_EXproof Ltd
P. O. Box 123
9876 Wordtown
Textland

Dear Sir;

We are most pleased to be able to answer your request for information about the use of L^AT_EX for general text processing at a scientific institute.

1. After some initial trepidation on the part of the secretarial staff, which was mainly due to the first experience with a non-WYSIWYG text system, the system is now fully accepted and appreciated.
2. Much to the surprise of many secretaries, they find that they are able to set the most complicated mathematical formulas in a reasonably short time without difficulties. The same applies to the production of detailed tables.
3. Creating cross-references and keyword indices no longer causes horror, even when the author is well known for demanding constant changes.
4. Finally, the high quality appearance of the output has assisted in winning acceptance for L^AT_EX in our house.

An additional positive note is the ability to write business letters readily, making use of the `letter` class provided with L^AT_EX. In our institute, we have designed a special version to print our own letterhead, saving the need to have special letter paper printed.

Yours truly,

Patrick W. Daly

encl: Listing of our `mpletter.cls`
Sample output

cc: H. Kopka
B. Wand

been specified in the preamble, they remain in force for all the letters in the file. It is possible to alter any one or more of these sender entries by reissuing the command within one of the letters, *before* the `\opening` command, but then this change is valid solely for that letter. If both `\name` and `\signature` have been declared, it is the latter that is printed below the signature space.

The first page contains no page number. Subsequent pages have either a centered page number at the bottom (default) or a heading line with recipient, date, and page number at the top (page style headings).

The sample letter on the facing page was generated with the following input text.

```
\documentclass[a4paper,11pt]{letter}
\name{Dr P. W. Daly}
\address{Max--Planck--Institut f\"ur Aeronomie\\
         Max--Planck--Str.\ 2\\
         D-37191 Katlenburg--Lindau\\Germany}
\signature{Patrick W. Daly}
\date{September 8, 2003}
\begin{document}
\begin{letter}{\TeX proof Ltd\\P.\,0. Box 123\\
              9876 Wordtown\\Textland}
\opening{Dear Sir;}
We are most pleased to be able to answer your request for
information about the use of \LaTeX{} for general text
processing at a scientific institute.
\begin{enumerate}
  \item
    After some initial trepidation on the part of the secretarial
    . . . . .
    in winning acceptance for \LaTeX{} in our house.
\end{enumerate}
An additional positive note is the ability to write business
. . . . .
special paper printed.
\closing{Yours truly,}
\encl{Listing of our \texttt{mpletter.cls}\\Sample output}
\cc{H. Kopka\\B. Wand}
\end{letter}
\end{document}
```

By adding the command `\makeLabels` in the preamble, the user can print out address stickers after all the letters have been output. The entries for the addresses are taken from the recipients' names and addresses in the argument to the `letter` environment. The standard \LaTeX letter class is designed for a page of labels $4\frac{1}{4} \times 2$ inches, ordered in two columns. This could be altered for other formats. An address sticker

without a corresponding letter may be printed by including an *empty* letter environment of the form

```
\begin{letter}{recipient}\end{letter}
```

16.2 A house letter style

The sample letter above demonstrates the possibilities of the standard L^AT_EX `letter` class. The height and width of the text may easily be altered with appropriate declarations in the preamble. The use of explicit English words and date style is no problem for other languages since they are all contained in special commands that can be redefined.

The `letter` class has been designed so that if the `\address` command is omitted, a company letterhead will be printed instead. This presupposes that the file has been reprogrammed at the local installation for this purpose. Each employee using this house letter style will have certain personal entries to make, such as his or her room and/or telephone number. These commands have been provided for in the standard `letter` class.

We have such a house letter style at our institute which we will illustrate here. However, it was found necessary to add some more personal entries, such as ‘Our Ref.’, ‘Your Ref.’, and email addresses. In addition, a command to print out ‘Subject:’ has also been added.

To distinguish our local house style from that of standard L^AT_EX, we have named it `mpletter`. It contains most of the features of `letter`, since it in fact reads in that class file and then makes its alterations and additions. The `\address` command is not necessary, since all letters are printed with the institute letterhead, including its address. The recipient’s name and address are taken from the argument of the `letter` environment and are vertically centered in the space provided in the letterhead.

The writer’s name and telephone extension are entered with

```
\name{author} and \telephone{ext.number}
```

which, if given in the preamble, apply to all the letters in the file. If different letters have other authors, these commands must be made in the appropriate `letter` environment *before* the `\opening` command. New entry commands specific to `mpletter` are

```
\yref{your.code}
\yemail{your.date}
\myref{our.code}
\subject{subj.text}
```

which produce the words

```
Your Ref.: Your letter of.: Our Ref.: Subject:
```


MAX-PLANCK-INSTITUT FÜR AERONOMIE Max-Planck-Str. 2
Katlenburg-Lindau
GERMANY

MPI für Aeronomie, D-37191 Katlenburg-Lindau

Mr George Murphy
35 Waterville Rd.
Centertown, Middlesex
United Kingdom

Dr P. W. Daly
Tel.: 05556-401-279
Email:
daly@linmpi.mpg.de

May 10, 2003

Your Ref.: GFM/sdf *Your letter from:* April 28, 2003 *Our Ref.:* PWD/sib

Subject: L^AT_EX information

Dear George,

Thank you for your inquiry about the latest version of the L^AT_EX installation and additional packages.

The entire T_EX installation, with binaries and of course L^AT_EX, along with a large number of contributed packages, is distributed annually by the T_EX Users Group, on their T_EXlive CD.

I am sending you a copy of the current version of this CD, as you requested. In a separate directory named `bibtex` you will find the special bibliography formatting package files mentioned in 'A Guide to L^AT_EX'. I hope you will find these of use.

Do not hesitate to get in touch with me again if you have any further questions about the installation or running of the package.

Regards,

Patrick W. Daly

encl: 1 CD-ROM with T_EXlive contents

cc: H. Kopka

<u>Telephone</u>	05556-401-1	<u>Bank</u>	<u>Train Station</u>
<u>Telefax</u>	05556-401-240	Kreis-Sparkasse Northeim	Northeim
<u>Telex</u>	9 65 527 aerli	41 104 449 (BLZ 262 500 01)	(Han.)

properly positioned under the letterhead together with the corresponding text argument. If any of these commands are missing, their text will not appear in the letter.

Since ours is a German institute, there is an option `german` that translates all these words into their German equivalents. The entry commands have the same names, however.

As in the standard `letter` class, the current date is printed automatically, but may be changed to any desired text with the command

```
\date{date_text}
```

if one wishes to back-date a letter or to fix the dating within the letter file itself. This is often handy if one only keeps electronic copies of the letters for the record. Otherwise, when a hard copy is run off months later, it will appear with the new current date and not with the original one.

The entry `author` that is given as the argument to the `\name` command appears in the letterhead as the name of the sender. It will also appear below the space left for the signature, unless it is overridden by the `\signature` command that specifies an alternative form of the name for this purpose.

The sample letter on the previous page has been generated with our house style, using the following input text.

```
\documentclass[12pt]{mpletter}
\name{Dr P. W. Daly} \signature{Patrick W. Daly}
\myref{PWD/sib}
\date{May 10, 2003}
\subject{\LaTeX{} information}
\telephone{279} \internet{daly}
\ymail{April 28, 2003} \yref{GFM/sdf}
\begin{document}
\begin{letter}{%
Mr George Murphy\\35 Waterville Rd.\\
Centertown, Middlesex\\United Kingdom}
\opening{Dear George,}
Thank you for your inquiry about the latest version
of the \LaTeX{} installation and additional packages.
. . . . .
Do not hesitate to get in touch with me again if you
have any further questions about the installation or
running of the package.

\closing{Regards,}
\encl{1 CD-ROM with \TeX{}live contents}
\cc{H. Kopka}
\end{letter}
\end{document}
```

The first page of our institute letter appears as shown, without a page number. If the text must continue beyond one page, the next page will have the heading

MAX-PLANCK-INSTITUT FÜR AERONOMIE

To Mr George Murphy

May 10, 1998

Page 2

The recipient's name that appears in this heading is taken from the first line of the *recipient* argument in the `\begin{letter}`. This argument is split up by the \LaTeX processing so that the first line is contained in the command `\toname`, and the rest of the lines in `\toaddress`. The words 'To' and 'Page' are in the standard commands `\headtoname` and `\pagename`, and may be changed by an appropriate language adaptation option as shown in Section D.4.2.

16.3 A model letter customization

Adapting the `letter.cls` class file to the requirements of a company style should present few difficulties to an experienced \LaTeX programmer. Even a normal user may be able to make the necessary changes with the help of the example in this section.

We present here the class file `mplletter.cls` that was used to produce the sample letter on page 357. It makes heavy use of the \LaTeX programming features described in Appendix D. In order to understand it, one should be familiar with Section D.2. It will not be necessary to make any changes to the file `letter.cls` itself, since all modifications are in a separate class file that inputs the original.

The new class file is to be called `mplletter.cls`. It begins by specifying the \TeX format that it requires, and by identifying itself.

```
\NeedsTeXFormat{LaTeX2e}
\ProvidesClass{mplletter}
```

It will be necessary to execute conditionals, so we will need the `ifthen` package described in Section 8.3.5. We will want a flag to decide if the letter is to be in German or not, determined by an option. Create the flag and define the option `german` to set it.

```
\RequirePackage{ifthen}
\newboolean{@german}
\setboolean{@german}{false}
\DeclareOption{german}{\setboolean{@german}{true}}
```

All other options that are valid in the standard `letter` class will also be accepted here, so simply pass them on to that class with the default option. Then process all options before loading `letter` itself with the `a4paper` option. We only have A4 paper in our institute.

```

\DeclareOption*{\PassOptionsToClass{\CurrentOption}{letter}}
\ProcessOptions
\LoadClass[a4paper]{letter}

```

This completes the preliminaries. So far, we have read in the standard `letter` class, along with the package `ifthen`, and defined a new option that is not present in the original class. Otherwise, all options and functions are unchanged, so far.

We now define the new ‘name’ commands to contain language-sensitive text, such as ‘*Subject*’, which are not provided for in the basic class. The actual definitions will be executed by two commands `\englishnames` and `\germannames`.

```

\newcommand{\englishnames}{%
  \newcommand{\yrefname}{\textsl{Your Ref.}}
  \newcommand{\ymailname}{\textsl{Your letter from}}
  \newcommand{\myrefname}{\textsl{Our Ref.}}
  \newcommand{\subjectname}{\textsl{Subject}}
  \newcommand{\telephonenumber}{Telephone}
  \newcommand{\stationname}{Train Station}
  \newcommand{\germanname}{GERMANY}
  \newcommand{\telcode}{[49]-5556-401}
  \newcommand{\postcode}{D--37191}
}

\newcommand{\germannames}{%
  . . . . .
  \newcommand{\telcode}{(05556) 401}
  \newcommand{\postcode}{37191}
}

\ifthenelse{\boolean{@german}}
  {\RequirePackage{german}\germannames}{\englishnames}

```

The last lines test whether the flag `@german` has been set (by the option `german`), and if so, the package `german` is loaded, and the German names are defined, otherwise the English names. The package `german` already translates the standard names commands `\toname`, `\headtoname`, and `\pagename`, so they are not included in `\germannames`.

Having settled the language problem, we now attack those commands for entering extra information in the header. Each of these stores its text argument in an internal command for future use. First the internal storage commands must be created.

```

\newcommand{\@yref}{}      \newcommand{\@ymail}{}
\newcommand{\@myref}{}    \newcommand{\@subject}{}
\newcommand{\@internet}{}

\newcommand{\yref}[1]{\renewcommand{\@yref}{\yrefname: #1}}

```

```

\newcommand{\ymail}[1]{\renewcommand{\@ymail}{\ymailname: #1}}
\newcommand{\myref}[1]{\renewcommand{\@myref}{\myrefname: #1}}
\newcommand{\subject}[1]{\renewcommand{\@subject}
                        {\subjectname: #1}}
\newcommand{\internet}[1]{\renewcommand{\@internet}{#1}}
\newcommand{\INTERNET}{@linmpi.mpg.de}

```

Set the dimensions of the text on the page and its margins. These numbers are appropriate for A4 paper (which does make the a4paper option superfluous).

```

\setlength{\textheight}{215mm} \setlength{\textwidth}{160mm}
\setlength{\oddsidemargin}{0pt} \setlength{\evensidemargin}{0pt}
\setlength{\topmargin}{-20pt} \setlength{\headheight}{12pt}
\setlength{\headsep}{35pt}

```

The next step is to define some fixed fonts that are needed for the letterhead. We refer to the fonts with their explicit NFSS attributes; in this case they are all Computer Modern sans serif fonts in various sizes. These fonts will not change if totally different families are used for the body of the letter.

```

\DeclareFixedFont{\xviisf}{OT1}{cmss}{m}{n}{17}
\DeclareFixedFont{\xsf}{OT1}{cmss}{m}{n}{10}
\DeclareFixedFont{\viiisf}{OT1}{cmss}{m}{n}{8}

```

The letterhead itself is divided into two fields, the left one containing the institute name in large letters, the right one the address in a smaller font. Below the first horizontal line, the left field displays the name and address of the recipient, positioned to fit in the window of an envelope, and the right one has the personal data of the letter writer, name, extension, computer address. The widths of these fields are established.

```

\newlength{\leftfield} \setlength{\leftfield}{117mm}
\newlength{\rightfield} \setlength{\rightfield}{43mm}

```

The total width of these two fields equals 160 mm, which is the same as `\textwidth`.

Next, we place the institute name and address in several saved boxes.

```

\newsavebox{\FIRM} \newsavebox{\firmaddress}
\newsavebox{\firm} \newsavebox{\firmreturn}

\abox{\FIRM}
  {\parbox[t]{\leftfield}
   {\xviisf MAX--PLANCK--INSTITUT F"UR AERONOMIE}}

\abox{\firm}
  {\xsf MAX--PLANCK--INSTITUT F"UR AERONOMIE}

\abox{\firmreturn}

```

```
{\viiisf\underline{MPI f"ur Aeronomie,
\postcode{ } Katlenburg--Lindau}}
```

```
\sbox{\firmaddress}
{\parbox[t]{\rightfield}{\viiisf\baselineskip10pt
Max--Planck--Stra{\ss}e 2\
\postcode{ } Katlenburg--Lindau\\\germanname}}
```

Using these boxes as building blocks, we put together the actual head and foot of the letterhead page in two further save boxes.

```
\newsavebox{\firmhead} \newsavebox{\firmfoot}
```

```
\sbox{\firmhead}
{\parbox{\textwidth}{\usebox{\FIRM}\raisebox{6pt}
{\usebox{\firmaddress}}\rule{\textwidth}{1pt}}}
```

```
\sbox{\firmfoot}
{\parbox{\textwidth}{\rule{\textwidth}{0.6pt}}\rule{\textwidth}{5pt}
\viiisf\setlength{\baselineskip}{12pt}%
\begin{tabular}[t]{@{}l}
\underline{\telephonenumber} & \telcode-1\
\underline{Telefax} & \telcode-240\
\underline{Telex} & 9\,65\,527 aerli
\end{tabular}\hfill
\begin{tabular}[t]{l}
\underline{Bank}\
Kreis--Sparkasse Northeim\
41\,104\,449 (BLZ 262\,500\,01)
\end{tabular}\hfill
\begin{tabular}[t]{l@{}}
\underline{\stationname}\
Northeim\
(Han.)
\end{tabular} }}
```

The box `\firmhead` is fairly clear: it is a `\parbox` of width `\textwidth` containing the boxes `\FIRM` and `\firmaddress` side by side, with a line below. The foot `\firmfoot` is also a `\parbox` of the same width, but containing three columns of general institute information, set in `tabular` environments.

It now remains to have the head and foot boxes placed on the first page. In the `letter` class, there is a special page style named `firstpage` that is always invoked for the first page of a letter. This must be redefined.

```
\renewcommand{\ps@firstpage}
{\setlength{\headheight}{41pt}\setlength{\headsep}{25pt}%
\renewcommand{@oddhead}{\usebox{\firmhead}}%
\renewcommand{@oddfoot}{\raisebox{-20pt}[0pt]
{\usebox{\firmfoot}}}%}
```

```
\renewcommand{\@evenhead}{}\renewcommand{\@evenfoot}{}}
```

This page style must (re)define the commands `\@oddhead` and `\@oddfoot`, which are always inserted at the top and bottom of odd pages, to place our special `\firmhead` and `\firmfoot`. The even pages are unimportant, since the first page is always odd. It is necessary to enlarge `\headheight` and `\headsep` to allow the big boxes to fit in.

Subsequent pages are set with the `headings` or `plain` page styles. We want to modify the former to include the firm address once more.

```
\renewcommand{\ps@headings}
{\setlength{\headheight}{41pt}%
 \renewcommand{\@oddhead}
 {\parbox{\textwidth}{\usebox{\firm}}\@[5pt]
 \slshape \headtoname{} \toname\hfill\@date\hfill
 \pagename{} \thepage\@
 \rule[3pt]{\textwidth}{1pt}}}}
\renewcommand{\@oddfoot}{}
\renewcommand{\@evenhead}{\@oddhead}
\renewcommand{\@evenfoot}{\@oddfoot}}
```

One small problem remains: the first time one of these page style commands is executed, the head and foot commands may not yet exist, causing `\renewcommand` to complain. We ensure that they are there at the start by predefining them with `\providecommand` (Section 8.3.1).

```
\providecommand{\@evenhead}{}\providecommand{\@oddhead}{}
\providecommand{\@evenfoot}{}\providecommand{\@oddfoot}{}}
```

Now make `headings` the active page style.

```
\pagestyle{headings}
```

There is only one last thing to do, and that is to redefine the opening command that prints the recipient's address and the salutation. We add a bit more, including the personal data of the sender, as well as the reference information. The address goes in the left field, the personal data to the right. The references go in a line below the rule, followed by the subject line. These entries are tested first, and are only included if they are not blank. Several stored entry commands used here are part of the standard `letter` class, such as `\toname` and `\toaddress`. The `\@date` entry is either `\today` or whatever text was stored with `\date`.

```
\renewcommand{\opening}[1]{\thispagestyle{firstpage}%
 \parbox[t]{\leftfield}
 {\usebox{\firmreturn}}\@
 \parbox[b][3.5cm][c]{\leftfield}{\toname\\\toaddress}}%
 \parbox[t]{\rightfield}
 {\fromname
 \ifthenelse{\equal{\telephonenumber}{} }
 {}{\@ Tel.: \telcode-\telephonenumber}}
```

```

        \ifthenelse{\equal{\@internet}{}}
        {}{\{\viiiisf Email: \@internet\INTERNET\}}
        \\[5mm] \@date}
\par
\rule{\textwidth}{0.6pt}
\makebox[\leftfield][l]
    {\ifthenelse{\equal{\@yref}{}}
    {\@ymail}{\@yref\hfill\@ymail\hfill}}
\@myref\par
\ifthenelse{\equal{\@subject}{}}
    {}{\@subject\par}
\vspace{2\parskip} #1 \par\nobreak}

```

The result of this formatting can be seen on page 357. It should be possible to modify the coding as needed for other organizations without too much difficulty.

The field for the recipient's name and address has been positioned so that it will appear in the address window of an envelope when properly folded. The smaller return address will also be visible through this window. The printing of extra address stickers is thus superfluous.

As an exercise, the user should design a document class `pletter` for writing personal letters. With the tips for formatting company letters, it should not be difficult to add a letterhead of the form

Sheila Joan McDonald

Tel.: 234-9871
31 Maple Drive
Willowtown

Hint: The name has been printed with the font `cmdunh10 scaled \magstep4`, declared with `\newfont`. Such a `pletter` class must remain in the personal directories of the user at a computer center. It would be rather embarrassing if everyone made use of the same personal letterhead.

Appendices

A

The New Font Selection Scheme (NFSS)

When $\text{T}_{\text{E}}\text{X}$ and $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ were invented, the fonts available for them were very limited in number. For this reason, the original $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ had an inflexible system of defining the fonts that were to be used, since it was not obvious that one might want to change them. The association between the high-level font commands such as `\large` and `\bf` and the external font name that is ultimately selected was rigidly fixed internally.

Today there are many additional fonts available, some of which should be used alongside the standard CM fonts, and others that should replace them altogether. For example, the Cyrillic fonts of Section 12.4.2 should be added parallel to the Latin fonts, but to make them operate automatically under the $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ size commands was a complex procedure. (We know: we have done it!) Similarly, installing PostScript fonts involved calling intricate interface macros.

Another problem was the behavior of the font style and size commands. As explained in Section F.2.1, each of the font declarations `\rm`, `\bf`, `\sc`, `\sl`, `\it`, `\sf`, and `\tt` activates a particular font in the current size, overriding the previous declaration. One can select either a bold or an italic font, but there is no way to select a bold, italic one. Furthermore, selecting a new size automatically switches to `\rm`, an upright, Roman, medium font. That is, the attributes cannot be selected independently of each other.

In 1989 Frank Mittelbach and Rainer Schöpf proposed a New Font Selection Scheme (NFSS) for $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ and a preliminary test package was ready in early 1990. A second release (NFSS2) was published mid-1993 with many substantial changes. With the official release of $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}2_{\epsilon}$ in June 1994, NFSS became firmly entrenched in the new standard. The new font declarations and commands are described in Sections 4.1.3 and 4.1.4. Here we explain the usage in more detail; in Section A.3 we describe how new sets of fonts may be installed.

A.1 Font attributes under NFSS

According to the NFSS scheme, every character set can be classified by five attributes called *encoding*, *family*, *series*, *shape*, and *size*, which may be selected with the commands

```
\fontencoding{encode} \fontfamily{fam} \fontseries{wt_wth}
\fontshape{form} and \fontsize{sz}{line_sp}
```

The *encode* attribute was new to the second release of NFSS. It specifies the layout of the characters within the font. Possible values for it are listed in Table A.1. It is unlikely that one would want to change encoding within a document, except to activate Cyrillic fonts perhaps. This feature is more for L^AT_EX programmers to install new fonts on the system.

Table A.1: The NFSS encoding schemes

<i>Encoding</i>	<i>Description</i>	<i>Sample Font</i>	<i>Page</i>
OT1	Original text fonts from Knuth	cmr10	492
OT2	Univ. Washington Cyrillic fonts	wncyr10	497
T1	The Cork (DC/EC) fonts	ecrm1000	500
OML	T _E X math letter fonts	cmmi10	495
OMS	T _E X math symbol fonts	cmsy10	495
OMX	T _E X math extended fonts	cmex10	496
U	Unknown coding	—	—

The argument *fam* in `\fontfamily` denotes a basic set of font properties. For the Computer Modern fonts, listed in Section G.2.2, all the serif fonts belong to the family `cmr`. The family `cms` includes all the sans serif fonts while `cmtt` contains the typewriter fonts. A number of special decorative fonts are the only members of their families. Table A.3 on page 370 lists the CM fonts according to the family and other attributes.

Note: The font attribute *family* has no relationship to the primitive T_EX concept of the same name. A T_EX family consists of three fonts of different sizes for use in math formulas as normal characters, and first- and second-level indices.

The argument *wt_wth* in `\fontseries` designates the *weight* (=boldness) and *width* of the characters. These are specified by 1 to 4 letters as shown in Table A.2 on the opposite page.

The argument for `\fontseries{wt_wth}` consists of the letter or letters for the weight, followed by those for the width. Thus `ebsc` indicates weight *extrabold* and width *semicondensed* while `bx` means weight *bold* and width *expanded*. The letter `m` is omitted when combined with any non-normal weight or width; if both are to be normal, it is sufficient to give `m` alone.

Table A.2: The NFSS *series* attributes

Weight class		Width class		
Ultralight	ul	Ultracondensed	50%	uc
Extralight	el	Extracondensed	62.5%	ec
Light	l	Condensed	75%	c
Semilight	sl	Semicondensed	87.5%	sc
Medium (normal)	m	Medium	100%	m
Semibold	sb	Semiexpanded	112.5%	sx
Bold	b	Expanded	125%	x
Extrabold	eb	Extraexpanded	150%	ex
Ultrabold	ub	Ultraexpanded	200%	ux

In `\fontshape`, the argument *form* is one of the letter combinations *n*, *it*, *sl*, or *sc* for selecting normal (or upright), italic, slanted, or small caps.

The `\fontsize` attribute command takes two arguments, the first *sz* being the point size of the font (without the dimension *pt* explicitly given) and the second *line_{sp}* being the vertical spacing from one baseline to the next. The second argument becomes the new value of `\baselineskip` (Section 3.2.4). For example, `\fontsize{12}{15}` selects a font size of 12 pt with interline spacing of 15 pt. (The second argument may be given a dimension, such as 15pt, but *pt* is assumed if no dimension is stated.)

Once all five attributes have been set, the font itself is selected with the command `\selectfont`. The new feature here is that the various attributes are independent of one another. Changing one of them does not alter the others. For example, if the selection

```
\fontfamily{cmr} \fontseries{bx} \fontshape{n} \fontsize{12}{15}
```

has been made for an upright, bold, expanded, Roman font of size 12 pt and interline spacing 15 pt, then when `\fontfamily{cms}` is later selected for a sans serif font, the attributes weight and width *bx*, form *n*, and size 12(15pt) remain in effect when the next `\selectfont` is issued.

Alternatively, all attributes but the size may be specified and the font activated immediately with the command

```
\usefont{code}{family}{series}{shape}
```

The table on the next page (by F. Mittelbach and R. Schöpf) lists the classification of the Computer Modern character sets according to the attributes `\fontfamily`, `\fontseries`, and `\fontshape`. That there are so many attribute combinations without a corresponding CM font may appear to be a weakness in the NFSS system, but it must be recalled that it is designed for the future. It may also be employed with the PostScript

Table A.3: Attributes of the Computer Modern fonts

Series	Shape(s)	Examples of external names
<i>Computer Modern Roman</i> — (<code>\fontfamily{cmr}</code>)		
m	n, it, sl, sc, u	cmr10, cmti10, cmsl10, cmcsc10, cmu10
bx	n, it, sl	cmbx10, cmbxti10, cmbxsl10
b	n	cmb10
<i>Computer Modern Sans Serif</i> — (<code>\fontfamily{cmss}</code>)		
m	n, sl	cmss10, cmssi10
bx	n	cmssbx10
sbc	n	cmssdc10
<i>Computer Modern Typewriter</i> — (<code>\fontfamily{cmtt}</code>)		
m	n, it, sl, sc	cmtt10, cmitt10, cmsl10, cmtcsc10

fonts, which are becoming ever more popular, to exploit their complete variability.

Formally it is possible to set any combination of attributes; however, there may not exist any font matching all the attributes selected. If that is the case, then when `\selectfont` is called, \LaTeX issues a warning stating which font has been activated in its place. The font size attribute of the `\fontsize` command may normally take on values of 5, 6, 7, 8, 9, 10, 10.95, 12, 14.4, 17.28, 20.74, and 24.88, but other values may also be added. The second argument, the interline spacing, may take on any value since it is not something intrinsic to the font itself.

With the `\begin{document}` command, \LaTeX sets the five attributes to certain preset default values. These are normally standard encoding OT1, family `cmr`, medium series `m`, normal shape `n`, and the base size selected. The user may change these initial values within the preamble, or they might be set differently by a special option, say when a PostScript font has been selected.

A.2 Simplified font selection

The attribute commands `\fontencoding`, `\fontfamily`, `\fontseries`, `\fontshape`, and `\fontsize`, together with the command `\selectfont`, are the basic tools in the New Font Selection Scheme. The user need not

employ these commands directly, but rather may make use of the higher-level declarations presented in Sections 4.1.2 and 4.1.3. In fact, a font declaration like `\itshape` is defined as `\fontshape{it}\selectfont`.

The high-level commands to select font sizes are:

<code>\tiny</code>	(5pt)	<code>\normalsize</code>	(10pt)	<code>\LARGE</code>	(17.28pt)
<code>\scriptsize</code>	(7pt)	<code>\large</code>	(12pt)	<code>\huge</code>	(20.74pt)
<code>\footnotesize</code>	(8pt)	<code>\Large</code>	(14.4pt)	<code>\Huge</code>	(24.88pt)
<code>\small</code>	(9pt)				

The sizes listed for the commands are those when 10pt (the default) has been selected as the basic size option in the `\documentclass` command; for 11pt and 12pt, they will all scale accordingly.

The family declarations and their standard family attribute values are:

`\rmfamily` (cmr) `\sffamily` (cmss) `\ttfamily` (cmtt)

which are the three Computer Modern families, Roman, Sans Serif, and Typewriter (Section G.2.2).

The series declarations and their initial attribute values are:

`\mdseries` (m) `\bfseries` (bx)

meaning that only a medium and a bold extended series are provided as standard.

Finally, the shape declarations and their attribute values are:

`\upshape` (n) `\itshape` (it)
`\slshape` (sl) `\scshape` (sc)

to select upright, *slanted*, *italic*, and SMALL CAPS.

Note that there are no high-level declarations for the encoding attributes. This is because there is normally no need to change encoding within a document. An exception might be to use Cyrillic fonts (coding OT2), in which case one could define

```
\newcommand{\cyr}{\fontencoding{OT2}\selectfont}
\newcommand{\lat}{\fontencoding{OT1}\selectfont}
```

to be able to switch back and forth more conveniently.

The family, shape, and series attributes may be reset to their standard values at any time with the `\normalfont` command, which also activates that font in the current size.

For each of the above font attribute declarations there is also a corresponding font command (Section 4.1.4) that sets its argument in that font. Thus `\textit{text}` is almost the same as `{\itshape text}`, the only difference being that the command also contains the *italic correction* automatically. The complete list of such commands is:

Family:	<code>\textrm</code>	<code>\textsf</code>	<code>\texttt</code>	
Series:	<code>\textmd</code>	<code>\textbf</code>		
Shape:	<code>\textup</code>	<code>\textit</code>	<code>\textsl</code>	<code>\textsc</code>
Other:	<code>\emph</code>	<code>\textnormal</code>		

The `\emph` command is described in Section 4.1.1; `\textnormal` sets its argument in `\normalfont`.

A.3 Installing fonts with NFSS

In this section, we wish to elaborate on the internal workings of NFSS, showing how a set of attributes are associated with a particular font and how special symbols are assigned to their proper positions within various encoding schemes.

A.3.1 Default attribute values

We implied in Section A.2 that the font attribute declarations like `\itshape` are defined as `\fontshape{it}\selectfont`, whereas in fact they make use of certain default attributes. Thus the true definition of `\itshape` is

```
\fontshape{\itdefault}\selectfont
```

The default commands available are

Family:	<code>\rmdefault</code>	<code>\sfdefault</code>	<code>\ttdefault</code>
Series:	<code>\mddefault</code>	<code>\bfdefault</code>	
Shape:	<code>\updefault</code>	<code>\itdefault</code>	<code>\sldefault</code> <code>\scdefault</code>

It is `\itdefault` that is defined to be the attribute `it`.

It is also necessary to define the standard attributes chosen when the command `\normalfont` is issued. These are contained in the four defaults

```
\encodingdefault \familydefault \seriesdefault
\shapedefault
```

All this may sound like a complicated route linking the high-level commands to a particular font. However, it does provide flexibility and modularity. The author only needs to know that three families, two series, and four shapes are available, and does not care what they really are. A programmer defines these with the defaults at a lower level.

An example of how all the standard fonts may be replaced by PostScript ones, by simply redefining the three family defaults, is shown on page 379. Such redefinitions are much simpler than trying to alter the font declarations themselves, including `\normalfont`. Those definitions are in fact much more complex than implied here, whereas the default commands really are as simple as indicated.

A.3.2 Defining font commands



There are a number of commands available for defining new font declarations and commands. These are intended mainly for \LaTeX package programmers but may be used in a normal document as well.

```
\DeclareFixedFont{\cmd}{code}{family}{series}{shape}{size}
```

defines \cmd to be a declaration that selects the font of the specified attributes. It is rigidly fixed in all attributes. This is equivalent to \newfont except that the font is determined by attributes and not by name.

```
\DeclareTextFontCommand{\cmd}{font_specs}
```

defines \cmd to be a font *command* that sets its argument according to *font_specs*. This command is used internally to define all the font commands like $\textbf}$, which is defined with *font_specs* as \bfseries .

```
\DeclareOldFontCommand{\cmd}{text_specs}{math_specs}
```

defines \cmd to be a font *declaration* that may be used in math mode in the manner of \LaTeX 2.09: as a declaration, not a command. It is useful for defining commands to be compatible with the old version, but should be avoided. For example, \it is defined with

```
\DeclareOldFontCommand{\it}{\normalfont\itshape}{\mathit}
```

A.3.3 Mathematical alphabets

The font that has been activated for text processing does *not* influence the characters and their fonts in math mode, since special mathematical symbol fonts are used for this purpose. If a formula is to appear in bold face, the command \boldmath (Section 5.4.9) must be issued, which remains in effect until it is countermanded by \unboldmath . Both of these declarations must be made outside of math mode.

These commands may still be employed in the same way under NFSS. However, the internal math font selection command is

```
\mathversion{vers_name}
```

in which the argument *vers_name* currently takes on values `normal` and `bold`. The declarations \unboldmath and \boldmath are defined in terms of this command. It is planned that special package files will become available to allow additional sets of math symbols.

On the other hand, mathematical alphabet commands may be issued within math mode itself, to set letters as symbols in particular fonts (Section 5.4.2):

```
\mathrm \mathcal \mathnormal \mathbf \mathsf \mathit \mathtt
```

These are all *commands* operating on arguments rather than *declarations*, unlike the \LaTeX 2.09 equivalents.

New math font alphabets may be defined by the user. For example, to define a slanted math font \mathsl , give

```
\DeclareMathAlphabet{\maths1}{OT1}{cmr}{m}{s1}
```

which means that the new math font command `\maths1` selects that font in family `cmr` with weight `m` and shape `s1`, which, with the normal font definitions, is font `cms1` in the appropriate size. However, this font will be selected in *all* math versions, whereas it would be more suitable if a bold font were selected when `\mathversion{bold}` is in effect. This is accomplished by adding to the definition of `\maths1`

```
\SetMathAlphabet{\maths1}{bold}{OT1}{cmr}{bx}{s1}
```

which redefines `\maths1` exceptionally for math version `bold` to be a font with weight `bx`. For the normal font definitions, this is `cmbxs1` in the current size.

New math versions can be created with

```
\DeclareMathVersion{vers_name}
```

and the fonts belonging to it are determined by issuing `\Set...` commands for each math alphabet or symbol font.

A.3.4 Mathematical symbol fonts



Mathematical symbols must be defined in a totally different manner from text characters: they bear a command name (like `\alpha`), may come from various fonts, behave differently depending on type, and can appear in different sizes. Under \LaTeX 2.09, the symbol names were fixed to the Computer Modern math fonts, but NFSS offers more flexibility for additional (or replacement) symbol fonts.

A symbol font name is declared with the command

```
\DeclareSymbolFont{sym_fnt_name}{code}{family}{series}{shape}
```

which associates the name `sym_fnt_name` with the given set of attributes. This name is not a command, but rather an internal designation for use in defining symbols. The selected font is valid for all versions, but if a different font is to be associated with the same name under other versions,

```
\SetSymbolFont{sym_fnt_name}{version}{code}{family}{series}{shape}
```

may be used to redefine `sym_fnt_name` for that one version.

The standard \LaTeX setup declares

```
\DeclareSymbolFont{operators}{OT1}{cmr}{m}{n}
\DeclareSymbolFont{letters}{OML}{cmm}{m}{it}
\DeclareSymbolFont{symbols}{OMS}{cmsy}{m}{n}
\DeclareSymbolFont{largesymbols}{OMX}{cmex}{m}{n}
```

the sequence of which is important for reasons that are built deeply into \TeX itself.

Once the symbol font names have been defined, they may be used to construct math alphabets and various types of symbols.

```
\DeclareSymbolFontAlphabet{\math_alph}{sym_fnt_name}
```

defines \math_alph to be a math alphabet based on the font with the internal name sym_fnt_name . This command is to be preferred over \DeclareMathAlphabet if a symbol font exists with the proper attributes for the math alphabet.

The primary command for defining symbols is

```
\DeclareMathSymbol{\symbol}{type}{sym_fnt_name}{pos}
```

which makes \symbol print the symbol in position pos of font sym_fnt_name . The pos is a number, in decimal (10), octal ('12) or hexadecimal ("0A) representation. The $type$ specifies the functionality of the symbol and is one of

\mathord	an ordinary symbol
\mathop	a large operator like Σ
\mathbin	a binary operator like \times
\mathrel	a relational operator like \geq
\mathopen	an opening bracket like $\{$
\mathclose	a closing bracket like $\}$
\mathpunct	punctuation
\mathalpha	an alphabetic character

Math alphabet commands operate only on the symbols of type \mathalpha ; other types always produce the same symbol, for a given math version, within all math alphabets.

Similarly, math accent commands are established with

```
\DeclareMathAccent{\cmd}{type}{sym_fnt_name}{pos}
```

where $type$ is either \mathord or \mathalpha ; in the latter case, the symbol changes with the math alphabet.

Math delimiters and radicals can appear in two different sizes. They are set up with

```
\DeclareMathDelimiter{\cmd}{type}{sym_fnt1}{pos1}{sym_fnt2}{pos2}
\DeclareMathRadical {\cmd}      {sym_fnt1}{pos1}{sym_fnt2}{pos2}
```

which define \cmd to print the smaller variant from position $pos1$ of font sym_fnt1 and the larger from position $pos2$ of sym_fnt2 .

The sizes have not been specified in any of the above math declarations. This is because there are normally four different sizes available, depending on the math style, as explained in Section 5.5.2. However, these sizes must somehow be specified. This is done with

```
\DeclareMathSizes{text}{math_text}{script}{sscript}
```

where the four arguments are numbers giving a point size. When the normal text font is size $text$ pt, \textstyle will be in $math_text$ size, \scriptstyle in $script$, and \scriptscriptstyle in $sscript$ size. For example,

```
\DeclareMathSizes{10}{10}{7}{5}
```

All the $\Declare\dots$ and $\Set\dots$ commands may only be called in the preamble.

A.3.5 Addressing the attribute values



In some programming situations, it is necessary to make use of the current values of the attributes without knowing what they are. These are stored in the internal commands

```
\f@encoding \f@shape \tf@size
\f@family \f@size \sf@size
\f@series \f@baselineskip \ssf@size
```

The values of these commands should never be changed directly. However, they may be used to test if they possess a certain value. Since they all contain the character @ in their names, they may only be used in class or package files, and not in the main document file.

A.3.6 Defining fonts under NFSS

Under NFSS, fonts are specified within a document by giving the attributes required and then calling `\selectfont`. How is the set of font attributes then associated with a particular external font name such as those found in Appendix G? This is done by means of *font definition commands* which are usually stored in files with extensions `.def` and `.fd`.

First the declaration

```
\DeclareFontEncoding{code}{text_set}{math_set}
```

sets up a new encoding attribute named *code*; whenever a text font of this encoding is selected, *text_set* is executed in order to redefine accent commands or other things that are coding dependent; similarly *math_set* is called for every math alphabet of this encoding. It is possible to define default *text_set* and *math_set* with

```
\DeclareFontEncodingDefaults{text_set}{math_set}
```

This allows general text and math mode settings to be declared with this command, while more specialized ones, which are executed afterwards, appear in `\DeclareFontEncoding`.

If no font can be found for the specified attributes,

```
\DeclareFontSubstitution{code}{family}{series}{shape}
```

declares the values of the attributes that should be substituted; substitutions are made in order of *shape*, *series*, then *family*; the encoding is never substituted. If even this fails to find a valid font, then

```
\DeclareErrorFont{code}{family}{series}{shape}{size}
```

determines which font is to be used as a last resort.

A new family with a specified encoding scheme is established with

```
\DeclareFontFamily{code}{family}{option}
```

where *option* is a set of commands that may be executed every time a font of this family and encoding is selected.

The main font-defining declaration that associates external font names with font attributes is

```
\DeclareFontShape{code}{family}{series}{shape}
      {font_def}{option}
```

where *option* is additional commands that are executed when one of these fonts is selected.

The *font_def* contains a series of size/font associations, each consisting of a size part, a function, an optional argument, and a font argument. For example,

```
\DeclareFontShape{OT1}{cmr}{m}{n}
  { <5> <6> <7> <8> <9> <10> <12> gen * cmr
    <10.95> cmr10
    <14.4> cmr12
    <17.28> <20.74> <24.88> cmr17}{}
```

states that the medium series, normal shape members of the *cmr* family are to be represented by external fonts *cmr5* . . . *cmr12* for sizes 5–12 pt, by *cmr10* scaled to 10.95 pt for sizes near 11 pt, and so on. If the specified size is not present, the nearest size within certain limits is taken instead.

The size part consists of numbers in angle brackets, representing point sizes. The brackets may also contain ranges, as *<-10>* means all sizes up to, but excluding, 10 pt, *<10-14>* means 10 pt to less than 14 pt, and *<24->* indicates 24 pt and higher. The possible functions are:

(empty) loads the named font scaled to the requested point size; if an optional argument in square brackets precedes the font name, it acts as an additional scaling factor;

```
<11> [.95] cmr10    would load cmr10 scaled to 95% of 11 pt;
```

gen * generates the font name by appending the point size to the font argument;

```
<12> gen * cmr    loads cmr12;
```

genb * generates the font name by appending the point size times 100 to the font argument (for DC and EC fonts, page 501);

```
<14.4> genb * ecss    loads ecss1440;
```

sub * substitutes a different font whose attributes are given in the font argument as *fam/ser/shp*;

```
<-> sub * cmtt/m/n    this is best used when there is no font
of the required attributes; a message is output to the monitor and
to the transcript file;
```

subf * is like the empty function, but issues a warning that an explicit substitute font has been loaded;

fixed * loads the specified font at its normal size, ignoring the size part; if an optional argument is given, it is the point size to which the font is scaled, as in

```
<10> fixed * [11] cmr12    which loads cmr12 at 11 pt when
10 pt is requested.
```

All the above functions may be preceded by an *s* to suppress messages to the monitor. Thus silent *sub* * is *ssub* *, and silent empty is *s* *.

As another example, consider the definition of bold, italic, typewriter, for which there is no font in the Computer Modern collection:

```
\DeclareFontShape{OT1}{cmtt}{bx}{it}{
  <-> ssub * cmtt/m/it }{}
```

This substitutes (silently) for all sizes (<->) the medium italic typewriter attributes. Which fonts those are is determined by a `\DeclareFontShape` command with those attributes.

The font definition commands may be issued in a package file, or even in the document itself. However, the normal procedure is to store each of the `\DeclareFontEncoding` commands in a file named *codeenc.def* (for example, *ot1enc.def* for the OT1 encoding), and to place the commands `\DeclareFontFamily` and `\DeclareFontShape` in a file whose name consists of the encoding and family designations plus the extension *.fd*. For example, the shape specifications for encoding OT1 and family *cmr* are to be found in *ot1cmr.fd*. When a coding and family combination that is not already defined is selected, \LaTeX tries to find the appropriate *.fd* file for input. It is therefore not necessary to input such files explicitly, for they are loaded automatically as required.

Package: fontenc However, it is important that the encoding be declared beforehand. If it is not already known in the current format, `\DeclareFontEncoding` must be issued, either explicitly, or by loading the *codeenc.def* file. One way to do this is to invoke the standard package *fontenc*, as for example

```
\usepackage[OT2,T1]{fontenc}
```

where the desired codings are listed as options in square brackets, the last of which is made current.

The normal user will never need to worry about such problems. However, \LaTeX programmers will find things considerably easier for them. For example, to install PostScript fonts under NFSS is almost trivial. The common PostScript fonts are already defined as separate families in *.fd* files of their own; for example, *ot1ptm.fd* associates PostScript Times fonts to a family named *ptm*. A package to activate these fonts is supplied under the name *times.sty* containing essentially the lines

```

\renewcommand{\rmdefault}{ptm}
\renewcommand{\sfdefault}{phv}
\renewcommand{\ttdefault}{pcr}
\renewcommand{\bfdefault}{b}

```

This makes Times ptm the default Roman family, invoked with the command `\rmfamily`, Helvetica phv the default sans serif family (called by `\sffamily`), and Courier pcr the default typewriter family (activated by `\ttfamily`). The default attribute for bold face is defined to be `b` instead of the regular `bx`, since bold extended is not provided by these fonts.

Another two examples of the usefulness of NFSS are the Cyrillic fonts of the University of Washington (Section 12.4.2) and the extended EC fonts with the Cork encoding (Section G.4.3). Both of these may be activated within a document simply by selecting another encoding, OT2 for Cyrillic, T1 for the EC fonts. (These encodings must first be declared, for example with the `fontenc` package as illustrated on the facing page.)

A.3.7 Encoding commands



In \LaTeX , special characters and accents are addressed by means of commands, such as `\O` to print the Scandinavian letter Ø. The position of this character in the font tables depends on the encoding (character 31 in OT1 and 216 in T1), so that it is necessary to redefine all such symbol commands when the encoding is altered. This is carried out with the help of certain *encoding commands*, which normally appear in the `codeenc.def` file along with the `\DeclareFontEncoding` command.

To define a command that functions differently in the various encodings,

```

\ProvideTextCommand{\cmd}{code}[narg][opt]{def}
\DeclareTextCommand{\cmd}{code}[narg][opt]{def}

```

are available and behave just like `\providetextcommand` and `\newcommand` except `\cmd` has the definition `def` only when the encoding `code` is active. Thus `\cmd` may have different definitions for each encoding.

```

\DeclareTextSymbol{\cmd}{code}{pos}

```

defines `\cmd` to print the character in the font position `pos` when encoding `code` is active.

```

\DeclareTextAccent{\cmd}{code}{pos}

```

defines `\cmd` to be an accent command, using the character in font position `pos` as the accent symbol, when encoding `code` is active.

```

\DeclareTextComposite{\cmd}{code}{letter}{pos}
\DeclareTextCompositeCommand{\cmd}{code}{letter}{def}

```

define the action of command `\cmd` followed by the single `letter` either to print the character in font position `pos` or to execute the definition `def`. These declarations are most useful with the T1 encoding, where many accented letters are separate

symbols on their own (Section G.4.3). Thus `\'e` in OT1 prints an acute accent (character 19) over the letter e, while in T1, it prints the single character in position 233. This behavior is achieved with

```
\DeclareTextAccent{\'}{OT1}{19}
\DeclareTextComposite{\'}{T1}{e}{233}
```

The command must already have been defined for the encoding, either with `\DeclareTextAccent` or with `\DeclareTextCommand`; in the latter case, it must be defined to take a single argument.

All of the above definition commands create new commands for a specific encoding. If the defined commands are invoked in some other encoding, an error message is issued. Default definitions may be provided for all unspecified encodings with

```
\DeclareTextCommandDefault{\cmd}[narg][opt]{def}
\ProvideTextCommandDefault{\cmd}[narg][opt]{def}
\DeclareTextAccentDefault{\cmd}{code}
\DeclareTextSymbolDefault{\cmd}{code}
```

where the first two create a default definition that applies to all unspecified encodings, while the second two declare which encoding is to be taken as the default.

B

The L^AT_EX Clockwork

In this appendix, we describe how the T_EX program and L^AT_EX files are installed, how they are organized, what their roles are. Throughout this book we have given examples of contributed packages, but here we list those packages and other files that belong to the ‘kernel’, the essential installation. In Section B.6, we explain how L^AT_EX ticks, what happens during a processing run, and what all the various file types mean.

B.1 Installing L^AT_EX

We explain first L^AT_EX installations in general before looking at the particular one provided on the enclosed T_EXLive CD.

B.1.1 T_EX implementations

One must have the T_EX program and its auxiliaries (METAFONT, font files) before L^AT_EX can be set up on top of it. Installing T_EX is a somewhat daunting experience, but thankfully it need not be done very often and there are many ready-to-run implementations available for practically every computer operating system. These can be obtained from CTAN under the directory systems (Figure B.4 on page 390) or from the T_EX Users Group (www.tug.org).

The system delivered with the T_EXLive CD is that developed by Karl Berry known generically as *Web2c*. This name derives from the fact that it converts Donald Knuth’s original T_EX source files from his Web language (no relation to the World Wide Web) into the C programming language for subsequent compilation with a C compiler. The teT_EX implementation, by Thomas Esser, applies Web2c to Unix machines, while Fabrice Popineau’s fpT_EX is the Win32 (Windows 95, 98, NT, 2000, XP) version.

Another excellent T_EX implementation for Windows is MikT_EX by Christian Schenk, available from CTAN under `systems/win32/miktex/`.

The implementation for DOS, emT_EX by Eberhardt Mattes is still available from CTAN, but is no longer appropriate for modern PCs. We used to produce the first two editions of this book and found it superb for its time.

Commercial packages for T_EX also exist, offering graphics display of the output while you type: for Windows (Y&Y Inc., www.YandY.com/) and *Textures* for Macintosh (Blue Sky Research, www.bluesky.com/). A ‘what-you-see-is-what-you-get’ T_EX system is *Scientific Workplace*, which can be purchased from MacKichan Software Research (www.tcisoft.com/).

It should be stressed that the T_EX and pdfT_EX programs in all the above implementations are identical (for the same version number). They provide ready-to-run executable programs from the same source code, which are necessarily different for different computer types. There are also minor variations as to how the programs are run.

The L^AT_EX files are all ASCII so they are fully compatible with all systems. One uses the already installed T_EX or pdfT_EX program to generate the L^AT_EX formats (Section B.1.3). Even this task is normally done for you by the above implementations.

A graphics interface to T_EX and L^AT_EX is not absolutely essential, but today it is almost unthinkable to do without one. This is an editor program for writing and managing the L^AT_EX source files, and calling the various programs (L^AT_EX, BibT_EX, MakeIndex) and invoking viewers by clicking icons. For Unix, the emacs is normally used for this; for Windows, the two editor programs mentioned in Section 1.6.2, Winshell and WinEdt can be highly recommended.

B.1.2 The T_EXLive CD

The T_EX Users Group, TUG issues a set of CDs each year to its members containing the latest T_EX and L^AT_EX installations, with executable files for Win32, Linux, Macintosh, and all known flavors of Unix. As of the 7th issue in 2002, it was necessary to split the contents over 2 CDs, separating the Unix versions from the others. Each CD is otherwise complete, missing only the executables of the other one.

The T_EXLive CDs are maintained by Sebastian Rahtz who has kindly agreed to allow the CD for Windows, Linux, Mackintosh to be included with this book, as it stands in June 2003. It thus corresponds to something between the 7th and 8th regular issues.

The startup window in Figure B.1 appears when the CD is inserted into your computer. If the autorun function does not work, you can run the `autorun.exe` program directly from the CD.

You then proceed with the installation by clicking Install on the upper bar. You then follow the instructions on the various pages that then appear, making selections as you go. One choice is whether to install to run from the CD, or to install to the hard disk. In the former case,



Figure B.1: The T_EXLive welcome

you have the entire installation available with little lost of storage, but will need to have the CD mounted in the player whenever you run L^AT_EX. Processing time will also be slower.

If you elect to install only part of the system to hard disk, you may still add further packages and support programs later by clicking maintenance. Or you may run `texsetup --maintenance` which does the same thing bypassing the Welcome window. Running `texsetup --help` produces a list of all the options.

You may also click Documentation→View TeXLive doc to open the instruction manual for T_EXLive, with details for all systems. (Or you can go directly to `\texmf\doc\tldoc\english\` and select `live.pdf` or `live.html`.)

Documentation for most of the packages and collections are available on the CD under `\texmf\doc\...`, if the author has provided a description. We often refer to such manuals throughout this book, indicating more precisely where they are to be found. By clicking Documentation→Run TeXDocTK, you may open a documentation browser (Figure B.2) to assist finding descriptions for any module.

The T_EXLive installation program will do all the housekeeping for you,

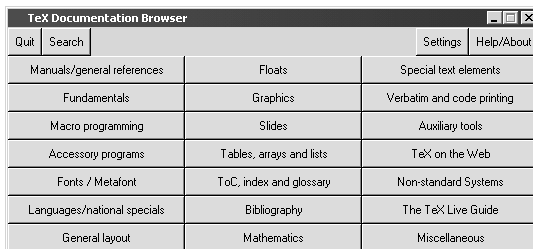


Figure B.2: The T_EXLive documentation browser

placing files in the right directories, setting up font mapping files, and generating the formats. However, there might still be times when you want or have to do some of this yourself. This we explain in the next sections.

B.1.3 Making the L^AT_EX format

Adding or updating L^AT_EX on to an existing T_EX installation by hand is relatively straight forward. One must obtain the source files, which on T_EXLive are located at `\texmf\source\latex\base\` or on CTAN at `tex-archive/macros/latex/base/`. At CTAN, instruction files with extension `.txt` are available for the various implementations, such as `miktex.txt` and `web2ctex.txt`, as well as the general instruction file `install.txt`.

These source files are a set of packed files consisting of a large number of `.dtx` files, the integrated source and documentation files. These are unpacked by running `initex` on the batch job file `unpack.ins`. This generates the necessary `.cls`, `.sty`, `.clo`, and other files. It also constructs the fundamental file `latex.ltx` which is needed to produce the format file. On CTAN, the unpacked files are already provided in a parallel directory `unpacked`.

The next step should be to run `initex` on the `latex.ltx` file to produce the L^AT_EX format `latex`. However, before doing that, there are a number of configuration aspects to be considered. At several points during the processing, certain files are read in, but if a file of the same name but extension `.cfg` exists, it is loaded instead. It is this device that permits one to configure the final format for local conditions or desires. The possible configuration files are:

`texsys.cfg` offers the possibility of adding some very machine-specific adjustments for older versions of T_EX or for some peculiarities of the T_EX installation; information is to be found in the specific `.txt` file, or in `ltdirchk.dtx`;

`fonttext.cfg` is loaded in place of `fonttext.ltx` if it is present; this defines the fonts that are to be available for processing text; details can be found in `fontdef.dtx`;

`fontmath.cfg` is loaded in place of `fontmath.ltx` if it is present; this is the equivalent of `fonttext.cfg` for math fonts;

`preload.cfg` is loaded in place of `preload.ltx` if it is present; this determines which fonts are preloaded into the format; a number of other `preload` files may be extracted from `preload.dtx`, any one of which may be renamed to `.cfg` to be implemented;

`hyphen.cfg` is loaded in place of `hyphen.ltx` if it is present; this specifies the hyphenation patterns and their assignments; by default, the patterns in `hyphen.tex` are loaded into language 0; the `babel` system provides such a configuration file (Section 11.1) which must be used if `babel` is to be incorporated into the format, in which case, `language.dat` must be tailored to local requirements.

The only configuration file that you are likely to want to change is `hyphen.cfg`, especially if you are going to be using L^AT_EX for languages other than American English.

Once any configuration files have been set up and located where T_EX can read them, `initex` may be run on `latex.ltx` with

```
initex latex.ltx    or
tex -ini latex.ltx
```

The resulting `latex.fmt` must be placed where format files are read. For fpT_EX as installed by T_EXLive, this is in `texmf-var\web2c\`. Other unpacked files must be moved to `texmf\tex\latex\base\`; these are

`latexbug.tex`, `testpage.tex`, `labl1st.tex`, `idx.tex`, `nfssfont.tex`, `small2e.tex`, `sample2e.tex`, and `docstrip.tex`,

and all files with extensions `.cls`, `.clo`, `.sty`, `.fd`, `.def`, and `.cfg`.

Files with extension `.ist` are moved to `texmf\makeindex\base\`.

To make up the L^AT_EX format with pdfT_EX, run instead

```
pdfinitex -fmt=pdflatex latex.ltx    or
pdftex -ini -fmt=pdflatex latex.ltx
```

This processes `latex.ltx` base file once more, but names the resulting format file `pdflatex.fmt` rather than `latex.fmt`. This is necessary because the format files may only be used with the program that generated them, so the two must be distinguished even though they both are essentially the same thing. Move this format too to the format file directory.

The actual commands to invoke T_EX or pdfT_EX with L^AT_EX (what we normally call ‘running L^AT_EX or pdfL^AT_EX’) are

```
tex &latex
pdftex &pdflatex
```

meaning ‘run the T_EX or pdfT_EX program with the specified format file’. The system should have shortcuts named `latex` and `pdflatex` that translate to the above.

The `web2c` system, for which `fpTEX` is the Win32 implementation, has a different method. It stores all the necessary configuration information in a file named `texmf.cnf` located in the `texmf\web2c` directory. This sets up environments according to the name of the program being run, and in particular, adds the format name automatically for a T_EX-like program. Thus a T_EX program named `latex` will use the `latex.fmt` format file if none is specified. However, there is no real program named `latex`, so on Unix systems, an alias with this name is established to point to the `tex` executable program. On Win32, the actual T_EX executable code is in a dynamic link library `tex.dll` and very small files named `tex.exe`, `latex.exe` exist to use this one library. These `.exe` files are in fact identical, and are really only there to ensure that different formats are invoked automatically when they are called. Similarly, there are `pdftex.dll`, `pdftex.exe`, and `pdflatex.exe`. If any additional formats are ever needed for these programs, one only needs to copy one of these `.exe` files to the new name.

B.1.4 Updating the database

T_EX works with a very large number of files, for classes, packages, fonts, formats, and so on. A set of environments are used to indicate where the program should search for these files. With `web2c`, these are all defined in the `texmf.cnf` configuration file mentioned above. The user normally does not have to worry about this. However, to speed up the search, a database is prepared giving the exact location of all the files in the search paths. This database will be created and updated automatically if installation programs are used, such as that for T_EXLive.

If the user should add a new package or fonts collection by hand, without going through an installation program, it will be necessary to update this database. Under `web2c` (and `fpTEX`), this is carried out with the command

```
mktexlsr
```

Under MikT_EX, one must run

```
configure --update-fndb
```

or click ‘refresh now’ in the MikT_EX options program.

It is not necessary to update the database if existing files are being replaced. It is only the names and locations of the files that go into the database, not their actual versions or sizes.

B.2 Obtaining the Adobe euro fonts

As pointed out in Section 2.5.8, the type 1 euro currency symbol fonts from Adobe Systems Inc. that are used with the `europs` and `eurosans` packages cannot be distributed on CDs like T_EXLive, nor on CTAN, since Adobe reserves the exclusive right to distribution, even though free of charge. T_EXLive and CTAN do provide all other files needed, like the font metric `.tfm` and font definition `.fd` files.

You can obtain the Adobe euro `.pfb` files from www.adobe.com/type/eurofont.html, downloading the appropriate file for your computer type. They must be unpacked (on Windows, for example, you just execute the downloaded `eurofont.exe`) and then rename them as follows:

Windows	PostScript	T _E X
<code>_1_____ .PFB</code>	EuroSans-Regular	<code>zpeurs.pfb</code>
<code>_1I_____ .PFB</code>	EuroSans-Italic	<code>zpeuris.pfb</code>
<code>_1B_____ .PFB</code>	EuroSans-Bold	<code>zpeubs.pfb</code>
<code>_1BI_____ .PFB</code>	EuroSans-BoldItalic	<code>zpeubis.pfb</code>
<code>_3_____ .PFB</code>	EuroSerif-Regular	<code>zpeur.pfb</code>
<code>_3I_____ .PFB</code>	EuroSerif-Italic	<code>zpeuri.pfb</code>
<code>_3B_____ .PFB</code>	EuroSerif-Bold	<code>zpeub.pfb</code>
<code>_3BI_____ .PFB</code>	EuroSerif-BoldItalic	<code>zpeubi.pfb</code>
<code>_2_____ .PFB</code>	EuroMono-Regular	<code>zpeurt.pfb</code>
<code>_2I_____ .PFB</code>	EuroMono-Italic	<code>zpeurit.pfb</code>
<code>_2B_____ .PFB</code>	EuroMono-Bold	<code>zpeubt.pfb</code>
<code>_2BI_____ .PFB</code>	EuroMono-BoldItalic	<code>zpeubit.pfb</code>

The first column is the name as unpacked on Windows, the second the internal PostScript name, and the third, the name used by T_EX. The `.pfb` files must be renamed to those in the third column, and placed in `texmf\fonts\type1\adobe\euro` (or better in `texmf-local`).

The font map file `zpeu.map` must also be added to the lists of font maps for `dvips`, `dvipdfm`, and `pdfTEX` (Section 10.1.3). The T_EXLive installation does all this for you; you only need to get and store the `.pfb` files.

B.3 T_EX directory structure

The T_EX system, of which L^AT_EX is only one part, albeit a large one, requires a very large number of files, for fonts, formats, classes, packages, bibliographies, and much more. Section B.6 lists the types of files and their extensions, at least for what concerns L^AT_EX. Other flavors of T_EX have their own types in addition.

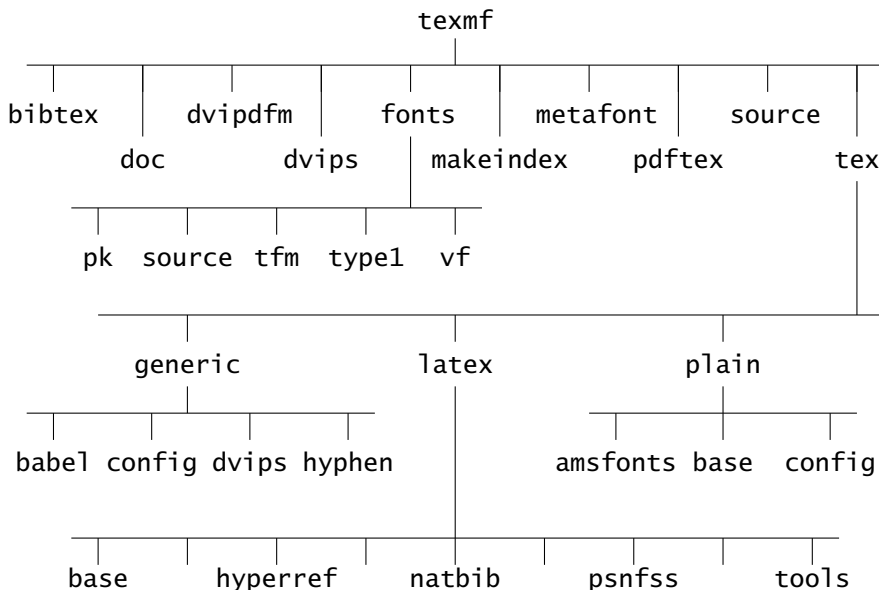


Figure B.3: The TDS directory tree

In the early days, anyone setting up a T_EX installation would try to create order of some sort by distributing the files into different directories (also called *folders*) according to their functions. However, everyone had their own ideas how to do this. Thus changing from one installation to another required a totally new road map.

The T_EX Users Group, TUG, commissioned a working group to prepare a recommended standard, which published its results in 1994. The latest version of this paper is on T_EXLive at `\texmf\doc\tds\` in various formats. The T_EX Directory Structure (TDS) described there can only be a recommendation, but it is fairly universally followed today. The T_EXLive CD certainly conforms to it.

Figure B.3 offers an overview of TDS. The top directory is named `texmf`, to demonstrate that it holds the entire T_EX and METAFONT systems. This may not be the absolute top directory on any installation. For example, if you install to a Windows hard disk, you might find it in `\program files\texlive\texmf`. Furthermore, there might be parallel directories named `texmf-var` (where the system writes files it creates, like font `.pk` files) and `texmf-local` for any private packages you install yourself. The idea is to keep the main `texmf` tree intact, to let the T_EXLive installation program manage it. These parallel trees should have the same structure, but may be incomplete.

The subdirectories under `texmf` are the main classification of the subsequent files, sorted mainly by program, such as B_IB_TE_X (Section 14.1),

`dvipdfm` (Section 10.2.2), `dvips` (Section 10.1.1), `MakeIndex` (Section 9.4.3), `METAFONT` (Section G.3), and `pdfTeX` (Section 10.2.3). Others are

`doc` containing documentation of all sorts; its subdirectories are similarly structured to those under `tex`; most of the documentation files that we have referred to in this book are to be found here;

`fonts` is subdivided according to the types of files explained in Section G.1: `pk` for the pixel files (these usually go into `texmf-var`), `tfm` for the font metric files, `vf` for virtual font files, `source` for the METAFONT `.mf` sources, `type1` for the `.pfb` or `.pfa` PostScript outline font files; the contents of each of these directories are further sorted by supplier (`adobe`, `public`, ...), and then by font family (`times`, `cm`, ...);

`source` contains the delivery files for packages and collections; for \LaTeX , these are the `.dtx` and `.ins` files, found under `latex\base`; similarly for packages, such as `latex\geometry` containing `geometry.dtx` and `geometry.ins`; these are not needed any more once installed; the subdirectories under `source` mirror those under `tex`;

`tex` is the main directory for files directly related to \TeX ; some of its subdirectories are

`generic` for files that apply to all \TeX applications, like hyphenation patterns;

`latex` for all the \LaTeX related files; this is further subdivided into directories for individual packages; only a handful are shown in the figure; `base` contains the fundamental \LaTeX files, the kernel;

`plain` for Plain \TeX , which is often just called \TeX (Section 1.3.2).

This directory structure allows a user to locate documentation, source, running files for a package, collection, program, on all installations. The documentation and source files can readily be removed, or not copied at all from the CD, since they play no role during the processing. This structure makes it easy to remove such unnecessary branches of the tree.

B.4 The CTAN server

The easiest way to obtain the \LaTeX software not available on the \TeX Live CD is via one of the network servers supported by various educational institutions. They also provide the most up-to-date standard \LaTeX installation, \TeX extensions, programs for running \TeX , collections of drivers for different printers, hyphenation patterns for other languages, etc. Such a server is a treasure trove for the dedicated \TeX and \LaTeX user.

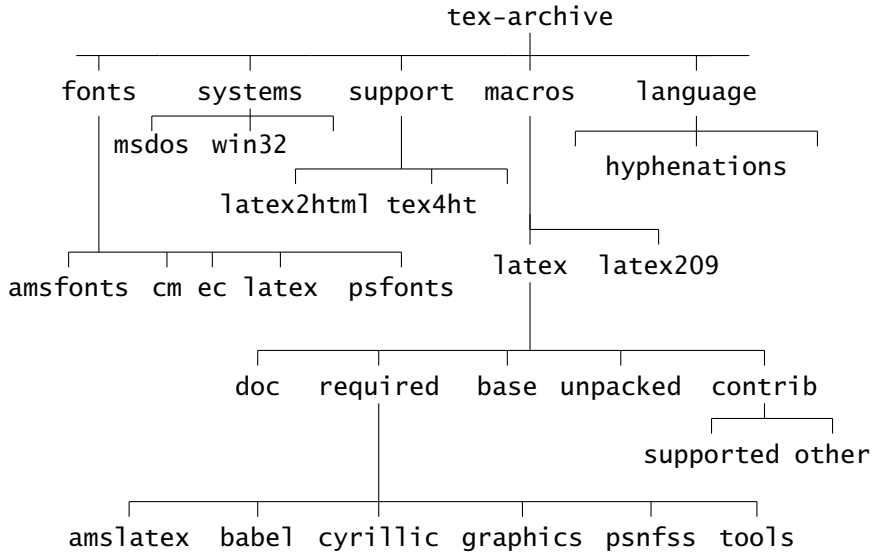


Figure B.4: Partial directory tree of CTAN servers

There are three main network servers for T_EX and L^AT_EX located in the United States, Great Britain, and Germany, forming the Comprehensive T_EX Archive Network, CTAN. They are not only kept up to date but also regularly exchange contributions among themselves. They are all reachable on the Internet.

<i>Country</i>	<i>Internet address</i>
USA	<code>ftp://ctan.tug.org/tex-archive/</code>
UK	<code>ftp://ftp.tex.ac.uk/tex-archive/</code>
Germany	<code>ftp://ftp.dante.de/tex-archive/</code>

In addition, there are many full and partial mirrors of these sites. See the TUG home page, <http://www.tug.org>, for details.

The directory structure is the same for all three servers. A sketch of the main parts of the directory tree is presented in Figure B.4.

The latest version of the L^AT_EX source files may be found under the subdirectories `base` or `unpacked`, where in the latter the files are already unpacked and `latex.ltx` is ready. The L^AT_EX extensions and general style files that have been contributed by other users are located in the subdirectory `contrib/supported`, with each contribution in a subdirectory of its own. Extensions offered by the L^AT_EX3 Team are found in the `required` subdirectory, which include `babel`, `graphics`, `tools`, and so on.

B.5 Additional standard files

Throughout this book we have pointed out and explained many contributed packages that expand L^AT_EX functionality. However, there are a number of service documents, additional classes, and packages that are delivered with the basic L^AT_EX installation, found in `texmf\tex\latex\base\`. We list them all here, although some have been mentioned in other sections.

B.5.1 Special documents

The standard installation includes a number of special ‘documents’, files with the `.tex` extension. These are:

`small2e.tex` a short sample document;

`sample2e.tex` a longer sample document;

`tablst.tex` (Section 9.2.1) for printing out all the cross-reference labels, with translations and page numbers; it asks interactively the name of the document that is to be so listed;

`idx.tex` (Section 9.4) lists all the `\index` entries for a document, ordered in two columns, by page; it asks interactively the name of the document that is to be so listed;

`testpage.tex` to test the positioning of the text on a page; this is more a test of the printer driver, to make sure that the margins are correct and that the scaling comes out properly;

`nfssfont.tex` is a document to print out a font table, sample text, and various other tests; it asks for the name of the font interactively; the command `\help` prints out a list of commands that can be given;

`docstrip.tex` (Section D.7.1) this is more a program than a document; it is the basic tool for unpacking operating files from their documented source files; it not only removes comments, but also includes alternative coding depending on various options.

B.5.2 Extra classes

In addition to the standard classes that have already been discussed (`book`, `report`, `article`, `letter`) the standard installation also contains

`proc` for producing camera-ready copy of conference proceedings; it is a variant of the two-column `article` class; it contains one extra command: `\copyrightspace`, which leaves blank space at the bottom of the first column for typing in a copyright notice;

`minimal` a bare-bones class for testing and debugging;

`slides` (Section 15.1) the former S_LT_EX, for producing presentation material;

`ltxdoc` (Section D.7.2) to produce class and package documentation.

B.5.3 Standard packages

The standard packages, some of which are described elsewhere, are:

`alltt` (Section 4.9.1) enables the `alltt` environment which is much like `verbatim` except that `\ { }` behave as normal; this means that commands included in the text are executed and not printed literally;

`doc` (Section D.7.2) provides many special features for documenting L^AT_EX packages;

`exscale` allows the mathematical symbols that appear in different sizes to scale with the font size option given in the `\documentclass` command; normally the size of these symbols is fixed, independent of the basic size of the text;

`flafter` (Section 7.2, page 171) ensures that floating objects (figures and tables) do not appear before their position in the text;

`fontenc` (Section A.3.6, page 378) declares font encodings by loading their `.def` files; the names of the encodings are listed as options;

`graphpap` (Section 13.1.5) provides the command `\graphpaper` which produces coordinate grids in the `picture` environment;

`ifthen` (Section 8.3.5) allows text or command definitions depending on the state of various conditionals; one may test the state of a boolean switch, the value of a counter or length, or the text definition of a command;

`inputenc` (Section D.5) allows a L^AT_EX document file to be prepared with a system-dependent input encoding scheme for special characters;

`latsym` loads the 11 special L^AT_EX symbols in the `lasy` fonts (Section G.2.2), which were part of L^AT_EX 2.09; this file is automatically read in in compatibility mode;

`makeidx` (Section 9.4.3) provides the commands that may be used with the MakeIndex program to generate a keyword index;

`showidx` (Section 9.4) makes the `\index` entries visible by printing them as marginal notes;

`shortverb` (Section 4.9.1) provides the commands `\MakeShortVerb` and `\DeleteShortVerb`, to designate (and remove) a certain character as the equivalent of `\verb` for printing literal text. The character, preceded by a backslash, is given as an argument to these commands. After `\MakeShortVerb{\|}` has been issued, `|\cmd{x}|` is equivalent to `\verb|\cmd{x}|`, producing `\cmd{x}`;

`syntonly` provides the command `\syntaxonly` which, when given in the preamble, suppresses all output to the `.dvi` file, but continues to issue errors and warnings; the job runs about four times faster than normal; this is used to check the processing when output is not immediately needed;

`t1enc` makes the T1 font encoding (Section G.4.3) the standard, for use with DC or EC fonts;

`textcomp` makes the special symbols in the text companion fonts available in text mode (Section G.4.4);

`tracefmt` is a diagnostic tool for checking NFSS font selections; the options given with `\usepackage` control its action:

`errorshow` suppresses all warnings and information messages to the monitor, which are still sent to the transcript file; only error messages are printed to the monitor;

`warningshow` prints warnings and error messages on the monitor; this behavior is much the same as when the package is not used at all;

`infoshow` (default option) sends font selection information to the monitor, which is normally only written to the transcript file;

`debugshow` writes considerably more information to the transcript file about every change of font; can produce a very large transcript;

`pausing` turns all warnings into error messages so that processing temporarily stops, awaiting user response;

`loading` shows the loading of external fonts.

B.5.4 The tools packages

The members of the L^AT_EX3 Team, as individuals, have written a number of packages that they collectively make available; these are to be found in the `texmf\tex\latex\tools\` directory. Although contributions, they are considered to be part of the standard installation.

Many of these have been described elsewhere in this book, but we list them all here.

`afterpage` (Section 7.1 on page 171) permits commands to be saved and executed at the end of the current page. This is useful for forcing stubborn floats to be output right away, with `\afterpage{\clearpage}`. If `\clearpage` were issued directly, a new page would be inserted at that point. With `\afterpage`, the command is reserved until the end of the page.

`array` (Section 4.8.4 on page 106) is a re-implementation of the `tabular` and `array` environments with several additional features.

`bm` permits individual math symbols to be printed in bold face with command `\bm{\sym}`. Thus `$\alpha + \bm{\beta}$` produces $\alpha + \boldsymbol{\beta}$ without recourse to the `\boldmath` command which would set the whole formula in bold face. There is also a command `\DeclareBoldMathCommand{\name}{\sym}` that defines `\name` to be `\bm{\sym}`.

`calc` re-implements the counter and length commands to allow ‘normal’ arithmetic with them, such as

```
\setlength{\mylen}{3cm + \textwidth}
\setcounter{page}{\value{section} * 3}
\parbox{\linewidth / \real{1.6}}{...}
```

Note that the arithmetical expressions can be used not only to set values but also as arguments to commands and environments.

`dcolumn` (Section 4.8.4) requires the `array` package; it allows decimal point alignment in the `tabular` tables.

`delarray` (Section 4.8.4) requires the `array` package; it permits large bracketing symbols to be put around `array` environments, for making matrices of various sorts.

`enumerate` (Section 4.3.5, page 74) re-implements the `enumerate` environment so that an optional argument determines the numeration style.

`fileerr.dtx` when unpacked, produces a set of small files that may be used to reply to T_EX when a file is not found; this makes the responses similar to those for error messages; the files are named `h.tex`, `e.tex`, `s.tex`, and `x.tex`; thus, replying `x(return)` loads the last one, which terminates the input.

`fontsmpl` is a package to output a sample text, accents, and special characters for a given font; with the accompanying file `fontsmpl.tex`, a family such as `cmr` can be printed with all attributes and encodings.

`ftnright` puts footnotes in the right-hand column in two-column mode.

`hhline` requires the `array` package; allows more flexibility in putting horizontal rules in tables.

`indentfirst` (Section 3.2.4 on page 46) indents the first paragraph of sections, which normally are not indented.

`layout` (Section 3.2.5 on page 47) defines the command `\layout` which draws a diagram of the current page format, with the values of the parameters printed.

`longtable` (Section 4.8.4 on page 108) makes tables that extend over several pages, with breaks occurring automatically.

`multicol` (Section 3.2.8) introduces the environment `multicols` which switches to multi-column output without a page break either before or after. It is called with

```
\begin{multicols}{num_cols}[header text][pre_space]
  Text set in num_cols columns
\end{multicols}
```

The optional *header text* is printed in a single column across the top of the multi-column part. A `\newpage` is issued only if the remaining space on the current page is less than a certain value, stored in the length `\premulticols`; the optional length argument *pre_space* overrides this value if given. Similarly the length `\postmulticols` determines whether a new page is inserted at the end of the multi-column text. Column separation and possible rule are set by the standard L^AT_EX lengths `\columnsep` and `\columnseprule` as for the `\twocolumn` command. The text in the multi-column format is balanced; that is, the columns are all equally long.

`showkeys` prints out all the cross-reference keys defined by `\label` and `\bibitem` and used by `\ref`, `\pageref`, and `\cite`; these are marginal and interlinear notes for a draft only, to check the cross-referencing.

`somedefs` allows only selected commands to be defined in a package, depending on options in `\usepackage`.

`tabularx` (Section 4.8.4) defines a `tabularx` environment which is like `tabular*`, a table of desired width, except that it is the column widths that expand and not the intercolumn spacing.

`theorem` provides extensions to the `\newtheorem` command for more flexible ‘theorem-like’ environments; it is very similar to the \mathcal{AMS} `amsthm` package (Section 12.3.1).

`varioref` (Section 9.2.4) defines `\vref` and `\vpageref` commands, analogous to `\ref` and `\pageref`, which check if the referenced object is only one page away, and if so, print text like ‘on the previous page’; the actual text printed can alternate between two variants.

`verbatim` (Section 4.9.1) is a re-implementation of the `verbatim` environment that prevents memory overflow for long texts; it also defines a command `\verbatiminput` to input a file and to print its contents literally, as well as a `comment` environment for a block comment in the input text.

`xr` (Section 9.2.3) is a package to allow `\ref` to cross-reference `\label` commands from other documents.

`xspace` (Section 8.3.1 on page 186) contains a device to fix the problem of command names swallowing up the blank that follows them; thus the command `\PS` defined as

```
\newcommand{\PS}{PostScript\xspace}
```

may be used as `\PS file` without having to terminate the `\PS` command with `_` or `{}`.

B.6 The various L^AT_EX files

A number of different files are used during the L^AT_EX processing: some are read in while others are created to store information for the next run. They all consist of two parts:

root_name.extension

For every L^AT_EX document, there is a *main* file, whose root name is used when the program L^AT_EX is called. It normally possesses the extension `.tex`, as do any other files that it might read in with `\input` or `\include` commands. (If they have a different extension, it must be given explicitly.)

The other files that are created during a L^AT_EX processing run normally have the same root name as the main file but a variety of different extensions, depending on their functions. If the main file contains `\include` commands, there will be additional files created having the same root names as the included `.tex` files but with the extension `.aux`.

Some of these files are created with every L^AT_EX run, whereas others appear only when certain L^AT_EX commands have been issued, such as `\tableofcontents` or `\makeindex`. The `.aux` files as well as those produced by special L^AT_EX commands may be suppressed by including the command `\nofiles` in the preamble. This command is useful if a document is being constantly corrected and reprocessed, so that the information in the special files is not yet finalized and may therefore be

dispensed with. Files created at the T_EX level of processing will always be generated.

Other extensions describe files that contain formatting information, or additional instructions (coding), or databases. The root part of these file names is not associated with any document file. An example of this type is the `article.cls` file that defines the `article` class.

The rest of this section contains a list of the L^AT_EX file extensions with a short description of the role they play in the L^AT_EX processing.

- .aux This is the auxiliary file written by L^AT_EX, containing information for cross-references as well as some commands necessary for the table of contents and other lists. There will be one .aux file created (or re-created) for the main file, in addition to one for every file read in by an `\include` command.

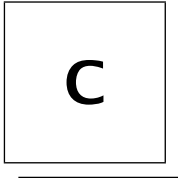
The auxiliary .aux files may be suppressed by issuing `\nofiles` in the preamble.

- .bb1 This file is not created by L^AT_EX, but by the program B_IB_TE_X. It has the same root name as the main file. B_IB_TE_X actually only reads the .aux file for its information. The .bb1 file is read into the next L^AT_EX processing run by the command `\bibliography` and produces the list of literature references.
- .bib Bibliographic databases have the extension .bib. B_IB_TE_X reads them to extract the information it needs to generate the .bb1 file. The root name describes the database and not (necessarily) any text file. The database name is included in the text by means of the `\bibliography` command.
- .b1g This is the transcript file from a B_IB_TE_X run. The root name is the same as that of the input file.
- .bst This is a *bibliography style file* that is used as input to B_IB_TE_X to determine the format of the bibliography. The name of the .bst file is included in the text by means of the `\bibliographystyle` command.
- .cfg Some classes permit local *configurations* for paper size or other requirements by putting specifications into a .cfg file of the same root name as the class. The `ltxdoc` class (Section D.7.2) is one of these.
- .c1o This is a *class option* file, containing the coding for certain options that might apply to more than one class. There is no special command to input them.
- .cls This is a *class* file, defining the overall format of the document. It is read in by the `\documentclass` command. A .cls file may also be input from another one with the `\LoadClass` command.

- .def Additional definition files of various types carry the .def extension. Examples are `t1enc.def` (to define the T1 encoding) and `latex209.def` (for compatibility mode between L^AT_EX 2_ε and 2.09).
- .dtx These are documented source files for the L^AT_EX installation. If a .dtx file is processed directly, the documentation is printed. This is an explanatory manual and/or a detailed description of the coding. The class, package, .ltx, .fd or other file(s) are extracted by processing the .dtx file with DocStrip (Section D.7.1), usually by running L^AT_EX or T_EX on a supplied .ins file.
- .dvi This is the T_EX output file, containing the processed text in a format that is independent of the output printer, hence a ‘device-independent’ file. It too is generated by every T_EX process run and cannot be suppressed by `\nofiles`.
The .dvi file must be further processed by a *printer driver* program that converts it into the special commands for the desired output device (printer).
- .fd Files containing the NFSS commands associating external font names with font attributes (Section A.3.6) are *font description files*. The root names consist of the encoding and family designations, such as `ot1cmr.fd`. When a font of a given family is requested for the first time, the corresponding .fd file is automatically read in, if it exists.
- .fdd Documented sources for .fd files have the extension .fdd, and are nothing more than a special type of .dtx file. They may be processed for the documentation, or have the .fd files extracted by DocStrip.
- .fmt This extension belongs to a T_EX *format* file that has been created with the special program `initex` (Section B.1.3). Format files contain all the basic instructions in a compact coding for quick loading. L^AT_EX is nothing less than T_EX run with the format `latex.fmt`. (Plain T_EX uses the format file `plain.fmt`.)
- .glo This file is only generated when the command `\makeglossary` exists in the preamble. It has the same root name as the main file and contains only `\glossaryentry` commands that have been produced by `\glossary` commands in the input text. This file will be suppressed in spite of the presence of `\makeglossary` if the command `\nofiles` is issued in the preamble.
- .gls This file is the glossary equivalent of the .ind file. It too is generated by the `MakeIndex` program, but with the .glo file as input. The input and output extensions must be explicitly given. There are no standard L^AT_EX commands to read in the .gls file. The `doc` package uses it to record a change history.

- .idx This file is only generated when the command `\makeindex` exists in the preamble. It has the same root name as the main file and contains only `\indexentry` commands that have been produced by `\index` commands in the input text. This file will be suppressed in spite of the presence of `\makeindex` if the command `\nofiles` is issued in the preamble.
- .ilg This is the transcript file from a MakeIndex run. The root name is the same as that of the input file.
- .ind This file is generated by the MakeIndex program, with the .idx file as input. It is read in by the `\printindex` command which is defined by the `makeidx` package. It contains a `theindex` environment, built up from the entries in the input file.
- .ins To facilitate the DocStrip run on a .dtx file, the necessary commands (and options) are put into an *installation* file. The extraction is then accomplished simply by processing (with T_EX or L^AT_EX) the appropriate .ins file.
- .ist This is an *index style file*, containing style settings for MakeIndex. The root name reflects the style and has no relationship to any text file. For the `doc` package, the files `gind.ist` and `gglo.ist` are provided for specialized index formatting.
- .lof This file contains the information for the list of figures. It behaves exactly like the .toc file except that it is opened by the command `\listoffigures` instead of by `\tableofcontents`.
- .log This is the transcript file, containing the protocol of the T_EX processing run, that is, all the messages that were sent to the monitor during the run as well as additional information that can be of use to T_EX experts when errors occur. This file is always generated, even when `\nofiles` has been issued.
- .lot This file contains the information for the list of tables. It behaves exactly like the .toc file except that it is opened by the command `\listoftables` instead of by `\tableofcontents`.
- .ltx For L^AT_EX installation, certain files that are inputs to the `initex` program bear the extension .ltx. They form the basis for generating the format `latex.fmt`. The main such file is named `latex.ltx`.
- .mf METAFONT source files (Sections G.1 and G.3) contain drawing instructions for the characters in a font. The METAFONT program converts these to bitmap .pk files in a given size and resolution for DVI driver programs.

- .pk Packed pixel, or bitmap, files (Section G.1) contain images of the characters in a font. These are read in by the DVI drivers to print the characters either on paper or on the computer monitor.
- .sty This is a *package* file, to be loaded with `\usepackage`. A package contains additional L^AT_EX commands to define new features or alter existing ones. It should not produce any printable text. It may be input by another package with the command `\RequirePackage`.
- .tex The file containing the user's input text should have the extension `.tex`. For every L^AT_EX document there is at least one `.tex` file. If there is only one `.tex` file, it is also the *main* file that determines the root name of all the others. If there are `\input` or `\include` commands within the input text, there are other files belonging to the document with different root names but all with the extension `.tex`. The main file is the one whose name appears when the program L^AT_EX is called. It contains the highest level `\input` commands and is the only file that may have `\include` commands.
- .tfm T_EX font metric files (Section G.1) contain all the font information that T_EX needs to process a document: height, width, depth of each letter, ligature information, italic correction, and so on. The only thing that is missing is what the character looks like. This is provided by `.pk` files.
- .toc This file contains the information for the table of contents. The command `\tableofcontents` reads in the `.toc` file, if it exists, and then outputs the table of contents. At the same time, a new `.toc` file is opened where all the contents information for the current processing run is written. This `.toc` file is closed by the `\end{document}` command, so that if the L^AT_EX run is interrupted before completion, the `.toc` file is lost.
 A `.toc` file is only generated if the document contains the command `\tableofcontents` and if the `\nofiles` command has not been issued. It has the same root name as the main file.
- .vf Virtual font files (Section G.1) are read in in place of `.pk` files for fonts that do not really exist independently. For each character, there are instructions for the driver program, usually to take character *nn* from real font *xx*.



Error Messages

Errors are bound to be made at times during the preparation of a long \LaTeX document. The mistakes can be of various kinds, from simple typing errors for command names to forgetting that some commands must be paired or giving an incorrect syntax for a complicated command.

Errors during the \LaTeX processing produce a list of messages on the monitor, which appear totally incomprehensible to the beginner. Even the advanced user can have difficulty figuring out a particular error message. However, these messages contain information about fundamental structures that can aid an experienced \TeX programmer to see much deeper into the heart of the problem.

In addition, the error messages contain useful information even for the beginner. It is the purpose of this chapter to explain some of these messages that can be of assistance to non-programmers.

Error messages are written both to the computer monitor and to the processing transcript file, with extension `.log`. Examine this file if the messages on the monitor went by too fast.

C.1 Basic structure of error messages

Error messages have two sources: those from \LaTeX and those from the underlying \TeX program. The \LaTeX messages are often followed by \TeX messages since \LaTeX operates at a higher level.

C.1.1 \TeX error messages

We start with a simple error as an example.

```
\documentclass{article}
\begin{document}
The last words appear in \textbf{bold face}.
\end{document}
```

Here the command `\textbf` has been mistakenly typed as `\txetbf`. During the processing, \LaTeX assumes that the user wants to invoke a \TeX command `\txetbf`. Since \LaTeX does not know the \TeX commands, it passes this text on to \TeX , which then decides that there is no such command in its repertoire. The following error message is written to the monitor:

```
! Undefined control sequence.
1.3 The last words appear in \txetbf
                                     {bold face}.
?
```

The program stops at this point and waits for a response from the user. This message can be understood even by beginners. It consists of an error indicator that starts with an exclamation point `!`. Here the indicator is: `! Undefined control sequence`, meaning that an *unknown command name* (control sequence) was the cause of the error. Next comes a *pair of text lines*, the *first* of which is prefixed with `1.3`, meaning that the error occurred in ‘line 3’ of the input text. The error itself was encountered at the last symbol printed in this *upper* line. The *lower* line shows the continuation of the input line being processed when the error was found, here the words `{bold face}`. Before continuing, \TeX waits for a reaction from the user, as indicated by the question mark in the last line of the message.

Entering another `?` and `<return>` as response produces the following information:

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

This is a list of the possible user responses:

1. `<return>`: simply typing the return key tells \TeX to continue processing after making an attempt to handle the error according to some preprogrammed rules. In the case of an unknown command name, the error treatment is to ignore it.
2. *S scroll mode*: \TeX continues the processing, writing further error messages to the monitor as they are encountered, but without stopping for a user response. This is as though `<return>` were pressed after all subsequent errors.
3. *R run mode*: \TeX continues processing as with *S*, but does not even stop as it would in *scroll mode* if the file named in an `\input` or `\include` command is missing.

4. *Q quiet mode*: the same as with *R* except that no further error messages are printed to the monitor. They are, however, written to the `.log` file.
5. *I insert*: the mistake can be corrected by inserting the proper text. \TeX puts the line of text entered from the keyboard into the processing in place of the error and then continues. Such a correction applies only to the processing: the original text in the `.tex` file is unchanged and must be altered with an editor. Typing in `I\stop` brings the program to a halt with the current page in the `.dvi` file.
6. `1 . . .`: entering a number less than 100 will delete that many characters and commands from the subsequent text. The program then stops to await further response from the user.
7. *H help*: an extended account of the problem is printed to the monitor, which is more informative than the brief error indicator and which may contain tips for relieving the error.
8. *X exit*: The \TeX processing is halted at this point. The current page does *not* appear in the `.dvi` file.
9. *E edit*: The process is halted as with *X* and a message is printed saying on which line of which file the error occurred. For some implementations, the editor may actually be called automatically, going directly to the faulty line.

The above response letters may be typed in either in capitals or in lower case. The response does not take effect until after *<return>* is pressed.

Typing *H* or *h* for *help* on the previous sample error message produces the text:

```
The control sequence at the end of the top line
of your error message was never \def'ed. If you have
misspelled it (e.g., '\hobx'), type 'I' and the correct
spelling (e.g., 'I\hbox'). Otherwise just continue
and I'll forget about whatever was undefined.
```

?

The error is described in more detail: the command name at the end of the upper line is unknown; if this is simply a typing error, enter the proper text with the *I* response, in this case `I\textbf`. Otherwise, press *<return>* and the faulty command will be ignored. The line of text will be processed as though it had been **The last word appears in bold face**. Of course, no bold face can actually appear.

The basic structure of a \TeX error message is summarized as:
Every error message begins with an error indicator, marked by a ! at the beginning of the first line. The indicator text is a brief description of the

problem. Following are one or more lines of input text. The last symbol of the first of these lines is the one that has caused T_EX to stop and print the error message. The last line contains the text or commands that are the next to be processed. T_EX waits for a response from the user. If that response is the typing of an H for help, a more detailed description, with possible tips, is printed to the monitor, and T_EX waits for a further response.

C.1.2 L^AT_EX error messages

As an example of a text with a L^AT_EX error, we take

```
\documentclass{article}
\begin{document}
\begin{quote}\slshape
  Text indented at both ends
\end{quote}
\end{document}
```

Here the call `\begin{quote}` was incorrectly typed as `quote`. The L^AT_EX processing writes the error message:

```
! LaTeX Error: Environment quote undefined.
```

See the LaTeX manual or LaTeX Companion for explanation.
Type H <return> for immediate help.

```
...
```

```
1.3 \begin{quote}
      \slshape
?
```

The first line of this message states that L^AT_EX itself discovered this error, with a brief error indicator, in this case `Environment quote undefined`. All L^AT_EX error messages begin with a line like this, followed by a reference to the L^AT_EX manuals for detailed explanation (which is also to be found in Section C.3 of this book). The third line of text is a reminder that the response H (*return*) will also type additional clarification.

The line of three dots `...` indicates that there are more lines of internal coding that have been suppressed. Sometimes it is desirable to look deeper behind the error message, especially for practiced T_EXperts who know how to interpret them. In this case, L^AT_EX can be made to output the missing lines of coding by setting

```
\setcounter{errorcontextlines}{num}
```

where *num* is the number of levels a macro will be decoded on an error. By default, *num* = -1. The knowledgeable user can set it to 99 to get more lines than he or she will ever likely to want.



The next pair of lines shows just where the processing was halted when the error was detected. As for \TeX messages, the current input line of text is broken at the error, with the processed part on the first line, here $\text{\begin{quote}}$, and the remainder on the next line. Here this remainder is \s\shape . The line indicator 1.3 (small letter L, not number one) shows on which line (3) of the input file the error was found.

\LaTeX now awaits a response from the user. Typing H $\langle\text{return}\rangle$ yields the additional information:

```
Your command was ignored.
Type I <command> <return> to replace it with another command,
or <return> to continue without it.
?
```

This means the last command in the upper line of the pair beginning with 1.3 has not been read into the processing. The mistake may thus be corrected *for the current process run only* with $\text{I}\text{\begin{quote}}$ $\langle\text{return}\rangle$. The misspelling will still be in the text file, though, and needs to be removed by an editor run later.

However, if the processing is continued by simply pressing $\langle\text{return}\rangle$, then $\text{\begin{quote}}$ is ignored, as though this text were not in the source file. This leads directly to another error when the command $\text{\end{quote}}$ is encountered, since now the matching $\text{\begin{quote}}$ command is missing. The actual text of this second error message is:

```
! LaTeX Error: \begin{document} ended by \end{quote}.
```

```
See the LaTeX manual or LaTeX Companion for explanation.
```

```
Type H <return> for immediate help.
```

```
...
```

```
1.5 \end{quote}
```

```
?
```

The message again contains the standard \LaTeX announcement, with error indicator, in the first line, followed by a reference to the manuals, and an invitation to type H for help. The error indicator in this case is

```
\begin{document} ended by \end{quote}.
```

This arises because when \LaTeX encountered $\text{\end{quote}}$, it checked the name of the current environment. Since $\text{\begin{quote}}$ was missing, the matching \begin command is the $\text{\begin{document}}$ statement, producing a mismatched \begin\dots\end pair.

The last pair of lines again shows just how far the processing had occurred before the error was detected. In this case, the whole of the current line has already been taken in, so the remainder line is blank.

The response H *<return>* at this point leads to the same message as for the first error. A correction with an I entry will not do any good since the missing `\begin{quote}` can no longer be inserted ahead of the environment text. Entering `I\begin{quote}` will replace the `\end{quote}` with `\begin{quote}`, but that does not solve the real problem. The best response now is to type *<return>* so that the command `\end{quote}` is ignored and the processing continues.

Now both the faulty `\begin{quote}` and correct `\end{quote}` commands are removed and the processing takes place as if the `quote` environment had never been in the input text at this point.

If the typing error `quote` had been made in the `\end` instead of in the `\begin` command, the error message would have been:

```
! LaTeX Error: \begin{quote} on input line 3 ended by \end{quote}
```

```
See the LaTeX manual or LaTeX Companion for explanation.
Type H <return> for immediate help.
```

```
...
```

```
1.5 \end{quote}
```

```
?
```

The previous explanations should be enough for the user to understand what is now being said. The error indicator here is

```
\begin{quote} on input line 3 ended by \end{quote}
```

and the last pair of lines indicate that the problem is in line 5 and that the troublesome command is `\end{quote}`. The obvious thing to do now, and the H message encourages this conclusion, is to make a correction with `I\end{quote}`. However, now a new message appears on the monitor:

```
! Extra \endgroup.
<recently read> \endgroup
1.5 \end{quote}
```

```
?
```

With the exception of the last pair beginning with 1.5, this makes no sense at all. The error indicator `! Extra \endgroup` is seemingly meaningless. That this is a \TeX error message and not a \LaTeX one is hardly any compensation.

The frustrated user is not really to blame. The response was perfectly reasonable even if it was wrong. Only experience could say that the best action at that point was to have just pressed *<return>*. The `quote` environment is closed off anyway, although any special actions associated with `\end{quote}` would be left off.

The help message at this point is

Things are pretty mixed up, but I think the worst is over.

This is at least encouraging, and the user should not lose heart. The best thing is to just keep on pressing *<return>* to get through the run.

We give here two recommendations for choosing a response, one specific and one general. The specific one is:

If a false environment name appears in a `\begin` command, the proper correction of the error is

```
I\begin{right_name}
```

If the misspelling has occurred in the `\end` command, the best way to handle this mistake is just to press *<return>*. The environment will be closed and any local declarations or definitions will be terminated. However, if there are any commands to be executed or text to be printed by the `\end` command, these will be missing.

The general recommendation is

If the user knows how to correct the error with the help of the error message, this should be done with

```
I correction
```

Otherwise, one may give *<return>* and wait and see what happens. Even if more peculiar (T_EX) error messages appear, one can keep on pressing *<return>* until the processing is finally at an end. The following print-out should indicate where the mistake was.

Instead of continually pressing *<return>*, one may also enter S, R, or Q and *<return>* to speed up the error treatment (Section C.1.1). Here, as with the simple *<return>* entry, the faulty commands are not just ignored. T_EX attempts to treat them by making assumptions about what the user wanted to do at this spot. Only when this is no longer possible will T_EX ignore the command completely. For example, if the indicator reads

```
\begin{environment} ended by \end{environment}
```

there was at least a `\begin` command with a valid environment name earlier. It could be assumed that the name of the environment in the `\end` command is wrong. L^AT_EX thus tries to execute this command using the name of the current environment.

C.1.3 Error messages from T_EX macros

The majority of T_EX commands and practically all the L^AT_EX commands are so-called T_EX macros. These are combinations of primitive commands grouped together under a new command name, by which they may be

called as a unit. \TeX macros are structures similar to those that may be defined by the \LaTeX command `\newcommand`. Up to nine arguments may be passed to them, just as for \LaTeX commands. However, the corresponding \TeX commands for generating macros are more general than `\newcommand`.

In fact, of the approximately 900 Plain \TeX commands available, only 300 are primitives, or fundamental commands. The remaining 600 are macros. If an error occurs within a macro, the other commands within it may also be affected.

Here is an example for clarification. The command `\centerline` is a macro defined as

```
\def\centerline#1{\@@line{\hss#1\hss}}
```

in which `\@@line` is itself a macro while `\hss` is a \TeX primitive, a rubber length that can be infinitely stretched or shrunk. To avoid leading the user into the murky depths of \TeX commands, we will simply point out that the above macro definition is more or less equivalent to the \LaTeX command sequence

```
\newcommand{\centerline}[1]{\makebox[\textwidth][c]{#1}}
```

Now take the following sample input text

```
\documentclass{article}
\begin{document}
\centerline{This is an \invalid command}
\end{document}
```

in which a `\` has been placed before the word `invalid`, making a false command named `\invalid`. During the \LaTeX processing, the following \TeX error message appears:

```
! Undefined control sequence.
<argument> This is an \invalid
                                command
1.3 \centerline{This is an \invalid command}
?
```

This \TeX message is now a bit more understandable. The error indicator is the same as for the example in Section C.1.1:

```
! Undefined control sequence.
```

The following pair of lines claim that the error was recognized after the 'command' `\invalid` was processed, and that the next piece of text to be read in is the word `command`. At the same time, the `<argument>` at the beginning of the upper line says that this text is the argument of some other command.

The next pair of lines are familiar: the error occurred in line 3 of the input text, after the entire line, `command` and `argument`, had been read in for processing.

C.2 Some sample errors

C.2.1 Error propagation

The example with the incorrect `\begin{quote}` environment showed that a simple response with the `<return>` key led to a second error message in spite of the fact that the `\end{quote}` command that produced it was correct. That one wrongly corrected error leads to further errors is more often the rule than the exception.

Let us look at the input text

```
\documentclass{article}
\begin{document}
\begin{itemie}
  \item This is the first point in the list
  \item And here comes the second
\end{itemize}
\end{document}
```

The only mistake in this text is the misspelled environment name `itemie` in place of `itemize`. The \LaTeX processing first produces the same error message as for the incorrect `quote` environment earlier:

```
! LaTeX Error: Environment itemie undefined.
```

See the LaTeX manual or LaTeX Companion for explanation.
Type H `<return>` for immediate help.

...

```
1.3 \begin{itemie}
```

```
?
```

At this point, entering `<return>` leads to a new error messages:

```
! LaTeX Error: Lonely \item--perhaps a missing list environment.
```

See the LaTeX manual or LaTeX Companion for explanation.
Type H `<return>` for immediate help.

...

```
1.4 \item T
      his is the first point in the list
```

```
?
```

What has happened here is that without the `\begin` command, the `\item` has been issued outside of a list environment, where it is rather meaningless. (Actually it is defined to print the above error message!) It is now too late to try to insert the missing start of the `itemize` environment. Typing H `<return>` for help yields

Try typing `<return>` to proceed.
 If that doesn't work, type `X <return>` to quit.
 ?

Following this advice and pressing `<return>`, one obtains the same error message once again, but this time on line 5, for the second `\item` command. Persevering further and pressing `<return>` once again, one is presented with

```
! LaTeX Error: \begin{document} ended by \end{itemize}.
```

See the LaTeX manual or LaTeX Companion for explanation.
 Type `H <return>` for immediate help.
 ...

```
1.6 \end{itemize}
```

?

The `itemize` environment has now come to its end, but since it was never properly started, \LaTeX complains about a mismatch of `\begin` and `\end` commands. Now at last, typing another `<return>` leads to a proper continuation of the processing. Of course the itemized text will be incorrectly formatted, but the rest of the document will not be affected.

In this example, a single mistake in the input text generated three further error messages. This is by no means unusual. Some \LaTeX errors can produce hundreds of such successive errors. It is even possible that the chain of errors never ceases and that the processing never advances. In this case, there is nothing else to do but to terminate the program. This should be done with the entry `I\stop` after the next error message. It may be necessary to give it several times before it takes effect. If this does not work, that is, if the same message appears every time, then the response `X <return>` will halt the program immediately.

It is better to stop the program with `I\stop` than with `X`, since then the output will include the last page being processed. This can be of assistance in trying to deduce what the source of the error was.

The final lesson of this section is simply: *even when faced with a host of error messages, don't panic! Continue to press the `<return>` key to advance the processing.*

Pressing `S <return>` instead will produce the same set of error messages on the monitor but without waiting for a user response in between (Section C.1.1).

C.2.2 Typical fatal errors

Occasionally it may happen that a user forgets to include one of the commands `\documentclass` or `\begin{document}`, or the entire preamble.

The last can easily occur when a \LaTeX file is to be read in with `\input` or `\include`, but is mistakenly entered directly with the \LaTeX program call. If a file with the text

```
This file has no preamble.
```

is put directly into the \LaTeX processing, the following message appears on the monitor:

```
! LaTeX Error: Missing \begin{document}.
```

See the LaTeX manual or LaTeX Companion for explanation.
Type H <return> for immediate help.

```
...
```

```
1.1 T
    his file has no preamble.
```

```
?
```

with the accompanying help message after typing H (*return*):

```
You're in trouble here. Try typing <return> to proceed.
```

```
If that doesn't work, type X <return> to quit.
```

```
?
```

One sees from the error message that \LaTeX has discovered a mistake on reading the very first letter of the text. The help message is also not very encouraging. There is no point trying to continue the processing with (*return*). Rather one should stop it with X or E right away, since nothing useful can be achieved here.

Even when the above example file contains the environment

```
\begin{document}
  This file has no preamble.
\end{document}
```

it is not possible to carry out a proper processing. The \TeX error message now printed is

```
! LaTeX Error: The font size command \normalsize is not defined:
    there is probably something wrong with the class file.
```

See the LaTeX manual or LaTeX Companion for explanation.
Type H <return> for immediate help.

```
...
```

```
1.1 \begin{document}
```

```
?
```

The error indicator is rather peculiar since the command `\normalsize` never appears in the input. Only the last two lines of this message are easily understood. They state that the error was recognized on line 1 after `\begin{document}` was read in. The fact that this is the text of the first line is enough to show that no meaningful processing can take place, since the mandatory `\documentclass` command that must precede it is missing.

Here again there is no choice but to halt the program with X or E, since a continuation of the processing would be meaningless.

(The reason for the strange error indicator is that many formatting parameters are initiated by the `\begin{document}` statement, including the standard font. It is here that `\normalfont` is called internally, and that command must be defined in the class file, which is missing. Other initiating commands are defined in the \LaTeX format itself, and so they do not cause this error.)

If the name of the document class is wrongly typed, say as

```
\documentclass{fred}
```

the following message appears:

```
! LaTeX Error: File 'fred.cls' not found.
```

```
Type X to quit or <RETURN> to proceed,  
or enter new name. (Default extension: cls)
```

```
Enter file name:
```

This message should be fairly clear: the program is looking for a file with the name `fred.cls` but cannot find it, so would the user be so kind as to enter an alternative name. If the new name has the same extension as that requested (`.cls`), it need not be explicitly given. In this case, the name of any standard \LaTeX class, such as `article`, `report`, `book`, or `letter`, may be typed in, as well as that of any additional classes that you might have access to. Of course, it should be the class for which the document was written.

This same error message is printed whenever a file is to be read in that cannot be found on the system. The issuing command may be `\input`, `\include`, or `\usepackage`. If the file sought really does exist, perhaps it is not located where \TeX is looking for files. Usually there is a system parameter set by the installation to point \TeX to its files. If your file is somewhere else, you can try entering its full name, with directory or path designations.

If \LaTeX is asking for a file that you know does not exist, or which is totally unknown to you, you will want to halt the processing right away or tell \LaTeX to skip the silly file. At this point, you have a problem. \LaTeX insists on a valid file name. Typing X (*return*) only produces the

message once again, this time stating that it cannot find the file `x.ext`. Some installations provide a dummy file named `null.tex`, while one of the extension packages available (Section B.5.4) offers a set of files named after the standard response letters `x.tex`, `e.tex`, `r.tex`, `h.tex`, `s.tex` to emulate the responses to normal error messages.

Emergency stop: sometimes one reaches a situation where the program cannot be halted after an error, even with `I\stop` or `X`. In such a case, one has to apply the operating system's program interrupt, usually `CTRL Z`.

C.2.3 Mathematical errors

Surprisingly few errors occur as a result of incorrect application of mathematical formula commands themselves, even for a user with only a little experience. More often, the errors in mathematical formulas are fiddly ones such as forgetting a closing brace `}` or neglecting to switch back to text mode. Another type of common error is to use a symbol in text mode that may only appear in math mode. We will point out a few typical examples here.

One wants to produce the text: 'The price is \$3.50 and the order number is `type.sample`', and types the input text:

```
The price is $3.50 and the order number is type_sample.
```

This text contains two errors, such that the first cancels the second one: the `$` sign is the math mode switch for generating formulas within text (Section 5.1). The proper way to write a true dollar sign in text is as `\$`. Instead, in the sample text, the `$` alone switches to math mode, setting everything that follows as a formula. However, the closing switch-back `$` is missing, something that \TeX will first notice at the end of the current paragraph.

```
! Missing $ inserted.
```

```
<inserted text>
```

```
$
```

```
1.4
```

```
?
```

If `<return>` is simply pressed as a response, \TeX inserts a `$` at this point. For our sample text, this would be at the end of the text before the blank line. This means that the text from the first `$` to the end of the paragraph will be set as a text formula:

```
The price is 3.50andtheordernumberistype_sample.
```

This output should show the user right away what went wrong. Near the end of the line, there is a letter `s` printed as an index. This is the second error in the example. The underbar character `_` is only permitted

in math mode and should have been typed here as $_$. However, after the first $\$$ had switched (incorrectly) into math mode, the $_$ sign became allowed, with the result that the following letter s was lowered.

If we now correct the text by replacing the $\$$ sign with $\backslash\$$, then the $_$ symbol is no longer in math mode, producing the error message:

```
! Missing $ inserted.
<inserted text>
      $
1.5 ...ice is \backslash$3.50 and the order number is type_
                                                    sample.
?
```

Pressing *<return>* here tells \TeX to recover from the error by inserting the apparently missing $\$$ sign at this point before the math command $_$. The processing continues, and at some place before the end of the current paragraph, \TeX will notice again that the closing $\$$ is not present. The same error message is printed as in the first case. The processing goes on with another *<return>* response, with the result:

The price is $\$3.50$ and the order number is type $_sample$.

In all three cases, asking for more help with H would type to the monitor:

```
I've inserted a begin-math/end-math symbol since I think
you left one out. Proceed, with fingers crossed.
```

The last sentence above is just what we recommend for mathematical error messages: *keep on pressing <return> or S to get through to the end of the processing, and then look at the printed output to find the mistake.*

C.2.4 Errors from multi-file texts

If the document text is split over many files that are to be read in with \backslashinput or \backslashinclude commands, the line number in the error message refers to the file currently being read. A response with E *<return>* will call the editor program and open that file, going to the indicated line where the error was recognized. With the other responses, the editor has to be called separately, with the faulty file explicitly named.

It is possible to determine which file was being processed at the time of the error by examining the processing messages or the \backslashlog file. As the files are opened for reading, \TeX writes an opening parenthesis (and the name of the file to the monitor and to the transcript \backslashlog file. When the file is closed, a closing parenthesis) is printed. Output page numbers are similarly written to both the monitor and transcript file in square brackets. For example, if the monitor shows the processing messages

```

..(myfile.tex [1] [2] [3] (part1.tex [4] [5]) (part2.tex [6] [7]
! Undefined control sequence
1.999 \finish
?

```

this can be interpreted as follows: a file `myfile.tex` was being read, and after pages 1, 2, and 3 had been output, the file `part1.tex` was read in with an `\input` or `\include` command inside the file `myfile.tex`. Pages 4 and 5 were output and `part1.tex` was closed, after which another file `part2.tex` was opened for input. An error was discovered in line 999 of this file. If this error is corrected from the keyboard, or if the processing is otherwise continued, the monitor messages proceed as

```

[8] [9]) [10]
! Too many }'s
1.217 \em sample}

```

The closing parenthesis after page 9 indicates that the file `part2.tex` has been closed. The next error is on page 10 in the main file `myfile.tex`, since there is no closing `)` for it. The error was discovered on line 217 of this file.

C.3 List of L^AT_EX error messages

The L^AT_EX error messages are listed here, divided into general, package, or font error messages. Within each group, they are ordered alphabetically according to the error indicators. A description of the possible causes and solutions is also given.

C.3.1 General L^AT_EX error messages

The following error messages are those not involving font selection or definition, nor any of the special features for L^AT_EX programming class and package files (Appendix D).

```
! LaTeX Error: ... undefined.
```

The argument of a `\renewcommand` or `\renewenvironment` has not been previously defined. The corresponding `\new...` command should be used instead.

```
! LaTeX Error: \< in mid line.
```

The command `\<` in a `tabbing` environment occurred in the middle of a line. This command may only appear at the beginning of a line (Section 4.6.3).

! LaTeX Error: Bad \line or \vector argument.

The first argument of a `\line` or `\vector` command specifies the angle of the line or arrow. This message states that the selected angle entries are invalid. See pages 293–294.

! LaTeX Error: Bad math environment delimiter.

\LaTeX has encountered a math switch command in the wrong mode: either a `\[` or `\(` command in math mode or the corresponding `\]` or `\)` in normal text mode. Either the math switches have been improperly paired or some braces `{...}` are incorrect.

! LaTeX Error: \begin{...} on input line ... ended by \end{...}.

\LaTeX has encountered an `\end` command without a corresponding `\begin` of the same name. This may be due to a typing mistake in the name of the environment, or to the omission of a previous `\end` command. A good way to avoid this error is always to enter the `\end` command immediately after the `\begin`, inserting the actual environment text with the editor in between the two. This is especially useful for long, nested environments. It also reduces the risk of typing the environment name incorrectly in the `\end` command.

! LaTeX Error: Can be used only in preamble.

Many commands may only be called within the preamble. These include `\documentclass`, `\usepackage`, `\nofiles`, `\includeonly`, `\makeindex`, `\makeglossary`, and several others. Certain commands that only have meaning within class or package files, such as `\ProvidesClass` and `\ProvidesPackage` (Section D.2.1), as well as many `\Declare..` and `\Set..` commands are also only allowed in the preamble. If one of these commands is issued after `\begin{document}`, this message is printed.

! LaTeX Error: Command ... invalid in math mode.

A command has been issued in math mode that only makes sense in text mode, such as `\item` or `\circle`. The font declarations `\itshape`, `\bfseries`, and so on, also produce this error in math mode, since the math alphabet commands `\mathit`, `\mathbf` should be used instead.

! LaTeX Error: Command ... already defined.

The user has tried to redefine an existing structure with one of `\newenvironment`, `\newcommand`, `\newtheorem`, `\newsavebox`, `\newfont`, `\newlength`, `\newcounter`, or `\DeclareMathAlphabet`. Either a different name must be selected or, in the case of commands and environments, the `\renew...` version must be employed. (Note that when an environment named `sample` is defined, the commands `\sample` and `\endsample` are also created.)

! LaTeX Error: Command ... undefined in encoding

The specified command has been defined with `\DeclareTextCommand` for a certain NFSS encoding (say OT1) but was executed while another encoding (for example T1) for which there is no definition was active.

! LaTeX Error: Counter too large.

A counter that is to be printed as a letter contains a value greater than 26.

! LaTeX Error: Environment ... undefined.

L^AT_EX has encountered a `\begin` command with an unknown environment name. This is probably due to a typing mistake. It may be corrected during the processing with the response I followed by the correct name. (This does not alter the source file, where the error remains.)

! LaTeX Error: File '...' not found
Type X to quit or <RETURN> to proceed,
or enter new name. (Default extension: ...)
Enter file name:.

A file is to be loaded with one of the inputting commands, but it cannot be found. You may type a new file name, or quit, or proceed without it. If the file name has been given correctly, and it does exist, maybe it is not located where L^AT_EX looks for files. Make sure that it is in one of the right directories. The user is offered a chance to type in an alternative, or correctly typed, name via the keyboard. Type in the file name, with optional extension, and press *<return>*. L^AT_EX proposes a default extension that is the same as that requested. There is no default for the main part of the file name.

! LaTeX Error: Float(s) lost.

A `figure` or `table` environment or a `\marginpar` command was given within a vertical box (`\parbox` or `minipage` environment), or these structures were issued within a L^AT_EX command that uses vertical boxes internally, such as a footnote. This error is first recognized by L^AT_EX when a page is output so that the actual cause could be many lines earlier in the text. A number of tables, figures, or marginal notes may have been lost as a result, but certainly not the one that triggered the problem.

! LaTeX Error: Illegal character in array arg.

A `tabular` or `array` environment contains an unknown column formatting character (see Section 4.8.1) or the formatting entry in the second argument of a `\multicolumn` command is wrong.

! LaTeX Error: \include cannot be nested.

An attempt has been made to call `\include` from a file that has already

been read in by an `\include` command. All `\include` commands must be issued in the main file (Section 9.1.2).

! LaTeX Error: LaTeX2e command ... in LaTeX 2.09 document.

This error occurs if a $\LaTeX 2_{\epsilon}$ command is used in compatibility mode (Appendix F), that is, if the document uses `\documentstyle` instead of `\documentclass`. These can be `\LaTeXe`, `\usepackage`, `\ensuremath`, the `lrbbox` environment, as well as the new syntax for adding an optional argument with `\newcommand` and `\newenvironment`.

! LaTeX Error: Lonely \item--perhaps a missing list environment.

An `\item` command has been given outside of a list environment (Section 4.3). Either the environment name has been misspelled in the `\begin` command and not corrected by keyboard entry, or the `\begin` command has been forgotten.

! LaTeX Error: Missing @-exp in array arg.

The column formatting argument of a `tabular` or `array` environment contains an `@` symbol without the necessary following text in curly braces `{ }` that must go with it (Section 4.8.1 for `@`-expressions), or the same thing occurs in the second argument of a `\multicolumn` command.

! LaTeX Error: Missing begin{document}.

Either the `\begin{document}` command has been forgotten or there is printable text inside the preamble of the document. In the latter case, there could be a declaration with incorrect syntax, such as a command argument without curly braces `{ }` or a command name without the backslash `\` character.

! LaTeX Error: Missing p-arg in array arg.

The column formatting argument of a `tabular` or `array` environment contains a `p` symbol without the necessary width specification that must go with it (Section 4.8.1), or the same thing occurs in the second argument of a `\multicolumn` command.

! LaTeX Error: No counter '...' defined.

A `\setcounter` or `\addtocounter` command was called that referred to a counter name that does not exist. Most likely the name was typed incorrectly. If this error occurs while an `.aux` file is being read and if the name of the counter is indeed correct, the defining `\newcounter` command was probably given outside of the preamble. Therefore it is highly recommended always to give the `\newcounter` commands inside the preamble. (If the other \LaTeX counter commands are used with an undefined counter name, a long list of funny \TeX error messages appears.)

! LaTeX Error: No \title given.

The \maketitle command has been given before \title has been declared.

! LaTeX Error: Not in outer par mode.

A figure or table environment or a \marginpar command was given within math mode or inside a vertical box (\parbox or minipage environment). In the first case, the math switch-back command was probably forgotten.

! LaTeX Error: Page height already too large.

The command \enlargethispage is trying to extend the vertical size of the page, which L^AT_EX already considers too large.

! LaTeX Error: \pushtabs and \poptabs don't match.

The number of \poptabs commands in a tabbing environment does not agree with the number of previous \pushtabs given (Section 4.6.4).

! LaTeX Error: Something's wrong--perhaps a missing \item.

The most likely cause of this error is that the text in a list environment (list, itemize, enumerate, or description) does not begin with an \item command. It will also occur if thebibliography environment is given without the argument {sample.label} (Section 9.3).

! LaTeX Error: Suggested extra height (...) dangerously large.

The command \enlargethispage is trying to extend the vertical size of the page more than L^AT_EX considers reasonable.

! LaTeX Error: Tab overflow.

The last \= command in a tabbing environment exceeded the maximum number of tab stops allowed by L^AT_EX.

! LaTeX Error: There's no line here to end.

The command \newline or \\ has been issued after a \par or blank line where it makes no sense. If additional vertical space is to be inserted here, this should be done with a \vspace command.

! LaTeX Error: This may be a LaTeX bug.

This message states that L^AT_EX is fully confused. This could be the result of a previous error after which the user response was to press *<return>*. In this case, the processing should be brought to a halt with I\stop or X or E and the earlier error corrected. It is also possible, although unlikely, that there is a bug in the L^AT_EX program itself. If this is the first error message

in the processing, and the text seems otherwise to be satisfactory, the file should be saved and submitted to the computing center for further investigation.

! LaTeX Error: Too deeply nested.

Too many list environments (`description`, `itemize`, `enumerate`, or `list`) have been nested inside one another. The maximum depth of such nesting is dependent on the installation but should always be at least four.

! LaTeX Error: Too many columns in eqnarray environment.

The `eqnarray` environment may only have three columns per line. You may have forgotten to start a new row with `\\`, or have placed an extra `&` in the line.

! LaTeX Error: Too many unprocessed floats.

This error may occur if there are too many `\marginpar` commands on one page. However, it is more likely that \LaTeX is retaining more `figure` and `table` floats than it can hold. This happens if too many such float objects have been given before they can be output (Chapter 7). In this case, the last figure or table should be added later in the text. Another cause could be that the figure or table cannot be located on a normal text page, but rather on a special float page at the end of the text or after a `\clearpage` or `\cleardoublepage` command. Since the output sequence of figures and tables will be the same as that with which they were input, one such float can block the entire queue. A `\clearpage` or `\cleardoublepage` command can free the blockage.

! LaTeX Error: Undefined tab position.

A `\>`, `\+`, `\-`, or `\<` command in a `tabbing` environment has tried to move to a tabulator stop that does not exist (Section 4.6).

! LaTeX Error: \verb ended by end of line.

The text of an in-line verbatim command `\verb+...+` extends over more than one line of text. This is forbidden in order to catch a common error: the missing terminating character. Make sure that the entire text between the initial and terminating characters is all on one input line.

! LaTeX Error: \verb illegal in command argument.

The `\verb` command may not be used in the argument of any other command, except `\index` and `\glossary`. It may not be used within section titles or footnotes, for example.

C.3.2 L^AT_EX package errors

The special programming commands for handling class and package files (Appendix D) have their own set of error messages. If one of these features issues a serious error, there is often little the user can do about it other than report the problem to the author of the file. On the other hand, some errors are due to the improper use of the file or of the options that it provides.

Often classes and packages contain their own error or warning messages with text and meanings that are peculiar to them. These are indicated as such, along with the name of the class or package that issued them. For example, the package `mypack` could print the error

```
Package mypack Error: cannot mix options 'good'
(mypack)                and 'bad'.
```

A help message should also be available when H is typed. Obviously, such error (and warning) messages cannot be explained here, since they depend entirely on the package in question.

```
! LaTeX Error: \LoadClass in package file.
```

A package file has called `\LoadClass`, which it is not allowed to do. A class file can only be loaded from another class file.

```
! LaTeX Error: Option clash for package ....
```

The specified package has been requested a second time with a different set of options. A package file will only be loaded once and a second attempt will be ignored. Thus, if two `\usepackage` or `\RequirePackage` commands load the same package with different options, there is a conflict. Try to arrange for a consistent set. Typing H for help after this message will print out the two sets of options.

```
! LaTeX Error: \RequirePackage or \LoadClass in Options Section.
```

These two commands may not appear in the definition of a class or package option made with the `\DeclareOption` command. Instead, the option should set some flag or other indicator that is later tested before calling the command in question.

```
! LaTeX Error: This file needs format '...' but this is '...'.
```

The `\NeedsTeXFormat` command specifies a different format from the one being used. The *format* is the prestored set of instructions that determine what type of T_EX is being run. For L^AT_EX 2_ε, the format name specified must be L^AT_EX 2_ε. This file cannot be processed at all with the current format in use.

! LaTeX Error: Two `\documentclass` or `\documentstyle` commands.

A document may contain only one `\documentclass` or `\documentstyle` command. If you can only see one in the main document file, check that other files being loaded do not contain an offending second one.

! LaTeX Error: Two `\LoadClass` commands.

The class file contains more than one `\LoadClass` command, something that is not allowed. The class file has been improperly written.

! LaTeX Error: Unknown option ‘...’ for package ‘...’.

An option has been specified with `\usepackage` but it is not defined for that package. Check the instructions for the package or look for a misprint.

! LaTeX Error: `\usepackage` before `\documentclass`.

The `\usepackage` command may not appear before `\documentclass`. A class file must be loaded before any packages.

C.3.3 **L^AT_EX font errors**

The following error messages occur when defining or selecting fonts with the New Font Selection Scheme (Appendix A). Some of these messages indicate that the fonts have not been properly set up, in which case the font description files may be corrupted or contain mistakes. In either case, the system manager must see that a proper set of files are installed.

! LaTeX Error: ... allowed only in math mode.

A math alphabet command such as `\mathbf` has been used in text mode. Perhaps a `$` has been forgotten.

! LaTeX Error: Command ‘...’ not defined as a math alphabet.

The name of a non-existent math alphabet has been specified in one of the `\Set..` or `\Declare..` commands that take a math alphabet name as argument. The math alphabet name must be declared with the command `\DeclareMathVersion` before it may be used.

! LaTeX Error: Command ... not provided in base LaTeX2e.

A number of symbols that were part of the basic L^AT_EX 2.09, but not in T_EX, are no longer automatically included in L^AT_EX 2_ε. Add one of the packages `latexsym` or `amsfonts` to include them.

! LaTeX Error: `\DeclareTextComposite` used on inappropriate command

`\DeclareTextComposite` (Section A.3.7) is used to redefine an existing

accenting command to print a single character for a certain encoding. If the accenting command does not already exist, this message is issued.

! LaTeX Error: Encoding scheme ‘...’ unknown.

A font declaration or selection command that refers to a non-existent encoding scheme has been issued. There is probably a typing error involved here.

! LaTeX Error: Font family ‘...+...’ unknown.

A `\DeclareFontShape` command has been issued for a font encoding and family combination that has not been previously declared by means of a `\DeclareFontFamily` command (Section A.3.6).

! LaTeX Error: Font ... not found.

The font with the specified attributes could not be found, nor could an adequate substitution be made. The font defined by `\DeclareErrorFont` is used instead.

! LaTeX Error: Math alphabet identifier ... is undefined
in math version ‘...’.

A math alphabet (Section A.3.3) that has not been defined for the current math version has been invoked. This means that the alphabet has been created by `\DeclareMathAlphabet` with an empty shape attribute, but no `\SetMathAlphabet` declaration has been given to define it for the selected math version.

! LaTeX Error: Math version ‘...’ is not defined.

The name of a non-existent math version has been specified in one of the `\Set...` or `\Declare...` commands that take a math version name as argument. The version name must be declared with `\DeclareMathVersion` before it may be used.

! LaTeX Error: Not a command name: ‘...’.

The first argument of `\DeclareMathAccent` must be a command name, like `\acute`. Most likely the backslash `\` character has been forgotten.

! LaTeX Error: Symbol font ‘...’ not defined.

The name of a non-existent symbol font has been specified in one of the `\Set..` or `\Declare..` commands that take a symbol font name as argument. The font name must be declared with `\DeclareSymbolFont` before it may be used as a symbol font.

**! LaTeX Error: The font size command `\normalsize` is not defined:
there is probably something wrong with class file.**

It is necessary for class files to define `\normalsize`, the basic size of standard text in the document. If the class file does not do this, if it only defines `\@normalsize`, then it must be repaired. This message also appears if `\documentclass` is missing, for an empty class file is clearly a faulty one.

! LaTeX Error: This NFSS system isn't set up properly.

Something is wrong with the font descriptions in the `.fd` files, or there is no valid font declared by `\DeclareErrorFont`. This is a serious problem, to be reported to the system manager.

! LaTeX Error: Too many math alphabets used in version

There is a limit of 16 math alphabets possible, a number set by \TeX itself. Any additional math alphabet definitions are ignored.

**! LaTeX Error: Unknown symbol font '...'.
The name of a non-existent symbol font has been used as argument to the command `\DeclareSymbolFontAlphabet`. The font name must first be declared with `\DeclareSymbolFont` before it may be used.**

The name of a non-existent symbol font has been used as argument to the command `\DeclareSymbolFontAlphabet`. The font name must first be declared with `\DeclareSymbolFont` before it may be used.

C.4 \TeX error messages

This section contains a list of some of the most common \TeX error messages, ordered alphabetically according to the error indicator, together with a brief description of the possible cause. Each one begins with an exclamation point only.

! Counter too large.

As a \TeX error, this message refers to a footnote marked either with letters or symbols in which the counter has exceeded a value of 26 or 9. It may also occur if there are too many `\thanks` commands on a title page.

! Double subscript.

A mathematical formula contains two subscripts for the same variable, for example, x_{2_3} or $x_{\{2\}_{3}}$. The proper way to produce x_{2_3} is with $x_{\{2_3}}$ or $x_{\{2\}\{3}}$ (Section 5.2.2).

! Double superscript.

A mathematical formula contains two superscripts for the same variable, for example, x^{2^3} or $x^{\{2\}^{\{3\}}}$. The proper way to produce x^{2^3} is with $x^{\{2^3}}$ or $x^{\{2\}^{\{3\}}}$ (Section 5.2.2).

! Extra alignment tab has been changed to \cr.

A line in a `tabular` or `array` environment contains more `&` commands than there are columns defined. The error is probably due to a forgotten `\\` at the end of the previous line.

! Extra `}`, or forgotten `$`.

In math mode, either an opening brace `{` has been left off or an extra closing brace `}` has been included by mistake. Another possibility is that a math mode switch command such as `$`, `\[`, or `\(` has been forgotten.

! Font ... not loaded: Not enough room left.

The text processing requires more character fonts to be loaded than T_EX can handle owing to memory limitations. If certain parts of the document need different fonts, you can try to split it up and to process the parts separately.

! Illegal parameter number in definition of

This error message is probably due to a `\newcommand`, `\newenvironment`, `\renewcommand`, or `\renewenvironment` command in which the substitution character `#` has been applied incorrectly. This character may appear within the defining text only in the form `#n`, where `n` is a number between 1 and the number of arguments specified in the command. Otherwise the character `#` may only appear in the definition as `\#`. This error may also arise if the substitution character is applied within the last argument `{end.def}` (Section 8.4).

! Illegal unit of measure (pt inserted).

If this error message comes right after another error with the message

! Missing number, treated as zero.

the problem lies with this previous error (see below). Otherwise, the mistake is that T_EX expects a length specification at this point but has only been given a number without a length unit. This occurs most often when a length is to be set to zero and `0` has been typed in instead of `0mm` or `0pt`. If this is the case, then responding with *return* produces the right result since for a zero value any unit specification is all right. This error may also occur if a length specification has been completely forgotten.

! Misplaced alignment tab character &.

The single character command `&` has been given in normal text outside of the `tabular` and `array` environments. Possibly the intention was to print `&`, in which case `\&` should be typed. This may still be achieved during the processing by responding with `I\&` to the error message.

`! Missing control sequence inserted.`

This error is most likely caused by a `\newcommand`, `\renewcommand`, `\newlength`, or `\newsavebox` command in which the backslash `\` is missing from the first argument. Pressing `<return>` as response will complete the processing correctly since \TeX assumes a backslash is missing and inserts it.

`! Missing number, treated as zero.`

This error is most likely due to a \LaTeX command that expects a number or length as argument, which is missing. It may also occur when a command that takes an optional argument is followed by text beginning with `[`. Finally another cause can be a `\protect` command preceding a length or `\value` command.

`! Missing { inserted.`

`! Missing } inserted.`

\TeX is totally confused when either of these error indicators is written. The line number printed will probably not be where the source of the error is to be found, which is a missing opening or closing brace. If the error is not obvious, continue the processing by pressing `<return>` and try to deduce where it might be from the printed output.

`! Missing $ inserted.`

Most likely a symbol or command that may only appear in math mode was used in normal text. Recall that all those commands described in Chapter 5 are only allowed in math mode unless otherwise stated. If an `\mbox` command is inserted within a math formula, its argument has temporarily exited from math to normal text mode. The message may also occur if a blank line appears within a math formula, signalling a new paragraph and the end of the formula without the necessary `$` sign.

`! Not a letter.`

The word list in a `\hyphenation` command contains a character that is not recognized as a letter, such as an accent command like `\'e`. Such words can only be hyphenated by explicitly inserting the hyphenation possibilities (Sections 2.8.1 and 2.8.2).

`! Paragraph ended before ... was complete.`

The argument of a command contains a blank line or a `\par` command, something that is not allowed. Probably a closing brace `}` has been omitted.

`! TeX capacity exceeded, sorry [...].`

\TeX sets up various storage buffers in the computer memory to carry out

the text processing. This message appears when one of these buffers is full and can no longer be used. The name of the buffer and its maximum size are printed in the square brackets of the error indicator. With this message, the T_EX processing is terminated. The source of this problem is hardly ever due to insufficient memory, no matter how much complicated text is being processed, but rather to an error in the text itself. The methods described in Section C.6 may be applied to try to detect the true error.

The following descriptions of the various buffers should help to decide whether the storage capacity allotted to T_EX really is too small and to explain what one might do to correct this.

buffer size The problem here can be that the text in the argument of a sectioning, `\caption`, `\addcontentsline`, or `\addtocontents` command is too long. The message then normally appears when the `\end{document}` command is processed, but may also arise at one of `\tableofcontents`, `\listoffigures`, or `\listoftables`. The way to avoid this is to use the optional argument for the short form of the heading text (Sections 3.3.3 and 7.4). Indeed, such a long entry in the table of contents is a nuisance anyway and should be shortened. After the correction has been made in the input text, the previous L^AT_EX .aux file must be deleted before reprocessing.

This problem can occur on a PC if a word processing program has been used to generate the input text instead of a text editor. Some of these programs put an entire paragraph into a single line even though the text on the monitor is broken up into lines.

exception dictionary The list of hyphenation exceptions that have been entered with the `\hyphenation` commands has become too large. Words used less frequently should be removed and their possible word divisions indicated explicitly with the `\-` command.

hash size The source file contains too many command definitions or uses too many cross-reference markers. This does not mean that the input text really needs all these commands, for it may be that the user has developed a large collection of private commands that are stored in a single file and read into every document, whether they are all applicable or not.

input stack size An overflow of this buffer is probably due to a mistake in a command definition. For example, the command defined with

```
\newcommand{\com}{One more \com}
```

produces `One more {One more {...One more \com}...}` going on for ever, since it continually calls itself. Actually, it does not go on for ever, but only until this buffer is full.

main memory size This buffer contains the text for the page currently being processed. It also overflows if a recursively defined command has been called. However, the more usual reasons are: (1) a large number of very complicated commands have been defined on one page; (2) there are too

many `\index` or `\glossary` commands on one page; (3) the page itself is too complex to fit within the allotted buffer space.

The solution to the first two situations is clear: reduce the number of command definitions and/or `\index` and `\glossary` commands on that page. In the third case, the cause might be a long `tabbing`, `tabular`, `array`, or `picture` environment, or a stuck float (figure or table) waiting for an output command.

To find out whether the memory overflow is really due to an overly complex page, add the command `\clearpage` just before the spot where the overflow occurs. If the error message no longer appears on the next processing run, then this page was indeed too complicated for \TeX . However, if the overflow still persists, the error is probably a mistake in the input text. If necessary, it may have to be located with the method explained in Section C.6.

If the page really is too complex for the \TeX processing, it must be simplified. However, first recall that the entire last paragraph is processed before that page is output, even if the page break occurs near the beginning of the paragraph. Introducing a `\newpage` may solve the problem and should be tried out before attempting a tedious restructuring of the text. If the error is due to a stuck figure or table, it might be alleviated by moving the float object to later in the text, or by changing the positioning argument (Section 7.1). If the whole text is not yet complete, one can try giving `\clearpage` for now in order to clear the blocked floats and then decide on a better ordering when the text is finalized.

pool size Most likely there are too many command definitions and/or labels, or their names are too long. Try shortening the names. This error may also occur if a closing right brace `}` has been forgotten in the argument of a counter command such as `\setcounter` or in a `\newenvironment` or `\newtheorem` command.

save size This buffer overflows when commands, environments, and the scope of declarations are nested too deeply. For example, if the argument of a `\multiput` command contains a `picture` environment, which in turn possesses a `\footnotesize` declaration with another `\multiput` command, and so on. Such a nesting must be simplified, unless the real problem is a forgotten closing brace `}` that merely makes the structure appear so complex.

! Text line contains an invalid character.

The input text contains a strange symbol that \TeX does not recognize. This could be a problem with the editor itself, that it is inserting extra characters. If an examination of the source file does not reveal the strange symbol, consult the computing center for help.

! Undefined control sequence.

Every \TeX user encounters this error message at some point. It is usually

the result of an incorrectly typed command name. It may be amended during the processing by responding with I and the proper name of the command, plus *<return>*. This does not alter the source file, which must be corrected separately after the \LaTeX run. If the command name has been entered correctly in a \LaTeX command, it may be that it was issued in an improper environment where it is not allowed (that is, not defined there).

! Use of ... doesn't match its definition.

If '...' is the name of a \LaTeX command, it is likely that one of the picture commands from Sections 13.1.3 and 13.1.4 has been called with the wrong syntax for its arguments. If the name is $\backslash@array$, there is a faulty @-expression (Section 4.8.1) in a `tabular` or `array` environment. Possibly a fragile command was given in the @-expression without the `\protect` command preceding it.

! You can't use 'macro parameter #' in ... mode.

The special symbol # has been used in normal text. Probably there should have been a $\backslash\#$ in order to print # itself. This can be corrected during the processing with the response I $\backslash\#$ and *<return>*.

C.5 Warnings

\TeX and \LaTeX errors both bring the processing run to a temporary stop and wait for a reaction from the user, or they may halt the program completely. Warnings, on the other hand, merely inform the user that the processed output may contain some faults that he or she might want to correct. Warnings appear on the monitor along with the page number where they occur, without the program coming to a stop. They are also written to the .log file where they may be examined after the \LaTeX processing and possible printing. Warnings may be issued either by \LaTeX or by \TeX itself.

C.5.1 General \LaTeX warnings

\LaTeX warnings are indicated by the words 'LaTeX Warning:' at their start, followed by the warning message itself.

```
LaTeX Warning: Citation '...' on page ... undefined on
input line ....
```

The key in a `\cite` or other citation command has not yet been defined with a corresponding `\bibitem` command (Section 9.3). If this message does not disappear on the next run, then the bibliography is missing

that defining `\bibitem` entry, either because `BIBTEX` has not been run, or because that reference is not in any of the specified databases.

LaTeX Warning: Command ... has changed.
Check if current package is valid.

The `\CheckCommand` statement is used to test if a given command has a certain definition. This warning is issued if the test fails. This is used to be sure that a given package is doing what the programmer thinks it is doing.

LaTeX Warning: Float too large for page by ..pt on input line...
A float (`figure` or `table` environment) is too big to fit on the page. It will be printed anyway, but will extend beyond the normal page margins.

LaTeX Warning: 'h' float specifier changed to 'ht'.
The float placement specifier 'h' for 'here' (Section 7.1) does not really mean exactly at the location of the float environment. It will be placed 'here' only if there is enough room remaining on the page for it, otherwise it appears at the top of the next available page. This message is a reminder of this fact.

LaTeX Warning: inputting '...' instead of obsolete '...'.
Some packages written for `LATEX 2.09` explicitly input certain files, such as `article.sty`, that have a new equivalent with a different name (in this case `article.cls`). Dummy files with the old names that issue this message and input the right file are provided.

LaTeX Warning: Label '...' multiply defined.
Two `\label` or `\bibitem` commands have defined keys with the same name (Sections 9.2.1 and 9.3). Even after the correction has been made, this message will be printed once more to the monitor since the information that led to it is to be found in the `.aux` file from the last processing run. On the run after that, it should be gone.

LaTeX Warning: Label(s) may have changed.
Rerun to get cross-references right.
The printed outputs from the `\ref`, `\pageref`, and `\cite` commands may be incorrect since their values have been altered during the processing. `LATEX` must be run once more so that the right values are used.

LaTeX Warning: Marginpar on page ... moved.
A marginal note on the given page has been shifted downwards to prevent it from being too close to another one. This means that it will not be beside the line of text where the `\marginpar` command was actually given.

LaTeX Warning: No `\author` given.

The `\maketitle` command has been issued without a previous `\author` command. Unlike a missing `\title` command, this is not an error, but merely peculiar. The warning is printed just in case you did mean to specify an author.

LaTeX Warning: Optional argument of `\twocolumn` too tall on page.

The `\twocolumn` command (Section 3.2.7) starts a new page and switches to two-column formatting. The text in the optional argument is printed in one wide column above the double column text. If that text is too large to fit onto one page, this warning is printed.

LaTeX Warning: `\oval`, `\circle`, or `\line size` unavailable on
input line

The size specified for an `\oval`, `\circle`, or slanted `\line` command in a `picture` environment is too small for \LaTeX to print.

LaTeX Warning: Reference ‘...’ on page ... undefined on
input line

The marker name in a `\ref` or `\pageref` command has not been defined by a `\label` command in the previous processing run (Section 9.2.1). If this message does not disappear on the next run, the corresponding `\label` command is missing.

LaTeX Warning: Text page ... contains only floats.

This message points out that the float style parameters (Section 7.3) have excluded any regular text from appearing on the specified page. This is not necessarily bad, but you might want to check that page visually.

LaTeX Warning: There were multiply-defined labels.

This message is printed at the end of the \LaTeX run if there were any `\label` or `\bibitem` commands that used the same marker name more than once. A warning is also printed near the beginning of the run for each repeated marker name.

LaTeX Warning: There were undefined references.

This message is printed at the end of the \LaTeX run if there were any `\ref` or `\pageref` commands whose markers had not been defined during a previous run. A warning is also printed earlier for each undefined marker used. If it does not disappear on the next run, then the corresponding `\label` is missing, maybe due to a typing error in the marker text.

C.5.2 L^AT_EX package warnings

The class and package warnings are those that check the names and versions of the loaded files against those requested, or the use of options, or whether the `filecontents` environment has written some text to a file. The commands involved are described in Section D.2.9.

Classes and packages can also issue their own warnings which are peculiar to them. These cannot be listed here, since they depend entirely on the class or package itself.

LaTeX Warning: File ‘...’ already exists on the system.
Not generating it from this source.

The `filecontents` environment is *not* extracting text from the main file because it has discovered a file of the same name already on the system.

LaTeX Warning: Unused global option(s):.

Options specified in the `\documentclass` statement are *global*, meaning they can apply to the class and/or to any following packages. However, if no class or package recognizes any of these options, this warning is printed, followed by a list of the unused options.

LaTeX Warning: Writing file ‘...’.

The `filecontents` environment (Section D.2.9) is extracting text out of the main file and writing it to a file of the given name.

LaTeX Warning: You have requested class/package ‘...’,
but the class/package provides ‘...’.

The name of the class or package as given by its internal identifying command `\ProvidesClass` or `\ProvidesPackage` does not agree with the file that was read in with `\usepackage` or `\RequirePackage`.

LaTeX Warning: You have requested, on input line ..., version
‘...’ of class/package ...,
but only version ‘...’ is available.

The date of a class or package file, as given by its internal identifying command `\ProvidesClass` or `\ProvidesPackage`, is earlier than that asked for by the `\usepackage` or `\RequirePackage` command. The class or package may not have all the features that the inputting file expects.

LaTeX Warning: You have requested release ‘...’ of LaTeX,
but only release ‘...’ is available.

The date of your L^AT_EX version is earlier than that specified for some input file in a `\NeedsTeXFormat` command (Section D.2.1). Your L^AT_EX may not provide all the features needed by that file.

C.5.3 L^AT_EX font warnings

Font warnings are those involving the NFSS commands (Appendix A). They are indicated by the text: `LaTeX Font Warning:` plus the warning text.

`LaTeX Font Warning: Command ... invalid in math mode.`

A command that should only appear in text mode has been given in math mode. The command is simply ignored. The commands `\mathversion`, `\boldmath`, `\unboldmath`, and `\em` lead to this message. There are other commands that produce an *error* message with the same text.

`LaTeX Font Warning: Command \tracingfonts not provided.`
 (Font) Use the ‘tracefnt’ package.
 (Font) Command found: on input line

The font tracing diagnostic tool `\tracingfonts` may only be used if the `tracefnt` package (page 393) has been loaded. Otherwise, this command is ignored.

`LaTeX Font Warning: Encoding ‘...’ has changed to ‘...’ for`
 (Font) symbol font ‘...’ in the math version ‘...’.

To make use of the specified symbol font in the given math version, it was necessary to change the font encoding temporarily.

`LaTeX Font Warning: Font shape ‘...’ in size <...> not available`
 (Font) size <...> substituted.

No font has been defined for the size and shape requested, so a substitute size is used instead.

`LaTeX Font Warning: Font shape ‘...’ undefined`
 (Font) using ‘...’ instead.

The shape attribute that has been requested is unknown, or has not been defined, so a substitute shape will be used instead.

C.5.4 T_EX warnings

A T_EX warning is recognized by the fact that it is not an error message (not prefixed with !) and that the processing is not halted. The most common T_EX warnings are:

`Overfull \hbox`

T_EX could not break this line in a reasonable way so part of it will extend into the right margin. The rest of the information in the message can be of assistance.



For example, with the complete warning message

```
Overfull \hbox (17.2122pt too wide) in paragraph at lines 4--6
[]\OT1/cmr/m/n/10 If T[X can-not find an ap-pro-pri-ate
spot to di-vide a word at the end of the line, as right
here aaaaaaaaaaaaaaaaaaaaaaaaaaaaa
```

one knows that the line is about 17.2 pt (6 mm) too long and extends this amount into the right-hand margin. The line is part of the paragraph in lines 4 to 6. The font used is designated by its attributes `\OT1\cmr/m/n/10`. The text of the problem line is `If right here aaaaaaaaaaaaaaaaaaaaaaaaaaaaa`. Possible word divisions are shown with hyphens, such as `di-vide`. The last word cannot be divided, which is the cause of the problem.

A way around this is to include some suggested hyphenations with the `\-` command, such as `aaaaaaaa\-----`. Similarly, a `\linebreak` command before the problem word, or setting the whole paragraph in a `sloppypar` environment, will get rid of this warning message.

If a badly broken line extends only a tiny bit into the right margin, say 1 pt or less, in most cases this will hardly be noticed and may be left as it is. A sample output should be printed just to verify the appearance.

```
Overfull \vbox ....
```

This warning occurs very rarely. \TeX could not break the page properly so that the text extends beyond the bottom of the page. More often \TeX sets less text on a page than too much. Thus this warning arises only when the page contains a very large vertical box, higher than the value of `\textheight`, such as a long table.

```
Underfull \hbox ....
```

This is the opposite of the `Overfull \hbox` warning. It appears when \TeX has filled a line right and left justified, but with so much interword spacing that it considers the appearance to be undesirable. This is often the result of a `sloppypar` environment, a `\sloppy` declaration, or a `\linebreak` command. It may also come about after an inappropriate application of a `\\` or `\newline` command, such as two `\\` commands one after the other. The additional information in the warning message contains the text of the badly formatted line plus an evaluation of the ‘badness’ of the word spacing.



If in the example of the `Overfull \hbox` a `\linebreak` is included in the text at the spot `...`, as `right\linebreak here`, then the warning becomes

```
Underfull \hbox (badness 5504) in paragraph at lines 4--6
[]\OT1/cmr/m/n/10 If T[X can-not find an ap-pro-pri-ate
spot to di-vide a word at the end of the line, as right
```

which states that the paragraph in lines 4 to 6 contains an output line in which the interword spacing may be unacceptably wide. The text of this line reads `If, as right` and is set in the font `\OT1\cmr/m/n/10`. The evaluation

`badness 5504` is \TeX 's estimate of how unacceptable the spacing is: *the smaller this number the better*.

`Underfull \vbox . . .`

The page has been broken with head and foot justified, but \TeX judges the amount of inter-paragraph spacing to be possibly unacceptable. The `badness` number here corresponds to the quantity with the same name from the `Underfull \hbox` warning.

C.6 Search for subtle errors

At some point or another you will encounter an error message for which you cannot identify any cause, try as you may. For such devious errors, we recommend the following search strategy:

1. Copy the file twice into a *previous* and a *working* copy (in addition to the original, which remains untouched during this search).
2. In the working copy, find the outermost environment where the error occurred and remove one or more inner environments. If there are no inner environments, shorten the remaining text. Process the file with \LaTeX once more.
3. If the error still occurs, copy the shortened working copy to the previous copy and repeat step 2. If the outer environment in step 2 is `\begin{document} . . . \end{document}`, the shortening may be carried out by simply inserting `\end{document}` at some earlier point.
4. If the error is no longer in the shortened working copy, copy the previous copy back to the working copy. The error is still present in this version. Remove less of the text than last time and repeat steps 2 to 4.
5. If the error is found to be in the next innermost environment, repeat the procedure for this environment with steps 2 to 4.

With this strategy, the error may be localized to one command or to the innermost environment with only a small remaining structure. If the error still cannot be identified in spite of its being precisely localized, seek help from a more experienced colleague or from the computing center. However, it is normally possible to recognize the mistake once the position of the error has been found.

It does happen that even though the error has been corrected, the same error message appears on the next \LaTeX process run. This is because of the internal transfer in information through the \LaTeX auxiliary files, which

are always one run behind on the current situation. For example, if there is a mistake in one of the sectioning commands, then after it has been eliminated, the faulty entry still exists in the `.toc` file. If the document contains the `\tableofcontents` command, \LaTeX will read in that `.toc` file on the next run, and issue the error message once more, since a new `.toc` file is only created after a successful processing.

In this case, the `.toc` file should also be edited and the error removed. If that is not possible, the file should be erased and the corrected source file processed *twice* with \LaTeX . If the error was in `\caption`, `\addcontentsline`, or `\addtocontents`, the same applies to the corresponding `.lof` or `.lot` file.

Occasionally the `.aux` file itself must be erased to prevent an error in it from being repeated even after the `.tex` file has been repaired. Here one must be careful that the command `\nofiles` has not been given in the preamble, for then a corrected `.aux` file will not be generated after a further \LaTeX process run.

D

L^AT_EX Programming

In this appendix, we present the special commands that were designed for class and package files, with several examples of useful packages. We also explain the system for integrating documentation with coding in a single file, the system used for the core L^AT_EX files and standard packages.

D.1 Class and package files

D.1.1 The L^AT_EX concept, an open system

The wealth of contributed L^AT_EX programming was probably never anticipated by Leslie Lamport when he released L^AT_EX. It is now a fact of life, and indeed one of the great strengths of the system. The L^AT_EX Team not only accommodates such ‘foreign’ extensions, it actually supports and encourages them, as witnessed by the copious presentations of such packages in *The L^AT_EX Companion* (Goossens *et al.*, 1994) as well as in this book.

And this is the way it should be. The extensions have been written by people who needed them, who realized that L^AT_EX was missing something vital for them. On the other hand, to add all of them to the basic L^AT_EX installation would overload it with features that 90% of the users would never require. The philosophy now is that L^AT_EX provides a fundamental core, or kernel, which is extended first by the standard class files, and then by the myriad of contributed packages and other classes.

It is the role of the L^AT_EX Team to establish guidelines for programming, to ensure that packages do not clash needlessly with the kernel, or with each other, and to provide a basis of stability so that useful packages continue to operate through further updates to the kernel and the standard classes. These L^AT_EX features for class and package control, together with a set of programming tools, offers an enhanced degree of reliability and durability, both among packages and against future updates of the kernel.

D.1.2 Levels of commands

There are a number of levels of commands with varying degrees of security for the future:

user commands (highest level) described in this and the other manuals, consisting of lower case letters, such as `\texttt`, are part of the L^AT_EX external definition to be supported forever;

class and package commands with longish names of mixed upper and lower cases (like `\NeedsTeXFormat`) are intended mainly for programmers, and are also guaranteed; most are preamble-only commands, but there is otherwise no real restriction to class and package files;

internal L^AT_EX commands containing the character @ in their names can only be used in class and package files; they are not guaranteed forever, although many of them are indispensable for special effects; a programmer makes use of them at the risk that some day his or her package may become obsolete;

low-level T_EX commands also have names with lower case letters, and no @; they should be safe against future evolution of L^AT_EX, but even this is not absolutely certain; they should be avoided where possible, as explained below;

internal private commands are those used within a contributed class or package file; it is recommended that they all be prefixed with some upper case letters representing the package name and @ in order to avoid clashes with other packages; for example, `\SK@cite`, from the `showkeys` package.

A question that confronts L^AT_EX programmers is to what extent the internal L^AT_EX commands may be used in class and package files. There is always a danger that such commands may vanish in later versions, since they have never been documented in the official books (Lamport, 1985, 1994; Goossens *et al.*, 1994). Like the T_EX commands discussed in the next section, their use cannot be forbidden, but one must be aware that a certain degree of risk will accompany them.

The guidelines issued by the L^AT_EX Team strongly recommend employing the high-level L^AT_EX commands whenever possible.

- Use `\newcommand` and `\renewcommand` instead of `\def`; if one of the T_EX defining commands must be used, because a template is required, or because it must be `\gdef` or `\xdef`, issue a dummy `\newcommand` beforehand to test for a name clash. If it is unimportant whether the command name already exists, issue a dummy

`\providecommand` followed by `\renewcommand`. The ability to define commands with one optional argument at the high level removes one reason for wanting to reach down to the lower ones.

- Use `\newenvironment` and `\renewenvironment` instead of defining `\myenv` and `\endmyenv`.
- Assign values to lengths and glues (rubber lengths) with the `\setlength` command, rather than by simply equating.
- Avoid the \TeX box commands `\setbox`, `\hbox`, and `\vbox`; use instead `\sbox`, `\mbox`, `\parbox` and the like. With the extra \LaTeX optional arguments, the need for the \TeX equivalents is greatly diminished, and the \LaTeX versions are far more transparent. Moreover, the \LaTeX boxes will function properly with the `color` package, while the others are unpredictable.
- Issue error and warning messages with `\PackageError` and `\PackageWarning` rather than with `\@latexerr` or `\@warning`; the former also inform the user of the source of the message, instead of labeling them all as \LaTeX messages.
- There is no suggestion that one should exclusively use the `\ifthenelse` command from the `ifthen` package (Section 8.3.5) in place of the \TeX conditionals. It seems that this package is offered to simplify employing conditionals, in a manner more consistent with \LaTeX syntax. Although most of the examples in this book use it rather than the \TeX versions, we never employ it ourselves in our own programming.

Adhering to these and similar rules will help ensure that a package will remain fit through future extensions of the \LaTeX kernel.

D.1.3 \TeX commands

Why should primitive \TeX commands be shunned? To define commands with `\def` rather than `\newcommand` must be just as good, and is often unavoidable. Is there really a chance that it might be removed from a future \LaTeX version? The primitives are the building blocks on which all flavors of \LaTeX are constructed. Surely they must remain!

This is not really the point. The primitive \TeX commands form the bedrock of any format, and anything defined with them will always do exactly what the programmer expected. However, the equivalent \LaTeX tools could actually do more as time goes on. The `\newcommand` checks for name clashes with existing commands, for example. It might even be possible that a debugging device that keeps track of all redefinitions could be added later; any commands defined with `\def` would be excluded from

such a scheme. Even now there is something like this to keep track of all files input with middle and high-level commands.

Another example of how low-level programming can go astray is the case of robust commands. Many commands are intrinsically fragile, meaning that they are prematurely interpreted when used as arguments of other commands, but they may be made robust by prefixing them with `\protect`. In L^AT_EX 2.09, several fragile commands were defined to be robust by including the `\protect` in the definition, as for the L^AT_EX logo command:

```
\def\LaTeX{\protect\p@LaTeX}
\def\p@LaTeX{...}
```

The true definition is in the internal `\p@LaTeX`, not the external `\LaTeX`. Since the original definition for the logo actually possessed some flaws, several packages included an improved version. Those that simply redefined `\LaTeX` itself made the command fragile; those that were cleverer only redefined `\p@LaTeX`, with the result that they are totally left behind in L^AT_EX 2_ε, where commands are made robust in a completely different (and much better) manner. (Incidentally, the internal definition of the L^AT_EX logo today has been greatly improved.)

In spite of the desirability of employing only official L^AT_EX commands, there are many occasions when either the internal L^AT_EX commands or the T_EX primitives just must be used. The risk of future incompatibility must be taken in order to have a workable package now. However, one should not take this risk lightly, where a high-level equivalent is available.

D.2 L^AT_EX programming commands

All the commands described in this section are new to L^AT_EX 2_ε. They are not essential to class and package files, but they do extend their usefulness and guarantee that they are employed properly.

D.2.1 File identification

Three commands test that the external environment in which the class or package has been inserted is correct. The first of these is

```
\NeedsTeXFormat{format}[version]
```

The first statement in a class or package should be the declaration of the T_EX format needed. Although there are existing formats with other names, only the one named `LaTeX2e` actually recognizes this statement. All others will immediately issue the error message

```
! Undefined control sequence.
```

```
1.1 \NeedsTeXFormat
      {LaTeX2e}
```

which all by itself is fairly informative.

What is perhaps of more use is the optional *version* argument, which must contain the date of issue in the form *yyyy/mm/dd*. If a package makes use of features that were introduced in a certain version, its date should be given, so that if it is used with an earlier version of L^AT_EX 2_ε, a warning is printed. For example, the command `\DeclareRobustCommand` did not exist in the preliminary test release of L^AT_EX 2_ε, but was first introduced with the official release of June 1, 1994. Thus any package containing this command should begin with

```
\NeedsTeXFormat{LaTeX2e}[1994/06/01]
```

The form of the date is important, including the zeros and slashes.

This declaration is not limited to class and package files: it may also be issued at the start of the document itself to ensure that it is processed with the right L^AT_EX. It must, however, be given in the preamble.

The next two commands identify the class or package file itself:

```
\ProvidesClass{class}[version]
\ProvidesPackage{package}[version]
```

In both cases, the *version* consists of three parts: date, version number, and additional information. The date is in the same format as above, while the version number can be any designation without blanks, and the additional information is text with or without blanks. An example is

```
\ProvidesPackage{shortpag}[1995/03/24 v1.4 (F. Barnes)]
```

Only the date part is actually checked by L^AT_EX against the date specified in the calling `\usepackage` command. The version number and additional information are printed out if `\listfiles` has been requested. However, the above format is necessary for the `\GetFileInfo` command in the doc package (Section D.7.2).

Both the `\documentclass` and `\usepackage` commands (as well as `\LoadClass` and `\RequirePackage`) may take an optional argument to specify the earliest acceptable release date for the class/package. For example, with

```
\documentclass[12pt]{article}[1995/01/01]
```

if the `article` class file loaded contains

```
\ProvidesClass{article}[1994/07/13 v1.2u
  Standard LaTeX document class]
```

a warning message is printed. The same procedure applies to the commands `\usepackage` and `\ProvidesPackage`.

This system of version checking allows a document to insist that suitable versions of the class and package files are loaded. It assumes, however, that all later versions are fully compatible with earlier ones.

There is a further identifying command for general files, those to be loaded with `\input`.

```
\ProvidesFile{file.name}[version]
```

There is no checking of the name or version in this case, but both pieces of information will be printed by `\listfiles`.

D.2.2 Loading further classes and packages

In the main document file, classes are read in by means of the initializing `\documentclass` command, and packages with `\usepackage`. Within class and package files, the commands

```
\LoadClass[options]{class}[version]
\RequirePackage[options]{package}[version]
\LoadClassWithOptions{class}[version]
\RequirePackageWithOptions{package}[version]
```

must be used instead. The first allows one class file to load another, with selected options, if desired; the second permits class and package files to load other packages. Only one `\LoadClass` command may appear within any class file; it may not be called from a package file. Neither command may be invoked in the document file. The *packages* argument may be a list of several package names, separated by commas.

The `...WithOptions` variants load the class or package with all those options that were specified for the current one, something that is often required.

How the optional *version* arguments interact with the corresponding `\Provides..` command has been explained in the previous section; how the *options* argument is treated is described below.

D.2.3 Processing options

Both classes and packages may take options which are defined with

```
\DeclareOption{option}{code}
```

where *option* is the name of the option and *code* is the set of instructions that it is to execute. Internally, a command named `\ds@option` is created. Often the code does nothing more than set flags, or input an option file. (`\RequirePackage` may *not* be used within the option code!) Two examples from `article.cls` are

```
\DeclareOption{fleqn}{\input{fleqn.clo}}
\DeclareOption{twocolumn}{\setboolean{@twocolumn}{true}}
```

A default option is defined with `\DeclareOption*`, which takes no option name, specifying the code to be executed for all requested options that are undefined.

There are two special commands that may be used only within the *code* of the default option definition:

`\CurrentOption` contains the name of the option being processed;

`\OptionNotUsed` declares `\CurrentOption` to be unprocessed.

For example, to have a class file emulate L^AT_EX 2.09 behavior where all undefined options load a `.sty` file of the same name, define

```
\DeclareOption*{\InputIfFileExists{\CurrentOption.sty}%
  }{\OptionNotUsed}}
```

which first checks if there is a `.sty` file of the requested name, and if not declares the option to be unused. Requested options that have not been used (processed) are listed in a warning message.

The options are then processed with the commands

```
\ExecuteOptions{option_list}
\ProcessOptions
\ProcessOptions*
```

where `\ExecuteOptions` calls those commands defined for the options in *option_list*. This is normally done to establish certain options as being present by default. `\ProcessOptions` executes all the requested options *in the order in which they were defined* and then removes them from the list. Options are therefore executed only once by this command. The **-version* is similar, except that the options are executed *in the order requested*.

It is also possible to transfer options to a class or package file with

```
\PassOptionsToClass{options}{class_name}
\PassOptionsToPackage{options}{package_name}
```

where *options* is a list of valid options recognized by the specified class or package file. These commands may be used within the definition of other options. The class or package named must later be loaded with `\LoadClass` or `\RequirePackage`.

If the default options for class and package files have not been altered by `\DeclareOption*`, the standard procedure for handling options that have been requested but are undefined is

- all options requested in the `\documentclass` statement are designated *global*; they are considered to apply to all subsequent packages, but not to classes loaded with `\LoadClass`; if they are not defined in the class, no error or warning is issued;

- all options requested with other commands, including `\LoadClass` and the `\PassOptionsTo...`, are *local*; if they are not defined in that class or package, an error is issued;
- if there global options that are defined in neither the class nor any of the packages, a warning is issued;
- options, global and local, are executed in the order in which they are defined in the class and packages, unless `\ProcessOptions*` has been called in which case they are executed in the order in which they are listed.

D.2.4 Deferred processing

Sometimes, to achieve certain special effects or to avoid possible conflicts with other packages, it is desirable to have some commands executed at the end of the package or class, or at the beginning or end of the document. This can be accomplished with

```

\AtEndOfClass{cmds}
\AtEndOfPackage{cmds}
\AtBeginDocument{cmds}
\AtEndDocument{cmds}

```

The first two store away *cmds* to be carried out at the end of the class or package file. They can be used by local configuration files that are read in at the beginning, but contain modifications that should be made at the end so that they are not overwritten by the defaults. The last two declarations store away the *cmds* to be executed with `\begin{document}` and `\end{document}` respectively. All of these may be issued more than once, in which case the *cmds* are processed in the order in which they were issued.

The *cmds* stored with `\AtBeginDocument` are inserted into the processing stream effectively within the preamble, but after the command `\begin{document}` has done almost everything else that it does. Thus the *cmds* may be considered to be part of the main body but preamble-only commands are also allowed.

D.2.5 Robust commands

Commands may actually be *fragile*, meaning that if they are used in the arguments of other commands, they could be prematurely interpreted, causing unexpected problems. This happens with moving arguments, those that appear somewhere else other than where they were given: in the table of contents and in running headlines. Complex commands with conditionals or redefinitions are likely to be fragile.

Many intrinsic commands in L^AT_EX 2.09 were fragile, and it was necessary to precede them with `\protect` when they appeared in the argument of a `\section` command, for example. In this case, the command name is transferred rather than its translation. Some commands could be made *robust* using the trick shown on page 440 for the `\LaTeX` command itself.

In today's L^AT_EX, almost all regular commands are robust. However, the commands a user may define with `\newcommand`, `\renewcommand`, and `\providelcommand` (Section 8.3) may very well be fragile. Alternatively, one can define the commands with

```
\DeclareRobustCommand{\com_name}[narg][opt]{def}
```

which has the same syntax as the other defining commands. If the command to be defined already exists, a message is written to the transcript file, and the old definition is overwritten.

Another command with the same syntax simply checks the current definition of `\com_name`:

```
\CheckCommand{\com_name}[narg][opt]{def}
```

and issues a warning message if the actual definition is not the same as `def`, with the same number of arguments, and so on. This is used to ensure that the state of the system is as one expects, and that no previously loaded packages have altered some important definition.

Both `\DeclareRobustCommand` and `\CheckCommand` may be called at any point in the document.

D.2.6 Commands with 'short' arguments

Normally, the arguments to user-defined commands are allowed to contain new paragraphs, with the `\par` command or with a blank line. In T_EX jargon, these commands are said to be 'long'. This is not the standard behavior for commands created with the T_EX `\def` command, where the arguments must be short in order to act as a test for forgotten closing braces.

With the version from December 1, 1994, L^AT_EX provides *-forms of all the defining commands:

```
\newcommand*           \renewcommand*
\newenvironment*      \renewenvironment*
\providelcommand*
\DeclareRobustCommand* \CheckCommand*
```

which create user-defined commands with 'short' arguments in the same way as does `\def`.

It is recommended that one should almost always take the *-version of these defining commands, unless there is some very good reason to expect that the possible arguments may be 'long', that is, contain new paragraphs. Long arguments should be the exception, not the rule.

D.2.7 Issuing errors and warnings

Classes and packages may be programmed to issue their own error messages and warnings. This is useful to indicate which file is responsible for the message.

Error messages are generated with

```
\ClassError{class_name}{error_text}{help}
\PackageError{package_name}{error_text}{help}
```

where *error_text* is the message printed to the monitor and to the transcript file, and *help* is additional text printed after the user responds with H. If the texts contain command names that are to be printed literally, they must be preceded by `\protect`; spaces are generated with `\space`, and new lines with `\MessageBreak`. For example,

```
\PackageError{ghost}{%
  The \protect\textwidth\space is too large\MessageBreak
  for the paper you have selected}
  {Use a smaller width.}
```

produces the error message

```
! Package ghost Error: The \textwidth is too large
(ghost)                for the paper you have selected.
```

See the ghost package documentation for explanation.
Type H <return> for immediate help.

Typing H <return> produces

Use a smaller width.

after which L^AT_EX halts again to wait for a response as described in Section C.1.

Warnings may also be issued from classes and packages in a similar way. The difference is that there is no *help* text, and the processing does not stop for a response. The line number of the input file where the warning occurred may be optionally suppressed.

```
\ClassWarning{class_name}{warning_text}
\ClassWarningNoLine{class_name}{warning_text}
\PackageWarning{package_name}{warning_text}
\PackageWarningNoLine{package_name}{warning_text}
```

For example, with the warning

```
\PackageWarning{ghost}
  {This text is haunted}
```

one obtains the message

```
Package ghost Warning: This text is haunted on input line 20.
```

and the processing continues. Warnings may be split into several lines with the `\MessageBreak` command, just like error texts.

Two last commands of this type are

```
\ClassInfo{class_name}{info_text}
\PackageInfo{package_name}{info_text}
```

which write their texts only to the transcript file, and not to the monitor. They are otherwise just like the corresponding `NoLine` warnings.

D.2.8 Inputting files

Files other than classes and packages may also be input, in which case it is often desirable to make sure that they exist beforehand. Or, alternative actions might be taken depending on the existence of a certain file. These goals are met with

```
\IfFileExists{file_name}{true}{false}
\InputIfFileExists{file_name}{true}{false}
```

Both these commands test for the presence of the specified *file_name* in the area that L^AT_EX is looking for files, and execute *true* if it is found, otherwise *false*. In addition, `\InputIfFileExists` reads in that file after executing *true*.

These commands are not restricted to the preamble, nor to class or package files. In fact, the regular `\input` command is defined in terms of them.

Many special classes make use of these commands to read in a local configuration file. For example, the class `ltxdoc` contains

```
\InputIfFileExists{ltxdoc.cfg}
{\typeout{Local config file ltxdoc.cfg used}}
{}
```

just before `\ProcessOptions` is called. This allows one to have a local configuration that might specify

```
\PassOptionsToClass{a4paper}{article}
```

for a European installation, without altering the files that are processed with the `ltxdoc` class.

D.2.9 Checking files

Although not really part of programming, two L^AT_EX features to keep track of input files are described here. The first of these, already mentioned in Section 9.1.1, is the command

```
\listfiles
```

which may be given in the preamble, even before `\documentclass`. It causes a list of all input files to be printed at the end of the processing, along with their version and release data. In this way, one has a record of just which files were included, something that may be of use when deciding to send a document file to another installation for processing there. Since any non-standard files may also have to be included, these may be more readily identified from such a listing.

For example, the simple document file

```
\documentclass{article}
\usepackage{ifthen}
\listfiles
\begin{document}
  \input{mymacros}
  This is \te.
\end{document}
```

produces the listing

```
*File List*
article.cls 2001/04/21 v1.4e Standard LaTeX document class
size10.clo 2001/04/21 v1.4e Standard LaTeX file (size option)
ifthen.sty 2001/05/26 v1.1c Standard LaTeX ifthen package
mymacros.tex
*****
```

In this case, the local file `mymacros.tex` contains no version information because it is missing a `\ProvidesFile` command.

What should one do if a local file, such as `mymacros.tex` above, is needed for the processing of a document file that is to be sent elsewhere? One could send it along with the main file, but that requires giving the recipient more instructions on what to do. Or, its contents could simply be included in the main file, for shipping purposes. For a package file, this is not so easy, since internal commands containing the `@` sign would cause trouble, and the options would not be handled properly. For this purpose, we have the environment

```
\begin{filecontents}{file_name}
  file contents
\end{filecontents}
```

which may only appear at the very beginning of the document, before the `\documentclass` command. It tests to see if there is a file on the system with the name *file_name*, and if not, it writes its contents literally to a file of that name. This may be a package file that is subsequently input with `\usepackage`. In this way, the missing non-standard files can be ported together with the main document file.

If we extend the above simple example by including at the very start

```
\begin{filecontents}{mymacros}
\newcommand{\te}{the end}
\end{filecontents}
```

the newly written file `mymacros.tex` contains

```
%% LaTeX2e file 'mymacros'
%% generated by the 'filecontents' environment
%% from source 'mydoc' on 2003/01/31.
%%
\newcommand{\te}{the end}
```

Note that the `filecontents` environment adds some comment lines to explain where the new file came from. If this is undesirable, the `filecontents*` environment may be used instead.

D.2.10 Useful internal commands

!

Notwithstanding the guidelines in Section D.1.2 that recommend avoiding internal L^AT_EX commands, there are a number that are fairly fundamental, and indeed form many of the building blocks of the L^AT_EX kernel and many standard packages. Since they are still internal commands, they are not guaranteed for all future updates. However, if they were to vanish, many of the interesting extension packages provided by the L^AT_EX Team itself would have to be drastically overhauled. We merely present them briefly here for the sake of the bolder user.

```
\@namedef{cmd}{def}
\@nameuse{cmd}
```

define and execute a command named `\cmd`, where the backslash is not included in the command name. This name may contain any characters, even those normally forbidden in command names.

```
\@ifundefined{cmd}{true}{false}
```

executes *true* if the command `\cmd` does not exist, else *false*. Again, the backslash is not included in `cmd`, and any characters may appear in the command name. This test is often used to define commands conditionally, a task that has been taken over by `\providecommand`. It may also be employed to determine whether the main class is article-like or not: `\@ifundefined{chapter}{.}{.}` tests for the existence of the `\chapter` command.

```
\@ifnextcharchar{true}{false}
```

tests if the next character is *char*, and if so, executes *true*, else *false*. This command is traditionally used to define commands with optional arguments, where *char* is `[`. The extended syntax of `\newcommand` offers a high-level means of achieving this.

```
\@ifstar{true}{false}
```

tests if the next character is a star *, and if so, executes *true*, else *false*. It is used to define *-forms of commands and environments, something that still cannot be done at the high level.

```
\@for \obj := \list \do {cmds}
```

where `\list` is a command that is defined to be a list of elements separated by commas, and `\obj` is successively set equal to each of these elements while the code `cmds` is executed once for each element. For example,

```
\newcommand{\set}{start,middle,end}
\@for \xx:=\set \do {This is the \xx. }
```

prints ‘This is the start. This is the middle. This is the end.’

D.2.11 Useful T_EX commands

!

Many of the most sophisticated features of L^AT_EX and its packages can only be programmed with the help of Plain T_EX commands. These are described not only in *The T_EXbook* (Knuth, 1986a), but also in the excellent reference manual by Eijkhout (1992), *T_EX by Topic, a T_EXnician’s Reference*.

We do not intend this book to a manual for T_EX; nevertheless, there are a few common T_EX commands that appear in many packages, and even in the examples to follow. A brief description of what they do will aid the understanding of these codings. A true T_EXpert or T_EXnician can skip this section altogether.

```
\def\cmd#1#2..{definition}
```

is the standard defining command in T_EX. It is the equivalent of `\newcommand*` except that there is no check for name clashes, and the arguments are specified differently. For example, a command `\Exp` to write scientific notation can be defined as

```
\def\Exp#1#2{\ensuremath{#1\times10^{#2}}}
or as \newcommand*\Exp}[2]{\ensuremath{#1\times10^{#2}}}
```

In both cases, `\Exp{1.1}{4}` produces 1.1×10^4 . However, `\def` can go further: it can put the arguments in a template, such as

```
\def\Exp#1(#2){\ensuremath{#1\times10^{#2}}}
```

to allow the more convenient notation `\Exp1.1(4)`, something that cannot be produced with `\newcommand`. The `\def` command is often used when a command is to be defined without knowing (or caring) whether its name already exists, or when a template is needed.

```
\gdef \edef \xdef
```

are variations on `\def`: the first makes a *global* definition, valid even outside the current environment or `{. .}` bracketing; the second is an *expanded* definition, such that any commands in it have their meanings and not the command itself inserted in the definition; the last is a combination of the other two, expanded and global.

```
\noexpand \expandafter
```

control the expansion of commands in definitions and execution. Any commands in the definition part of `\edef` are expanded (their meanings inserted) unless they have `\noexpand` before them. The opposite is achieved with `\expandafter`, which jumps over the following command, expands the next one, and then executes the one skipped. This is very deep TeXnology, and is best illustrated by an example with the `\Exp` command defined above.

```
\newcommand*{\mynums}{1.1(4)} \expandafter\Exp\mynums
```

is identical to `\Exp1.1(4)`, whereas `\Exp\mynums` is not; `\mynums` is expanded to `1.1(4)` *before* `\Exp` is executed.

```
\let\cmd.a = \cmd.b or \let\cmd.a\cmd.b
```

makes `\cmd.a` take on the *current* meaning of `\cmd.b`. This is often employed to save the current meaning of a command before redefining it, possibly using the older meaning too.

```
\relax
```

does absolutely nothing, but it is often inserted in places where something should be but nothing is wanted.

```
\ifcond true.code \else false.code \fi
```

is the form of a TeX conditional. There are too many variations on the condition *cond* to explain here, but one common application is the equivalent of the L^AT_EX boolean switch commands:

```
\newif\ifflag = \newboolean{flag}
\flagtrue     = \setboolean{flag}{true}
\flagfalse   = \setboolean{flag}{false}
\ifflag ..\else..\fi = \ifthenelse{\boolean{flag}}{..}{..}
```

For those who are used to it, the TeX form is more compact, but does not conform to the general L^AT_EX style of doing things.

```
\ifcase num text.0 \or text.1 \or ... \fi
```

executes one of the *text.num* according to the value of *num*.

```
\endinput
```

terminates the current file being input. This is not really necessary, but it is considered good programming to end all files this way. The main document file does not need it since `\end{document}` has the same effect.

D.3 Sample packages

We present here some demonstration packages to illustrate the programming commands of the previous section. These packages are not trivial and are all useful in their own right, even though their functionality is covered by others described in this book.

D.3.1 Modifying the text page size

The standard L^AT_EX classes set the text size parameters `\textwidth` and `\textheight` according to the size option specified in `\documentclass`, such as `a4paper` or `legalpaper`. They also adjust the margins so that the text is centered both horizontally and vertically. The value of `\textwidth` is restricted, however, so that there are at most 60–70 characters per line, this being considered optimal by the rules of typography.

Often one wants to ignore this limitation and use the paper to its maximum extent. The `geometry` package from Section 3.2.6 does this and much more. Here we present a simpler package for this single function.

The `fullpage` package presented here uses the values of `\paperwidth` and `\paperheight`, which have been set according to the paper size option, to produce a margin of one inch on all sides. It even considers what the page style is so that room for head and footlines may be taken into account. Optionally, it may set an even narrower margin of 1.5 cm.

Before proceeding, it might be useful to review the page format parameters shown in the figures on pages 48 and 602.

The package file begins by stating that it needs L^AT_EX 2_ε and by identifying itself. The package information contains the date in prescribed form, the version number, and additionally the initials of the author. The `ifthen` package is then loaded since conditionals will be required.

```
\NeedsTeXFormat{LaTeX2e}
\ProvidesPackage{fullpage}[2002/02/15 1.1 (PWD)]
\RequirePackage{ifthen}
```

Next the options are prepared. These are to be `in` and `cm` for margins of 1 in and 1.5 cm respectively (1 cm is really too narrow). A special length is used to store the margin value. This is a private, internal command, conforming to the convention mentioned on page 438.

```
\newlength{\FP@margin}
\DeclareOption{in}{\setlength{\FP@margin}{1in}}
\DeclareOption{cm}{\setlength{\FP@margin}{1.5cm}}
```

Furthermore, the four standard page styles are also to be option names. They will set two internal boolean switches and the page style.

```
\newboolean{FP@plain}
\newboolean{FP@empty}
\DeclareOption{plain}{\setboolean{FP@plain}{true}
                     \setboolean{FP@empty}{false}
                     \pagestyle{plain}}
\DeclareOption{empty}{\setboolean{FP@plain}{true}
                     \setboolean{FP@empty}{true}
                     \pagestyle{empty}}
\DeclareOption{headings}{\setboolean{FP@plain}{false}}
```



```

\setboolean{FP@empty}{false}
\pagestyle{headings}
\DeclareOption{myheadings}{\setboolean{FP@plain}{false}
\setboolean{FP@empty}{false}
\pagestyle{myheadings}}

```

Finally, the default set of options is executed, and then the selected options are processed, in this case, in the order specified. The reason for this is that if more than one page style has been given, the last one should dominate.

```

\ExecuteOptions{in,plain}
\ProcessOptions*

```

Now the calculation can begin. First, for `plain` and `empty`, there are no headlines, so set the relevant parameters to zero. This is when `FP@plain` is `<true>`. Then set the space reserved for the footline to zero for the `empty` page style (`FP@empty` is `<true>`). For `headings` and `myheadings`, this space is maintained since these styles normally have a `plain` page (with footline) on the first page.

```

\ifthenelse{\boolean{FP@plain}}
  {\setlength{\headheight}{0pt}
\setlength{\headsep}{0pt}}{}
\ifthenelse{\boolean{FP@empty}}
  {\setlength{\footskip}{0pt}}{}

```

With all the margins and headline and footline spacings set, the actual calculation can be made. Recall that the driver program leaves a 1 inch margin at the left and above, which must be subtracted from `\topmargin` and `\oddsidemargin`.

```

\setlength{\textwidth}{\paperwidth}
\addtolength{\textwidth}{-2\FP@margin}
\setlength{\oddsidemargin}{\FP@margin}
\addtolength{\oddsidemargin}{-1in}
\setlength{\evensidemargin}{\oddsidemargin}

```

```

\setlength{\textheight}{\paperheight}
\addtolength{\textheight}{-\headheight}
\addtolength{\textheight}{-\headsep}
\addtolength{\textheight}{-\footskip}
\addtolength{\textheight}{-2\FP@margin}
\setlength{\topmargin}{\FP@margin}
\addtolength{\topmargin}{-1in}

```

Remember that `\paperheight` and `\paperwidth` are set to the full dimensions of the paper by the paper size option. If this is wrongly specified, of course, the final result will be incorrect.

This completes the coding for the package file `fullpage.sty`. An example of how it might be invoked is

```

\documentclass[a4paper,12pt]{article}
\usepackage[headings]{fullpage}
. . . . .

```

D.3.2 Redesigning the head and footlines

Something that is often demanded by L^AT_EX users is the possibility of altering the head and footlines that appear on each page. Standard L^AT_EX does provide a limited number of *page styles* (Section 3.2) but these are not always sufficient. The most flexible of them is the `myheadings` page style which allows the author to determine the text of the running heads with `\markright` and `\markboth`. However, the general format, including font style and placement of the page number, is still fixed by L^AT_EX.

The `fancyhdr` package by Piet van Oostrum (Section 3.2.2) solves all this very nicely for most cases. Nevertheless we present this example to show how it is done internally, and to illustrate how some other special effects can be achieved.

We wish to modify the headline for documentation of large projects requiring particular information in the running head. Apart from a short version of the title and the section and page numbers, they might demand the document serial number, date, and version number. It would be useful to have a generalized documentation page style that allows these entries to be specified outside of the page style definition itself.

Since this coding is only feasible for the `article` class, we will create a new class, called `dohead`, that inputs `article.cls` and then defines a new page style. Actually this class could contain many other special features of which our new page style is only one.

Again we start by declaring the T_EX version that we need (release 4 from December 1, 1995), and by identifying the class file.

```

\NeedsTeXFormat{LaTeX2e}[1995/12/01]
\ProvidesClass{dohead}[2002/04/27 1.5 (PWD)]

```

This class has no options of its own, passing all specified ones on to the underlying `article` class by means of the `\LoadClassWithOptions` command, which only became available with release 4.

```

\LoadClassWithOptions{article}

```

Now come the commands that are used to enter the four pieces of information for the headline: short title, date, serial number, and version. Each of these commands stores its argument in an internal `\DH@` command, each of which is initially set to be empty. Finally, the entering commands are declared to be allowed only in the preamble, since it would be disastrous if they were called after the main text had started.

```

\newcommand*{\DocTitle}[1] {\renewcommand*{\DH@title}{#1}}
\newcommand*{\DocDate}[1] {\renewcommand*{\DH@date}{#1}}

```

```

\newcommand*{\DocNumber}[1]
    {\renewcommand*{\DH@number}{\MakeUppercase{#1}}}
\newcommand*{\DocVersion}[1]{\renewcommand*{\DH@version}{#1}}
\newcommand*{\DH@title}{} \newcommand*{\DH@date}{}
\newcommand*{\DH@number}{} \newcommand*{\DH@version}{}
\@onlypreamble{\DocTitle} \@onlypreamble{\DocDate}
\@onlypreamble{\DocNumber} \@onlypreamble{\DocVersion}

```

The `\@onlypreamble` command is an internal L^AT_EX one.

Note: The commands `\MakeUppercase` and `\MakeLowercase` (not used here) set the case of their arguments. The former is used here to ensure that the document number always appears in upper case letters.

We now define the new page style, `dochead`, which means we must create a command `\ps@dochead`, to be executed by `\pagestyle{dochead}`. What this command must do is redefine the four internals `\@oddhead`, `\@evenhead`, `\@oddfont`, and `\@evenfoot`. We make the footlines empty, and the even and odd headlines identical. That headline is to be a minipage, the full width of the page, containing a table with the relevant document information.

```

\newcommand*{\ps@dochead}{%
\renewcommand*{\@oddhead}{%
\begin{minipage}{\textwidth}\normalfont
\begin{tabular*}{\textwidth}{@{}l@{\extracolsep{\fill}}%
l@{\extracolsep{Opt}:~}l@{}}%
\DH@number & Version & \DH@version \\
\DH@title & Section & \thesection \\
Date:\DH@date & Page & \thepage
\end{tabular*}\vspace{0.5ex} \rule{\textwidth}{0.6pt}%
\end{minipage}}
\renewcommand*{\@evenhead}{\@oddhead}
\renewcommand*{\@oddfont}{}
\renewcommand*{\@evenfoot}{}
}
\pagestyle{dochead}

```

The last line activates the new page style.

It is also necessary to increase the size of `\headheight` and `\headsep` because our headline is much higher than normal. We pick a height of 3.5 times a regular line.

```

\setlength{\headheight}{3.5\baselineskip}
\setlength{\headsep}{3em}

```

We now add a further refinement. Such documentation normally wants the pages to be numbered within the sections. Therefore, we want to redefine the command `\thepage` which prints the page number from the page counter (Section 8.1.4), and we need to modify the `\section` command to start a new page and to reset the page counter. This is done by storing the current definition of `\section` and then redefining it.

```

\let\DH@section=\section
\renewcommand*{\thepage}{\thesection-\arabic{page}}
\renewcommand*{\section}{\newpage\setcounter{page}{1}\DH@section}

```

Notice that the new `\section` command calls the old one now stored in our own internal command `\DH@section`.

If the above is written to a file named `dohead.cls`, the following source text could be used to invoke it:

```

\documentclass[12pt,a4paper]{dohead}
\DocTitle{Spacecraft Cleanliness}
\DocNumber{Esa--xy--123}
\DocDate{2003 Feb 26}
\DocVersion{4.2}
\begin{document}
. . . . .

```

The headline on the fourth page of Section 3 would then appear as below.

ESA-XY-123	Version: 4.2
Spacecraft Cleanliness	Section: 3
Date: 2003 Feb 26	Page : 3-4

With this example as a model, it should not be difficult to create similar headlines for other applications with different entries.

D.3.3 Reprogramming the sectioning commands

Another aspect of L^AT_EX formatting that one might want to alter is the appearance of the sectioning titles. The fonts used, as well as their sizes and the spacing around them, are all rigidly set in the class files. We know users who feel so frustrated by the predefined sectioning that they type in their own by hand, including the numbers, something that completely violates the L^AT_EX concept of logical markup.

In fact, all the sectioning commands from `\section` to `\subparagraph` are defined by means of a generalized internal section command with the following syntax:

```

\@startsection{sec-name}{level}{indent}{pre-skip}{post-skip}
{style}* [short title] {title}

```

where both the `*` and `[short title]` are optional. A command like `\section` is defined to be `\@startsection` with all the arguments up to and including `style`; the remaining optional `*`, `short title`, and `title` are given as arguments to `\section` itself (Section 3.3.3). The meanings of these arguments are:

sec-name: the name of the section level, for example `subsection`; this name is used to select the appropriate counter and to enter the *title* correctly in the table of contents and page headlines;

level: is the number in the sectioning hierarchy as described on page 56, 1 for `\section`, 2 for `\subsection` ...;

indent: is the amount of indentation from the left margin;

pre-skip: is a rubber length, the absolute value of which is the space inserted above the title; if this is negative, the first paragraph following the section title is *not* indented;

post-skip: is a rubber length; if positive, it is the space inserted below the title; if negative, its absolute value is the space between the title and the subsequent run-in text;

style: font declarations issued when printing the section title, such as `\bfseries` and `\Large`;

***: optional; if present, the section counter is not incremented, the section is not numbered, no entry is made in the table of contents;

short title: optional alternative text for the table of contents and page headline; may only be given if the *** is absent;

title: the text printed as the section title; if *short title* is missing, this text is also entered in the table of contents and page headline.

The font style of the title is determined by the declarations in *style*; these must be declarations, like `\bfseries`, and not commands with arguments like `\textbf`. However, with the release from June 1, 1996, the last item in the *style* list may indeed be a command with an argument. This permits something like `\bfseries\MakeUppercase` to force the title to be bold face capital letters.

Rubber lengths with generous stretch and shrink should be given for *pre-skip* and *post-skip* to allow L^AT_EX more freedom in avoiding bad page breaks.

The section number is written with the command `\@secntformat` that takes one argument, the name of the sectioning counter (*sec-name* above) that is to be printed. This may be redefined for special effects, as illustrated in the example below.

Since both `\@startsection` and `\@secntformat` contain `@`, they are internal commands that can only be used in a class or package file. We give here a brief package, `mysects.sty`, which redefines all the sectioning commands. The values of *pre-skip* and *post-skip* are those in the standard `article.cls`.

```
\NeedsTeXFormat{LaTeX2e}[1996/06/01]
\ProvidesPackage{mysects}[2003/03/21 v2.1 (PWD)]
```

The date of the fifth L^AT_EX release is specified because we want to use a command in the font styles. We start with the `\section` command which is to be centered, `\Large` and upper case.

```
\renewcommand{\section}{\@startsection {section}{1}{0pt}%
    {-3.5ex plus -1ex minus -.2ex}%
    {2.3ex plus .2ex}%
    {\centering\normalfont\Large\MakeUppercase}}
```

The subsections and subsubsection titles are in small caps and bold slanted fonts respectively.

```
\renewcommand{\subsection}{\@startsection{subsection}{2}{20pt}%
    {-3.25ex plus -1ex minus -.2ex}%
    {1.5ex plus .2ex}%
    {\normalfont\large\scshape}}
\renewcommand{\subsubsection}{\@startsection{subsubsection}{3}%
    {10pt}%
    {-3.25ex plus -1ex minus -.2ex}%
    {1.5ex plus .2ex}%
    {\normalfont\normalsize\bfseries\slshape}}
```

The paragraph and subparagraph titles are to be run-in types (negative *post-skip*).

```
\renewcommand{\paragraph}{\@startsection{paragraph}{4}{0pt}%
    {3.25ex plus 1ex minus .2ex}%
    {-1em}%
    {\normalfont\normalsize\underline}}
\renewcommand{\subparagraph}{\@startsection{subparagraph}{5}%
    {\parindent}%
    {3.25ex plus 1ex minus .2ex}%
    {-1em}%
    {\normalfont\normalsize\itshape}}
```

Finally, redefine the section numbers to have a period after them.

```
\renewcommand{\@secntformat}[1]{\@nameuse{the#1}.\quad}
```

As an example of output with `mysects`, consider the short document:

```
\documentclass{article}
\usepackage{mysects}
\setcounter{secnumdepth}{3}
\begin{document}
\section{Historical Outline}
\subsection{Medieval Life}
\subsubsection{The Role of the Priest}
\paragraph{In the Church}
```

```
The priest fulfills several functions.
\subparagraph{At the Altar}
Here the priest was master of ceremonies.
\end{document}
```

which produces output:

```
1. HISTORICAL OUTLINE
  1.1. MEDIEVAL LIFE
    1.1.1. The Role of the Priest
```

In the Church The priest fulfills several functions.

At the Altar Here the priest was master of ceremonies.

Because the counter `secnumdepth` was set to 3, numbering only goes to the third level.

D.4 Changing preprogrammed text

D.4.1 Changing explicit names

There are a number of titles that appear automatically in L^AT_EX, such as ‘Contents’, ‘Bibliography’, ‘Chapter’. For works in languages other than English, it is necessary that they be replaced by their translations. And even in English, an author might prefer say ‘Summary’ in place of ‘Abstract’. All such explicit words are to be found in certain name commands that may be redefined as one pleases.

These name commands are not defined in the basic L^AT_EX format itself, but rather in the various class files, as they are needed. Thus `\chaptername` exists only in classes `book` and `report`, but not in `article`. This means, if a package were to redefine the word ‘Chapter’ for all classes, it must do so with something like

```
\providecommand*{\chaptername}{}
\renewcommand*{\chaptername}{\Chapter}
```

The standard set of name commands and their initial values are:

(defined in `book`, `report`, and `article` classes)

```
\contentsname    {Contents}
\listfigurename  {List of Figures}
\listtablename   {List of Tables}
\indexname       {Index}
\figurename      {Figure}
\tablename       {Table}
```

```

\partname      {Part}
\appendixname  {Appendix}
(defined in book and report classes)
\chaptername   {Chapter}
\bibname       {Bibliography}
(defined in article class)
\abstractname  {Abstract}
\refname       {References}
(defined in letter class)
\ccname        {cc}
\enclname      {encl}
\pagename      {Page}
\headtoname    {To}
(defined in makeidx package)
\seename       {see}
\alsoname      {see also}
(defined only in certain packages)
\prefacename   {Preface}
\glossaryname  {Glossary}
\proofname     {Proof}

```

The redefinition of these name commands is a fundamental part of the multilingual babel system (Chapter 11). The commands are not redefined directly but rather by means of certain `\captionlanguage` such as `\captionsgerman` and `\captionsenglish` that allow for convenient switching back and forth between different languages. For example,

```

\newcommand*{\captionsgerman}{%
  \renewcommand*{\contentsname}{Inhaltsverzeichnis}
  ...
  \renewcommand*{alsoname}{siehe auch}}

```

D.4.2 The date

The `\today` command for the current date is another one that outputs explicit English words. Its standard definition conforms to the American style of giving dates, that is ‘January 15, 2004’. If one wants to redefine this, either for the British style (15th January 2004), or for another language altogether, the best method is to follow the example of the other names commands: do not redefine `\today` directly, but create commands that allow one to switch back and forth.

For example, we can define `\dateUSenglish` and `\dateenglish` making use of the internal T_EX counters `\year`, `\month`, `\day` and the T_EX

`\ifcase` command (page 451).

```
\newcommand*{\dateUSenglish}{\renewcommand*{\today}{%
\ifcase\month \or
January\or February\or March\or April\or May\or June\or
July\or August\or September\or October\or November\or
December\fi \space\number\day, \number\year}}
```

```
\newcommand*{\dateenglish}{\renewcommand*{\today}{%
\number\day \ifcase\day \or
st\or nd\or rd\or th\or th\or th\or th\or th\or th\or
th\or th\or th\or th\or th\or th\or th\or th\or th\or
st\or nd\or rd\or th\or th\or th\or th\or th\or th\or
st\fi\space \ifcase\month \or
January\or February\or March\or April\or May\or June\or
July\or August\or September\or October\or November\or
December\fi \space\number\year}}
```

Definitions for other languages can be modeled after these examples.

D.5 Direct typing of special letters

Package: `inputenc` In Section 2.5.9, we explained the `inputenc` package that permits direct typing of accented and special letters, provided one has an appropriate keyboard and display font. For example, on a German keyboard set up for Windows, typing the key marked ‘ß’ inserts character 223, which is displayed on the author’s monitor as the ‘eszet’ letter for which the regular \LaTeX input is `\ss`. The source file however, receives only the code number 223, which \LaTeX would normally reject as unknown. The `inputenc` package with the `ansinew` option tells it that character 223 is to be treated as `\ss`. This will have the same result even if the file is displayed on a monitor set up for a different coding.

Table D.1 lists the current set of encoding options for the package. Others may be added in the future. For each of these options, there is corresponding `.def` file defining the extended characters with the commands

```
\DeclareInputText{pos}{text}    or
\DeclareInputMath{pos}{math}
```

which assign *text* or *math* coding to the character *pos*. For example, `latin1.def` contains

```
\DeclareInputText{223}{\ss}
```

to translate the input character code 223 to the \LaTeX command `\ss`.

Some \TeX installations automatically contain such conversions for their own local input coding scheme; files written under such a system without

Table D.1: Input coding schemes for `inputenc` package

<code>ascii</code>	7-bit ASCII encoding, characters 32-127 only
<code>latin1</code>	ISO Latin-1 encoding (Western Europe)
<code>latin2</code>	ISO Latin-2 encoding (Eastern Europe)
<code>latin3</code>	ISO Latin-3 encoding (Catalan, Esperanto, Galacian, Maltese)
<code>latin4</code>	ISO Latin-4 encoding (Scandinavian, Greenland Inuit, Lappish)
<code>latin5</code>	ISO Latin-5 encoding (Turkish)
<code>latin9</code>	ISO Latin-9 encoding (with euro symbol)
<code>decmulti</code>	DEC Multinational encoding
<code>cp850</code>	IBM 850 code page (Western Europe)
<code>cp852</code>	IBM 852 code page (Eastern Europe)
<code>cp437</code>	IBM 437 code page (North America)
<code>cp437de</code>	Variant on 437, with German ß replacing Greek β in position 225
<code>cp865</code>	IBM 865 code page (Scandinavia)
<code>applemac</code>	Macintosh encoding
<code>next</code>	NeXt encoding
<code>ansinew</code>	Windows ANSI encoding
<code>cp1252</code>	Windows 1252 code page (same as <code>ansinew</code>)
<code>cp1250</code>	Windows 1250 code page, for Central and Eastern Europe

the `inputenc` package will be processed correctly on their own system, but will generate garbage on another one. Thus this package should always be added when special symbols are directly typed in, especially if there is any possibility that the file may be processed on another computer system.

D.6 Alternatives for special symbols

A number of symbols in the text fonts cannot be addressed explicitly, but only as ligatures, for example ζ as ζ' . Other symbols that one might want in text are only available in math mode. L^AT_EX provides some `\text{..}` commands, listed in Table D.2 on the opposite page, to print these and other characters directly.

D.7 Managing code and documentation

This section describes two additional advanced features for maintaining L^AT_EX code and its documentation. There is no need to employ these at all, for any home-written packages and classes will function just as well without them. They do add a degree of sophistication and security, by tracing the history of the code's development, and by including the current documentation within the code itself. Here 'documentation' means both the user's manual and the programmer's description of what each step of

Table D.2: Alternative commands for special symbols in text mode

Command	Symbol	Replaces
<i>Ligatures</i>		
<code>\textemdash</code>	—	---
<code>\textendash</code>	-	--
<code>\textexclamdown</code>	¡	!‘
<code>\textquestiondown</code>	¿	?‘
<code>\textquotedblleft</code>	“	‘‘
<code>\textquotedblright</code>	”	’’
<code>\textquoteleft</code>	‘	‘
<code>\textquoteright</code>	’	’
<i>Math symbols</i>		
<code>\textbullet</code>	•	<code>\$\$\bullet\$</code>
<code>\textperiodcentered</code>	·	<code>\$\$\cdot\$</code>
<code>\textbackslash</code>	\	<code>\$\$\setminus\$</code>
<code>\textbar</code>		<code>\$\$ \$</code>
<code>\textless</code>	<	<code>\$\$<\$</code>
<code>\textgreater</code>	>	<code>\$\$>\$</code>
<i>Miscellaneous</i>		
<code>\textvisiblespace</code>	␣	<code>\verb*+ +</code>
<code>\textasciicircum</code>	^	<code>\verb+^+</code>
<code>\textasciitilde</code>	~	<code>\verb+~+</code>
<code>123</code>	¹²³	<code>\$\$^{123}\$</code>
<i>Special symbols</i>		
<code>\textcompwordmark</code>		(ligature break)
<code>\textregistered</code>	®	
<code>\texttrademark</code>	™	
<code>\textcircled{x}</code>	⊗	

the code is doing.

The \LaTeX installation files are written in this way. There are about 40 such files that are processed with the `DocStrip` utility (next Section) to extract the code from these files and merge it into one file `latex.ltx`. The documentation for each contributory file can be viewed alone, or a giant document can be created for the entire set. On the other hand, the standard class files, with much common coding, along with their option files, are all extracted from the one file `classes.dtx`, with a single documentation.

More practically, many packages are provided as `.dtx` files containing the package code plus user manual and programmer’s documentation. A `DocStrip` batch job with extension `.ins` is also given, which when processed by \LaTeX (or Plain \TeX for that matter) extracts the actual `.sty` file, along with a `drive.drv` file. \LaTeX ing the driver file generates the documentation. This is usually superfluous since the `.dtx` file itself is so constructed that

it behaves like a driver file. However, the `.drv` file can be edited by the user to select, say, just the user manual and to suppress the programmer notes.

The next sections describe first the extraction program `DocStrip`, which can be used for many other applications as well (e.g. `custom-bib`, Section 14.3), and then the integrated documentation scheme in the following section.

D.7.1 The `DocStrip` utility

Since the T_EX program is a programming as well as a text formatting language, it can be exploited to provide a number of utility ‘programs’ to manipulate files. Such programs are immediately portable: if you have T_EX, you can run them. One example of such a program is the `DocStrip` utility for extracting functioning code out of one or more source files containing documentation, as comments. The program was originally written by Frank Mittelbach and further developed by Johannes Braams, Denys Duchier, Marcin Woliński, and Mark Wooding.

The basic idea was to copy one file to another leaving off all the comment lines. From this simple concept came two additional features that extended the application of `DocStrip`: alternative lines of coding could be selectively suppressed or included depending on options chosen at processing time; and multiple files, or modules, could be input to form a single output file. This means that one source file can be the home of several different L^AT_EX packages, and that a single package file can be constructed out of many different components, as for the main L^AT_EX file `latex.ltx` mentioned above.

Running interactively

The simplest way of running `DocStrip` on a file is to invoke it with T_EX (or L^AT_EX, but T_EX is faster), as

```
tex docstrip
```

which produces the response

```
*****
* This program converts documented macro-files into fast *
* loadable files by stripping off (nearly) all comments! *
*****
*****
* First type the extension of your input file(s): *
\infilext=
*****
```

One replies by entering the input extension (usually `.dtx`); then one is asked in turn for the output extension, the options wanted, and finally, for the root name of the file(s) to be processed. Execution follows.

There are some limitations to this method, since the input and output files have the same root name, differing only in the extension, and initial and final comments added to the output are fixed. The more flexible means of running the utility is with a batch job.

Running as a batch job

A DocStrip batch job is a file containing instructions for the utility. For example, suppose the `fullpage` package illustrated in Section D.3.1 is put into a documented source file called `fullpage.dtx`, and the actual package file `fullpage.sty` is to be extracted with the option `package`, while a documentation driver file `fullpage.drv` is obtained with option `driver`; the batch file, named `fullpage.ins`, could look like

```
\input docstrip

\preamble
This is a stripped version of the original file.
\endpreamble

\postamble
This is the end of the stripped file.
\endpostamble

\declarepreamble\predriver
This is a documentation driver file.
\endpreamble

\declarepostamble\postdriver
End of documentation driver file.
\endpostamble

\keepsilent
\askforoverwritefalse

\generate{\file{fullpage.sty}{\from{fullpage.dtx}{package}}
          \file{fullpage.drv}{\usepreamble\predriver
                              \usepostamble\postdriver
                              \from{fullpage.dtx}{driver}}
          }
\endbatchfile
```

The first and last lines are vital: first the file `docstrip.tex` is loaded, defining all the special DocStrip commands; then after the instructions have been executed, `\endbatchfile` ensures an orderly termination.

The commands `\preamble` and `\postamble` allow one to insert explanatory comments at the beginning and end of the extracted file. The preamble is often a copyright notice and/or a caveat that the extracted file should never be distributed without the source. Additional labeled pre- and postambles may be declared with `\declarepreamble` and `\declarepostamble`, and activated with declarations `\usepreamble` and `\usepostamble`.

The instructions `\keepsilent` and `\askforoverwritefalse` are optional. The former suppresses processing information during the run while the latter turns off the warning that an existing file may be overwritten.

The main command is `\generate` which specifies the files to be created with a series of `\file` commands, each taking two arguments: the name of the new file and a list of instructions for its production. These instructions can be declarations like `\keepsilent` or `\usepreamble`, but the main one is the command `\from`. This again takes two arguments: the name of the input file and a list of the options to be applied. In the above example, each generated file has only a single input source, but multiple input files are possible with a series of `\from` commands.

The created `fullpage.sty` file now contains

```
%%
%% This is file 'fullpage.sty',
%% generated with the docstrip utility.
%%
%% The original source files were:
%%
%% fullpage.dtx (with options: 'package')
%% This is a stripped version of the original file.
%% Copyright (C) 1994 Patrick W. Daly
\NeedsTeXFormat{LaTeX2e}
. . . . .
\addtolength{\topmargin}{-1in}
%% This is the end of the stripped file.
%%
%% End of file 'fullpage.sty'.
```

It is possible to have a master batch job to process individual ones, in which case the master must input them with `\batchinput`, and not with `\input`.

Rules for removing lines

The `\generate` and `\file` commands cause the input file(s) to be transferred to the output file, line by line, according to the following rules:

1. any lines beginning with a *single* % sign are removed;

2. any lines beginning with double %% signs are retained;
3. any line beginning with %<opt> (or %<+opt>) will have the rest of its text transferred if opt is one of the selected options; otherwise it is removed;
4. any line beginning with %<!opt> (or %<-opt>) will have the rest of its text transferred if opt is *not* one of the selected options; otherwise it is removed;
5. all lines between %<*opt> and %</opt> are retained or removed depending on whether opt is a selected option or not.

Options can be combined logically, negated, and grouped:

```
a&b      (a and b);
a|b      (a or b);
!a       (not a);
(a|b)&c   (c and one of a or b)
```

For more information on DocStrip, see the documentation which can be obtained by processing `docstrip.dtx` with \LaTeX .

D.7.2 Documenting \LaTeX coding

The documenting of software products is extremely important: it provides on the one hand a manual for the user, and on the other details about the coding for the programmer. The original \LaTeX styles, as well as the basic `latex.tex` file, were heavily commented by Leslie Lamport, but only with straightforward normal text. It was Frank Mittelbach's `doc` package that first allowed sophisticated, integrated documentation of the source codes.

By *integrated* documentation, we mean that the descriptions and the coding are to be found merged together in a single source file. Thus two processes are necessary, one to extract the actual coding on its own (the `DocStrip` utility of Section D.7.1) and another to print the documentation (the `doc` package). The basic idea behind this package is that the comments are in fact regular \LaTeX text, with some extra features to allow automatic indexing and to record the program's development. The coding itself appears in a special type of `verbatim` environment.

The documentation is produced by running a special driver file through \LaTeX . Such a driver for a source file named `fullpage.dtx` would be, in its simplest form,

```
\documentclass{article}
\usepackage{doc}
\begin{document}
  \DocInput{fullpage.dtx}
\end{document}
```

The `\DocInput` command reads in the specified file, but it first alters the function of the `%` character from ‘comment’ to ‘do nothing’. This means all comment lines in `fullpage.dtx` become real text to be processed!

We describe some of the extra features that the `doc` package makes available for the ‘comments’ in the `.dtx` files, illustrated by an example, the source file `fullpage.dtx` for the `fullpage` package presented in Section D.3.1. As usual, a more complete manual can be acquired by processing `doc.dtx`.

The description part

The documentation consists of two parts: the *description*, which is a manual for the end user, and the *coding*, a detailed explanation of how the software works, including the lines of code themselves. It is possible to suppress the coding part and to print only the description by issuing

```
\OnlyDescription
```

in the preamble.

Special commands for the description part are:

```
\DescribeMacro{\macro.name}
\DescribeEnvironment{env.name}
```

which are placed at the start of the text that illustrates a new high-level command (macro) or environment. These commands do two things: they place the macro or environment name in a marginal note at that location (for easy reference when reading) and they insert an entry in the index.

Because documentation needs to use the `\verb` command frequently for printing input text, some abbreviations are provided with

```
\MakeShortVerb{\c} and \DeleteShortVerb{\c}
```

which first turn the character *c* into shorthand for `\verb c`, and then restore its normal use. For example, after `\MakeShortVerb{\|}`, `|\mycom|` prints `\mycom`. (These commands can be made available for any document by loading the package `shortvrb`, which is actually extracted from the `doc` package.)

If the comment character `%` has been deactivated, how can one put comments into the documentation text? One way is to make use of the T_EX conditional `\iffalse` to form a block, or *meta* comment, as

```
% \iffalse
%   These lines are ignored even when the
%   percent character is inactive
% \fi
```

The other method is to use `^^A` in place of `%`, a special `doc` feature.

The description part is terminated with


```
\StopEventually{final text}
```

where *final text* is to appear at the very end of the article; if only the description part is printed, *final text* is printed immediately and the documentation is ended.

The coding part

The coding part should normally contain the more specialized material that is of no interest to the everyday user. The special commands that may be used here are

```
\begin{macro}{macro_name} text and code \end{macro}
\begin{environment}{env_name} text and code \end{environment}
```

both of which again insert a marginal note and make an entry in the index. They also organize any `\changes` commands, as explained below.

The most important environment in the coding part is `macrocode`, which prints its contents as in `verbatim`, optionally with a code line number. The form of this environment is somewhat special:

```
    \begin{macrocode}
lines of code
    \end{macrocode}
```

The four spaces before the `\end{macrocode}` are obligatory; those before the `\begin` are not necessary, but it is good practice to insert them for symmetry. This environment also counts all the backslashes within it for a checksum test, and makes an index entry for every command name that it finds. So it is something more than a mere `verbatim` environment!

The coding part is brought to an end with

```
\Finale
```

which carries out the checksum test and prints the stored *final text* from `\StopEventually`. There may actually be more text following it, which is only printed when both description and coding parts are output.

Index of macros and record of changes

The `doc` package makes automatic entries into an index by means of the two `\Describexxx` commands and the two environments presented above. As well, all commands that appear in the coding are indexed. However, the indexing is turned on only if one of

```
\CodeLineIndex    or    \PageIndex
```

is given in the preamble. The first references the indexed commands to the number of the code line where they appear, the second to the page

number. In the second case, the code lines are not numbered, unless the declaration `\CodeLineNumbered` is also issued.

Since not all commands in the coding really need to be indexed, especially those that are part of standard L^AT_EX and T_EX, the command

```
\DoNotIndex{list of command names}
```

is given, often repeatedly, near the beginning, to exempt the listed commands from being indexed.

The automatic indexing of all the commands in the code slows down the processing considerably. Once the `index.idx` file has been produced, future runs do not need to repeat this effort (unless there have been changes to the code). The command

```
\DisableCrossrefs
```

will suppress this indexing, but it may be countermanded by an earlier `\EnableCrossrefs` which neutralizes the disabling command.

The text of the index is generated from the `idx` data file by the `MakeIndex` program (Section 9.4.3), which must be run with the special indexing style `gind.ist` as

```
makeindex -s gind.ist filename
```

The indexing style file `gind.ist` can be extracted from `doc.dtx`.

To print the index, the command

```
\PrintIndex
```

is placed where it should appear. Often this is part of the *final text* in `\StopEventually`. An up-to-date index can only appear after `MakeIndex` has been run between two L^AT_EX processings.

A record of changes to the software can be made by inserting

```
\changes{version}{date}{text}
```

throughout the documentation, in both the description and coding parts. To form the change history list, the command

```
\RecordChanges
```

must be placed in the preamble. This enables the change entries to be placed in a glossary file, which is then processed by `MakeIndex` as

```
makeindex -s ggl0.ist -o filename.gls filename.glo
```

(The indexing style file `ggl0.ist` is also extracted from `doc.dtx`.) The change history is then printed in the documentation where

```
\PrintChanges
```

is located, again often as part of *final text*. The texts of the `\changes` commands are ordered, first by version number, then by the name of the macro or environment in which they appear.

Integrity tests

If the source file is to be sent over electronic networks, there is a danger that it might be corrupted or truncated. Two tests are possible to check for this. By placing

```
\Checksum{num}
```

near the start of the documentation (before the coding anyway), all the backslashes in the macrocode environments will be added up, and the total compared with the number *num* by the `\Finale` command. If *num*=0, the true total will be printed on the monitor; otherwise, if the sum does not agree with *num*, an error is printed, with the two values.

The other test checks that the character set has not been corrupted by passing through computer systems with different character codes.

```
\CharacterTable
{Upper-case   \A\B\C\D\E\F\G\H. . .
. . . . .
. . . . . Tilde   \~}
```

The argument must agree exactly with that expected by `doc` (except for inactive % signs and multiple spaces). It should be copied from the `doc.sty` or `doc.dtx` files.

Obtaining the file information

File information may be obtained with the command

```
\GetFileInfo{filename}
```

which defines `\filename`, `\filedate`, `\fileversion`, and `\fileinfo` from the optional release information to be found in the `\Providesxxx` command identifying the specified file (Section D.2.1). The idea is that the `.dtx` file should contain this information once, and only once, but it needs to be known to print it in the title of the article. These `\filexxx` commands may be used for this purpose. The release information must conform to the sequence *date*, blank, *version*, blank, *text*.

The `\ltxdoc` class

A special class called `\ltxdoc` is provided to assist running the `doc` package. It invokes the `article` class with the `doc` package, and then issues commands

```
\AtBeginDocument{\MakeShortVerb{\|}}
\CodeLineNumbered
\DisableCrossrefs
```

and defines a number of other useful commands for aiding the documentation. See the description by processing `ltxdoc.dtx`. It also provides for local configuration: if `ltxdoc.cfg` exists, it is read in. This can pass paper size or other formatting options to `article`, issue `\OnlyDescription` by means of `\AtBeginDocument`, and so on.

A sample .dtx file

To illustrate these features, we show part of the source file `fullpage.dtx`. The initial lines ensure that all the files that can be extracted from it (the package `.sty` and the documentation driver `.drv`) receive their proper identifying commands. The date and version information appears only once, but is transferred to both extracted files.

```
% \iffalse      (This is a meta-comment)
%% Copyright (C) 1994 Patrick W. Daly
\NeedsTeXFormat{LaTeX2e}
%<*dtx>
\ProvidesFile      {fullpage.dtx}
%</dtx>
%<package>\ProvidesPackage{fullpage}
%<driver>\ProvidesFile{fullpage.drv}
% \fi
%\ProvidesFile{fullpage}
                [2002/02/15 1.1 (PWD)]
```

It is the last `\ProvidesFile{fullpage}` that enables the proper functioning of `\GetFileInfo`; the first one is only a dummy to absorb the information line when the `.dtx` file is read directly.

Next, the driver part is given. This is what L^AT_EX sees when it processes the file directly.

```
%\iffalse
%<*driver>
\documentclass[a4paper,11pt]{article}
\usepackage{doc}
\EnableCrossrefs
\RecordChanges
\CodeLineIndex
\begin{document}
  \DocInput{fullpage.dtx}
\end{document}
%</driver>
%\fi
```

Now the checksum and list of commands that are not to be indexed are given, followed by the start of the article.

```
% \Checksum{73}
% \DoNotIndex{\addtolength,\boolean,\ExecuteOptions,\ifthenelse}
```

```

% \DoNotIndex{\newboolean,\newlength,\ProcessOptions}
% \DoNotIndex{\RequirePackage,\setboolean,\setlength}
% \changes{1.0}{1994 Feb 15}{Initial version}
% \changes{1.1}{2002 Feb 15}{Next revision}

% \GetFileInfo{fullpage}
% \title{\bfseries A Package to Set Margins to Full Page}
% \author{Patrick W. Daly}
% \date{This paper describes package \texttt{\filename}\\
%       version \fileversion, from \filedate}
% \maketitle
% \MakeShortVerb{\|}
%
% \section{Purpose}
% To set a uniform margin of one inch or 1.5~cm on all four
% . . . . .

```

We advance to the end of the description and start of the coding part.

```

% \StopEventually{\PrintIndex\PrintChanges}
%
% \section{The Coding}
% The first thing is to read in the \texttt{ifthen} package,
% if it is not already there.
%   \begin{macrocode}
%<*package>
\RequirePackage{ifthen}
%   \end{macrocode}
%
% \begin{macro}{\DeclareOption}
% \begin{macro}{\FP@margin}
% Define the options with help of the length |\FP@margin|. The
% options |in| and |cm| select the actual margin size.
%   \begin{macrocode}
\newlength{\FP@margin}
\DeclareOption{in}{\setlength{\FP@margin}{1in}}
\DeclareOption{cm}{\setlength{\FP@margin}{1.5cm}}
%   \end{macrocode}
% \end{macro}

```

The end of the file finishes the coding and calls `\Finale`.

```

. . . . .
\setlength{\topmargin}{\FP@margin}
\addtolength{\topmargin}{-1in}
%</package>
%   \end{macrocode}
% \end{macro}\end{macro}
% \Finale

```


E

L^AT_EX and World Wide Web

Today it is no longer sufficient to produce professional-looking printed output on paper; one has to be able to get it online as well, that is, make it available in electronic form of some kind. To some extent, PostScript output fulfills this requirement in that it may be considered electronic paper. However, as we point out in Section 15.3, true electronic documents are something quite different.

The Internet used to be a nice, quiet neighborhood where academics could exchange simple, plain text emails or obtain known files by FTP, until it was invaded by the rowdy *World Wide Web* with its corporate identities, slick advertising, energetic yuppies, anarchists, and revolutionaries. In other words, it went cosmopolitan. It is here in this glittering marketplace that electronic documents have to compete for attention.

An electronic document is not something that is simply sent to a printer or leisurely viewed on a monitor: it is interactive, in that it guides the reader to other parts of itself or to other documents located anywhere else on the Web. With these *links*, the viewer can jump to other relevant passages with a mere mouse click. Colored illustrations are naturally part of such documents, but so are sounds and movies, as well as means of sending feedback to the author. This is a totally new medium for information exchange, more radical than the Gutenberg revolution from handwritten manuscripts to printed books.

In Section 1.2 we explain the structural similarities between L^AT_EX and the Web languages HTML and XML. Here we point out the possibilities for conversion from L^AT_EX to the others, and then how T_EX can be used as an engine to render XML documents in L^AT_EX formats. Detailed descriptions of the conversion programs are to be found in the supplied documentation, and in the *L^AT_EX Web Companion* (Goossens and Rahtz, 1999). This topic is far too extensive to be dealt with in this book.

E.1 Converting to HTML

E.1.1 The \LaTeX 2HTML program

The \LaTeX 2HTML translator, written by Nikos Drakos with additions by a large number of contributors, is a comprehensive Perl script that converts a \LaTeX source file into HTML with the help of several other programs, notably \LaTeX itself, `dvi ps`, Ghostscript, and the `netpbm` library of graphics utilities.

When \LaTeX 2HTML processes a \LaTeX file, it creates a new subdirectory with the same name as that file, to which it writes the resulting HTML output and any generated images as `.gif` files. The program interprets the \LaTeX input text in the same way as \LaTeX itself does, but instead of producing typesetting instructions in the `.dvi` file, it writes appropriate HTML code to an `.html` file. For example, `\section{Introduction}` is interpreted as `<H1>Introduction</H1>` for the output.

This means that \LaTeX 2HTML is essentially duplicating the \LaTeX processing, an enormous undertaking. Since the document classes contain varying commands or have common ones behaving differently, there must be Perl scripts for each one (`article.perl`, and so on) to program these commands properly. Additional packages loaded with `\usepackage` can also define new commands, or alter the functionality of existing ones; the translator must be informed about these by means of corresponding Perl scripts. For example, the `natbib` package described in Section 9.3.4 defines citation commands `\citet` and `\citep`, which need to be made available to \LaTeX 2HTML in a file `natbib.perl`. Most of the tools packages of Section B.5.4 are included as Perl scripts, as are many other popular contributed packages. In other words, the entire \LaTeX 2HTML installation must mirror the \LaTeX one.

This process is somewhat simplified by the fact that both formats are markup languages written in pure typewriter text. However, this similarity soon reaches its limits with the many \LaTeX features not available in HTML, such as complex math, included figures, cross-referencing. In the other direction, HTML exhibits hyperlinks, both internally and to external documents, something not provided by normal \LaTeX .

\LaTeX 2HTML attempts to reproduce math with the limited HTML possibilities, but failing that, formulas are handled the same as figures and other environments that cannot be directly rendered: they are converted to GIF image files along the route `.tex` \rightarrow `.dvi` \rightarrow `.ps` \rightarrow `.pbm` \rightarrow `.gif`, which are then included in the HTML file as in-line images.

Cross-references and citations are automatically provided with hyperlinks to their targets; the keyword index also links back to the text. Other features of HTML can be included by means of special commands defined in the `html.sty` package. For example:

- explicit hyperlinks, internal and external

- conditional text for the HTML or \LaTeX versions only
- raw HTML code
- segmentation of the HTML output
- finer image control
- ...

This package thus provides the \LaTeX writer with a more convenient interface for producing hypertext documents; furthermore, the same document can still be processed with \LaTeX to generate the ‘paper’ version at any time. The conditional text mentioned above allows the electronic and paper versions to exhibit some differences.

$\LaTeX2HTML$ is available on the CTAN servers (Figure B.4 on page 390) under the support directory. It can also be downloaded from the $\LaTeX2HTML$ home page <http://cb1.leeds.ac.uk/nikos/tex2html/doc/latex2html/latex2html.html>, where more information as well as a manual can be obtained.

E.1.2 The $\TeX4ht$ program

An alternative program is that by Eitan M. Gurari, called $\TeX4ht$. It produces much the same results as $\LaTeX2HTML$, but by a different route. Rather than trying to interpret the \LaTeX input text itself, it processes instead the $.dvi$ file to extract the HTML output. It is therefore applicable both to \LaTeX and Plain \TeX , as its name implies.

In reality, it is not as simple as that. Since the DVI output is normally only a list of typesetting instructions, containing no logical markup information at all, it is necessary to process the \LaTeX input with the matching $\TeX4ht.sty$ package that redefines all the regular \LaTeX commands to write appropriate code to the $.dvi$ file. This is accomplished by means of the `\special` command, a basic \TeX command for writing instructions to a particular DVI driver. In this case the driver is the $\TeX4ht$ program; no other driver will be able to process this $.dvi$ file.

The $\TeX4ht$ processor writes the HTML output according to various options specified in the \LaTeX input. For example, the HTML output can be segmented by chapters or sections, tables of contents may be added to each segment, links are automatically established for cross-references. As with $\LaTeX2HTML$, manual links to external documents or internal points can be made, raw HTML coding included, explicit images included. It is also possible to turn off the HTML conversion in order to produce a normal $.dvi$ file; conditional input for whether HTML is on or off is also available.

Any symbols, tables, equations, or imported figures that cannot be directly rendered in HTML are written to a new DVI file, with extension

.idv, one item per page. Finally, a log file is written containing conversion instructions for each such object; this file is so constructed as to act as a script, or batch job, for creating GIF images. Just how this conversion is realized and how the instructions are formatted depend on the local installation and can be configured by the user. However, the usual route is something like .idv → .ps (dvips) → .ppm (Ghostscript) → .gif (pbm). An example of T_EX4ht output with a GIF representation of a math equation can be seen in Figure E.1 on page 482.

Since T_EX4ht needs to redefine all the L^AT_EX markup commands, one could argue that it too is duplicating L^AT_EX just like L^AT_EX2HTML. To some extent this is true, although there is a very important difference: it is only the markup, not the formatting commands, that needs to be massaged. Most classes and additional packages will need no extra configuring to be processed by T_EX4ht. A package like natbib which adds new citation commands \citet and \citep will totally confuse L^AT_EX2HTML without the additional Perl script natbib.perl, whereas under T_EX4ht these commands will produce the correct output text in the HTML file without any additional definitions. (However, the automatic links between the citations and list of references will be missing, since this is a markup feature, but the printed text will be all right.)

T_EX4ht is available from the T_EXLive CD, or from <http://www.cis.ohio-state.edu/~gurari/TeX4ht/mn.html>.

L^AT_EX2HTML and T_EX4ht are only two examples of procedures for creating HTML output from L^AT_EX. In both cases, one should not try to convert arbitrary L^AT_EX files, but should view them as means of producing normal L^AT_EX and HTML output from a common source file. This source file must be constructed accordingly, possibly with conditional texts for the two outputs, with manual hyperlinks, formatting options for HTML, and so on.

The use of GIF bitmap images for rendering items not readily available in HTML, while producing the visual features on screen, does not allow these objects to be searched for or otherwise further processed. Such images also do not participate in automatic font size changes and other Web manipulations.

E.2 The Extensible Markup Language: XML

It has long been recognized that HTML has many severe limitations. Its simplicity may have been responsible for its rapid rise in popularity, but that simplicity also restricts it to the type of documents for which it was originally intended. Today the Web is offering much more than at the beginning, with databases, search engines, data verification. HTML is not programmable, so that browser suppliers have found it necessary to add additional features of their own, which only function with their browser.

Standardization is thus destroyed.

What is needed is a means of adding new features to an HTML file so that the browser can be informed of what they mean. This would be like adding new features to a \LaTeX file by means of a package. It is to this end that the Web Consortium began the development in 1996 of the *Extensible Markup Language*, or XML.

However, XML is not so much a language as a specification for defining languages in a standard manner. An XML interpreter must be able to determine whether an XML document conforms to the general rules (mainly that all tags are properly closed), in which case it is considered to be *well-formed*, and to the specific syntax of the tags that it uses (as defined in a DTD, Document Type Definition), in which case it is also *valid*. There remains the question of how those tags are to be rendered (how are sections formatted, what to do with cross references, how to include graphics), which is relegated to *style sheets* documented in the *Extensible Stylesheet Language*, XSL. Here we have true separation between content and format, between logical and typographical markup.

If all this sounds overwhelming, it is! Furthermore, the DTDs are considered to be too cumbersome and various alternatives have been developed, themselves conforming to XML (which the DTDs do not). This whole area is in transition, but the rewards will be high when a reliable standard for electronic data exchange is achieved. *Data* in this sense is very generic, and includes textual documents. We recommend the books by (Marchal, 2000) and (Williamson, 2001); or one can check the Web Consortium home page <http://www.w3.org/>.

E.2.1 XML and \LaTeX

What does all this have to do with \LaTeX ? Just as the similarity between \LaTeX and HTML allow relative easy conversion, so does the essential similarity with XML. The \TeX4ht system has already done the real work of converting \LaTeX structure into HTML tags; it is therefore simply a matter of changing the output for each of those tags, something that is put into corresponding configuration files.

Since XML itself is not a language with defined tags, how do we know what those tags are to be? Here we rely on existing DTDs for textual documents. These can be the DocBook DTD developed for software user manuals and other computer documentation, or the TEI DTD, the *Text Encoding Initiative* meant essentially for general text, including images and sounds.

The \TeX4ht collection on the \TeX Live CD includes configurations for producing XML output from \LaTeX for both of these DTDs. The preamble to the \LaTeX source file should then include

```
\usepackage[html]{tex4ht}           for HTML output
```

```
\usepackage[xhtml,docbook]{tex4ht}   for XML, DocBook output
\usepackage[xhtml,tei]{tex4ht}      for XML, TEI output
```

One might ask why does the author not write an XML file directly as the source document? First, one might very well want to convert older documents recorded in L^AT_EX to XML. Secondly, one might find it simpler to write in L^AT_EX (not everyone agrees) since no one would write an XML file by hand (everyone agrees) but would rely on some application to do it behind the scenes. Certainly L^AT_EX source text is easier to read, even when intersperse with commands, than an XML file.

E.2.2 MathML and L^AT_EX

One of the strengths of T_EX and thus L^AT_EX over other text processing systems is the ability to handle mathematics in a way that is acceptable to mathematicians. HTML has never been able to even begin to compete in this area. The only way conversion programs like L^AT_EX2HTML and T_EX4ht can render equations like that in Figure E.1 is to convert it to an image file. This is hardly a satisfactory solution.

The MathML project attempts to define an XML language to encode mathematics. We refer to chapter 8 of the *L^AT_EX Web Companion* (Goossens and Rahtz, 1999) for a description. T_EX4ht can produce output in MathML by specifying

```
\usepackage[xhtml,mathml]{tex4ht}
```

Symbols that do not exist in the browser fonts will still be converted to image files, but instructions are inserted to carry out the placement for fractions and superscripts and subscripts. Unfortunately, most browsers do not recognize MathML (yet). Again, once this becomes established there will be a standard for recording and exchanging documents with complex mathematics.

E.2.3 Rendering XML with T_EX/L^AT_EX

Another role that L^AT_EX, or more properly the T_EX program, can play in the XML world, is to translate it to a form that can be viewed or printed as a finished document. This is known as *rendering*.

David Carlisle has written macros in a file `xmltex.tex` to act as an XML parser for output in T_EX or L^AT_EX. Sebastian Rahtz has written an additional macro package *PassiveT_EX*, to incorporate an XSL style sheet for the TEI DTD into `xmltex`. With this combination, one can produce DVI or PDF output from a TEI-coded XML file.

There are a number of ways of going about this. The simplest is to write a ‘wrapper’ file for processing document.xml as

```
\def\xmlfile{document.xml}
\input xmltex.tex
```

and then to process this with either \LaTeX or pdf\LaTeX . The Passive\TeX macros will be found automatically, if they are on the system.

Another means is to generate an xmltex format, as described in Section B.1.3. This would be done with

```
initex &latex xmltex.tex      or
tex -ini &latex xmltex.tex
```

to generate a format named xmltex.fmt . One can then invoke it with

```
tex &xmltex document.xml
```

or simply with $\text{xmltex document.xml}$ if an alias or batch file for the command xmltex has been defined to equate to the real command.

Instead of using the \TeX program, one can also make use of pdf\TeX instead, to generate PDF instead of DVI output.

E.3 The techexplorer Hypermedia Browser

A completely different approach to Web viewing of \TeX and \LaTeX documents is offered by the IBM techexplorer Hypermedia Browser, a plug-in for Netscape Navigator and Microsoft Internet Explorer under Windows. When properly installed, it is launched automatically within the parent browser window when one opens a file with one of the extensions .tex , .bb1 , .ltx , .latex , or .tcx .

The techexplorer interprets the \TeX and \LaTeX commands directly and displays the results on the monitor. The original page height and line width are ignored, the paragraphs being fitted to the size of the window as is normal for any browser. Fonts, tables, environments, but most importantly mathematics are reproduced very well. Figure E.1 on the next page demonstrates a single formula represented by both \TeX4ht and techexplorer . Even user commands defined with \def and \newcommand are recognized, provided they occur within the same file. However, no external packages may be loaded, nor are the class files accepted. (Both \usepackage and \documentclass are simply ignored.)

Hypertext features can be included with additional \TeX -like commands that establish internal and external links, pop-up menus, multiple-file documents (segmentation) with automatic links between them, and inclusion of images. In other words, a techexplorer document can have the full range of hypertext features of HTML. Here one must make the same comment as for \LaTeX2HTML and \TeX4ht : it is not primarily intended for viewing arbitrary \LaTeX documents, but rather for preparing hypertext Web pages by means of \TeX or \LaTeX . The only problem here is that most

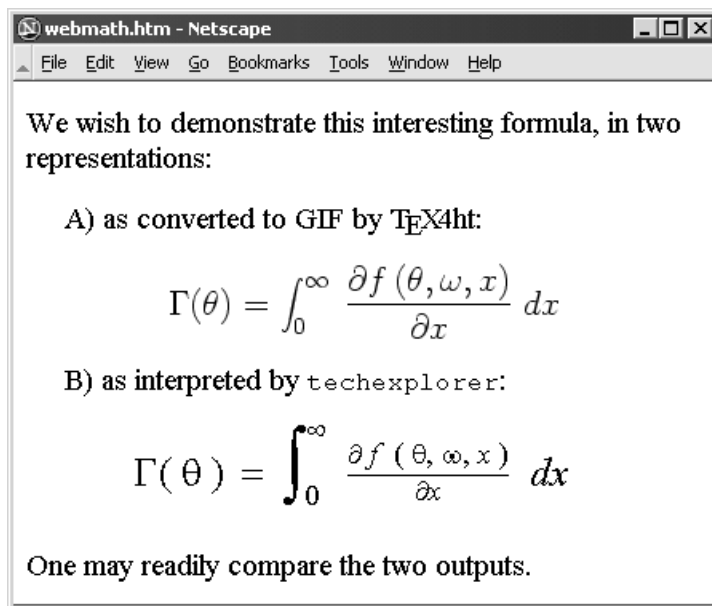


Figure E.1: Example of a math formula represented by T_EX4ht (as a GIF image of the original L^AT_EX output) and by techexplorer rendering.

Internet users will probably not have techexplorer installed, so that they will only be presented with the input text, and not its rendering.

One additional application of techexplorer which is not available to the other programs is to embed T_EX commands, especially mathematics, inside a regular HTML file. If the commands are stored in a file `formula.tex`, they could be embedded with

```
<EMBED SRC="formula.tex" WIDTH=300 HEIGHT=70>
```

or they can be entered directly as

```
<EMBED TYPE="application/x-techexplorer"
  TEXDATA="$$\Gamma(\theta)=\int_0^{\infty}\frac{\partial f(\theta,\omega,x)}{\partial x}dx$$" WIDTH=300 HEIGHT=70>
```

The result, shown in the lower part of Figure E.1, is a very acceptable display of the math formula in the middle of an HTML file. (This file was generated by T_EX4ht from a L^AT_EX file, with the above techexplorer text included as raw HTML code.)

The techexplorer is obtainable from <http://www.software.ibm.com/enetwork/techexplorer>. It comes in a free introductory version, as well as in a professional version for a nominal charge.

F

Obsolete L^AT_EX

Since 1994, L^AT_EX 2_ε has replaced L^AT_EX 2.09 as the official version. Although the newer version is backward compatible with the previous one, this is only to allow older source files written for L^AT_EX 2.09 to be processed under L^AT_EX 2_ε; it is not intended that newer files should make use of the obsolete syntax.

Human nature being conservative as it is, many authors continued to use the commands they were familiar with, even today. The purpose of this chapter is to explain those commands for users who may come across such legacy documents, and to indicate to traditional L^AT_EX users which commands they should no longer be employing. It is not meant to be a guide for using L^AT_EX 2.09!

At first sight, the differences seem very slight indeed. In fact, the real changes are mainly internal, allowing packages to be handled more systematically and fonts to be dealt with in a more flexible manner. The advantages of L^AT_EX 2_ε for class and package writers are considerable, as explained in Appendix D. Regular users benefit indirectly by being able to employ these extensions, and by being able to activate fonts other than the original Computer Modern families.

F.1 The 2.09 preamble

As for L^AT_EX 2_ε, the document preamble in L^AT_EX 2.09 contains overall specifications for the entire document, including general layout.

F.1.1 Style instead of class

L^AT_EX 2.09 works with *style* rather than class files, so the first command in the source file is

```
\documentstyle[options]{style}
```

rather than `\documentclass`. Possible values for *style* are `article`, `report`, `book`, or any other main style files that might exist locally. These styles may have various options associated with them, like `11pt`, `twoside`, and so on, which can be listed in the set of *options*. Not all the options available with the L^AT_EX 2_ε class files are recognized by the style files.

The *options* list has an additional function in L^AT_EX 2.09: for any option in the list that is not recognized by the style file, a file with that name and extension `.sty` is loaded, if it exists. The original idea of this mechanism was to allow certain options applicable to all styles to have the common coding stored in an extra file, rather than repeating it within each main style file. It was this that later led to the concept of *packages*.

There is no `\usepackage` command in L^AT_EX 2.09; packages can only be loaded with the *options* list, and no options may be specified for the packages.

To start a document with the `article` style and `12pt` option, with the `parskip` and `makeidx` packages, one gives

```
\documentstyle[12pt,parskip,makeidx]{article}
```

F.1.2 Compatibility mode

L^AT_EX 2_ε is designed to be able to process older L^AT_EX documents with exactly the same output as with L^AT_EX 2.09. To do this, it recognizes the `\documentstyle` command which switches it into *compatibility* mode, changing the functionality of many L^AT_EX 2_ε features. For example, the `\usepackage` command becomes inoperable, issuing an error message.

With a true L^AT_EX 2.09 installation, the above `\documentstyle` example would load the files `article.sty`, `parskip.sty`, and `makeidx.sty`. Under L^AT_EX 2_ε, in compatibility mode, it first tries to load the main style as a class file with the extension `.cls`, in this case `article.cls`, but if that fails, it then looks for the extension `.sty`. This is to handle local main style files that have no class file equivalent. The packages `parskip.sty` and `makeidx.sty` are loaded as well. However, they too may recognize the compatibility mode and behave differently as they would with regular L^AT_EX 2_ε.

F.2 Font selection

The other major difference between the two versions is font selection. The New Font Selection Scheme (NFSS) and font attributes described in Section 4.1.3 are missing in L^AT_EX 2.09, as are the font commands `\textbf`, `\texttt`, and so on, and the font attribute declarations such as `\bfseries` and `\ttfamily`. (They are still available even in L^AT_EX 2_ε compatibility mode.)

F.2.1 Old font declarations

In \LaTeX 2.09, only the two-letter font declarations that originally came from Plain \TeX are possible.

\rm	Roman	\it	<i>Italic</i>	\sc	SMALL CAPS
\bf	Bold face	\sl	<i>Slanted</i>	\sf	Sans Serif
\tt	Typewriter				

These are all declarations, changing the font until another font declaration is given, or until the current environment is ended. They are normally used as $\text{\{\bf bold face\}}$ to yield **bold face**.

The emphasizing declaration \em also belongs to this group, but it has been taken over as part of $\text{\LaTeX}2_{\epsilon}$ proper.

These old declarations have a different behavior from that of their NFSS counterparts: they rigidly select a particular font instead of altering only one attribute, but retaining the current size. Compare:

$\text{\{\sl slanted \bf bold\}}$	\Rightarrow	<i>slanted bold</i>
$\text{\{\slshape slanted \bfseries bold\}}$	\Rightarrow	<i>slanted bold</i>

It is not possible to obtain slanted or italic bold face with \LaTeX 2.09 even though such fonts are available.

These two-letter declarations are also retained in the standard $\text{\LaTeX}2_{\epsilon}$ classes, and not just in compatibility mode. Note carefully that wording: they are not part of $\text{\LaTeX}2_{\epsilon}$ itself, but are only included as part of the standard class files. This means other class files might not provide them, or that they might even be removed in some later version (although this is most unlikely). Therefore, their use is not to be encouraged at all.

F.2.2 Font size declarations

In \LaTeX 2.09, the font size declarations also reset all the other font attributes (Section 4.1.3) to their defaults, that is, Roman, upright, medium weight. By contrast, in $\text{\LaTeX}2_{\epsilon}$, these attributes remain unchanged. Compare the results of $\text{\{\sl slanted \Large larger\}}$:

\LaTeX 2.09:	<i>slanted larger</i>
$\text{\LaTeX}2_{\epsilon}$:	<i>slanted larger</i>

In $\text{\LaTeX}2_{\epsilon}$ compatibility mode, the size declarations behave as they do in \LaTeX 2.09.

F.3 Obsolete means obsolete

Many features have been added to $\text{\LaTeX}2_{\epsilon}$, and a number of commands have been given extended syntax, in the form of additional optional arguments. We have no intention of indicating them anymore in this book as

this is a manual for the newer version only. (Previous editions did make a distinction.)

Apart from the restrictions pointed out in the above sections, all of the L^AT_EX 2_ε features will work in compatibility mode. Nevertheless, we stress once more, compatibility mode is only intended for the processing of older source files. Every effort has been undertaken to ensure that the results are identical to those of a processing with the true L^AT_EX 2.09 itself.

Compatibility mode (`\documentstyle` in place of `\documentclass`) issues a very strong warning:

```

      Entering LaTeX 2.09 COMPATIBILITY MODE
*****
      !!WARNING!!    !!WARNING!!    !!WARNING!!    !!WARNING!!

```

This mode attempts to provide an emulation of the LaTeX 2.09 author environment so that OLD documents can be successfully processed. It should NOT be used for NEW documents!

New documents should use Standard LaTeX conventions and start with the `\documentclass` command.

Compatibility mode is UNLIKELY TO WORK with LaTeX 2.09 style files that change any internal macros, especially not with those that change the FONT SELECTION or OUTPUT ROUTINES.

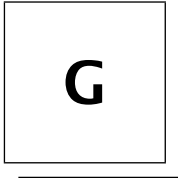
Therefore such style files MUST BE UPDATED to use

Current Standard LaTeX: LaTeX2e.

If you suspect that you may be using such a style file, which is probably very, very old by now, then you should attempt to get it updated by sending a copy of this error message to the author of that file.

```
*****
```

Take this message seriously, and stick to `\documentclass`.



T_EX Fonts

Computers work exclusively with numbers, or more precisely, only with bits which may be interpreted as numbers. They do not know the difference between the letter A and an apple, or that either even exists. For text processing, all symbols, both input and output, need to be represented as numbers somehow. The association between number and symbol is called the *encoding* or *layout*. The latter term derives from the common method of illustrating the encoding in the form of a table.

Encoding tables are by no means standard. The standard ASCII scheme is just one of several, and it is limited to 7 bits, or 128 characters. There are 8-bit (256 characters) versions as well, in fact, a large number exist, tailored to different computer systems and languages. The question of coding the input for L^AT_EX documents with more than 7 bits are addressed in Sections 2.5.9 and D.5.

In this appendix, we look at how the underlying T_EX program deals with output fonts, their nomenclature, and their encoding tables.

G.1 Font metrics and bitmaps

When T_EX decides to output character *mn* in a particular font, all it needs to know is how much room to leave for it. T_EX does not care what the character looks like, for that is the task of the DVI driver afterwards.

Information about the characters in each font are stored in various files, all bearing the root name of the font but with different extensions. This information is divided into files that contain only the sizes of each symbol, and those with the actual drawing or image data.

- .**tfm** T_EX font metric files are the only font files read in by T_EX itself. They contain the sizes of the characters, such as width, height, and depth. For slanted fonts, they also possess the ‘italic correction’ for each letter. Furthermore, they specify for which letter combinations a different spacing is required, such as AV instead of AV,

or for which a ligature is available. Finally, the `.tfm` files provide information about the slope of the characters (zero for an unslanted font), the standard word spacing and its stretch and shrinkage, the width of the `em` and `quad` spacings, and the spacings at the end of a sentence. Mathematical and symbol fonts require even more information which is also included in their `.tfm` files.

- `.pk` Compressed pixel files contain bitmaps (images) of the symbols in each font, in one size and one resolution. The DVI driver program uses these to send the output to a printer or previewer. These files are normally generated automatically by the METAFONT program (Section G.3) as needed.

Since these files might exist several times for a given font, in different sizes or resolutions, many installations distinguish them by adding the resolution to the extension, as `cmr10.300pk` or `cmr10.600pk` for 300 and 600 dpi versions, respectively. On systems that cannot support extensions with more than three characters, both files are named `cmr10.pk` but are stored in directories `dpi300` and `dpi600`.

Font magnification is achieved by selecting an appropriate resolution. If `cmr10` is to be printed on a 300 dpi printer at double its normal size, the 600 dpi version is used instead.

- `.mf` METAFONT source files contain the drawing instructions for each of the fonts. These are not read by the DVI driver but rather by the METAFONT program which converts them into `.pk` bitmap files at the required size and resolution.
- `.vfm` Virtual font files are an alternative to `.pk` files. Instead of having bitmaps for each character, they contain instructions that refer to characters in different, real fonts, or that tell the driver to draw a black box and issue a warning message (that the character does not exist, for example).

Virtual fonts are normally associated with PostScript fonts and are therefore described in Section G.5. However, there is no reason for them not to be used with bitmap fonts as well.

G.2 Computer Modern fonts

When Donald E. Knuth invented the T_EX program, he also provided it with an extensive set of character fonts, which he named *Computer Modern*, rather than relying on the fonts available on any given printer. At that time, the printer fonts were not so good, and certainly were not uniform.

With the supplied fonts, $\text{T}_{\text{E}}\text{X}$ could produce identical, high-quality results on all printers.

$\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$, of course, has inherited these fonts, so that they have almost become a trademark for documents produced by $\text{T}_{\text{E}}\text{X}$ or $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$. This is not really necessary, for $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ need not be married to any particular set of fonts, especially with the New Font Selection Scheme (Appendix A) which simplifies font installation enormously. The main fonts used in this book, for example, are Lucida Bright, Lucida Sans, and Lucida Sans Typewriter, designed by Bigelow & Holmes and distributed by Y&Y Inc.

G.2.1 Font families

Typography is the study and classification of typefaces, something that goes back to Gutenberg's invention of *movable type* (not of the printing press, which was invented by the Chinese) five and a half centuries ago. Since that time, many families of fonts have been created, bearing classical names like Baskerville, Garamond, Univers, etc. Each member of such a family has the same overall design, or basic look, but vary by being slanted, italic, bold, or thin; and of course, they come in different sizes.

Font families are classified according to certain criteria that often determine to what use they will be put.

Serif fonts: are those that have little horizontal lines, or *serifs*, at their edges, to guide the eye better. Experience has shown these to be best for general reading, and so they are regularly used for the main body of text. The NFSS terminology refers to these as *Roman* fonts.

Sans serif fonts: are those that are lacking any serifs. Such fonts with their starker appearance are often employed for titling or headlining. Compare sans serif with regular text.

Fixed fonts: are those with a uniform letter width, something that has evolved from the typewriter and has been carried over to computer listings. Classically, such fonts have no business in book printing, where *proportional* fonts (the letter *i* is narrower than *m*) have always dominated.

Decorative fonts: are ones that stand out because of some unusual characteristic. They are intended to catch attention and to attract the eye. Such families are not complete, with a full range of shapes and widths, and are employed mostly by advertising.

Mathematical fonts: are collections of special symbols needed for mathematical works. Their further classification cannot be compared to that of text fonts at all.

A book designer must decide what kinds of typeface families are needed. He or she might decide on a Roman (serifed) font for the main body, a sans serif one for headlines, and then, if it is a book containing computer code, select a fixed font for setting those parts. Finally, symbol fonts will be needed if the work contains mathematical sections.

The Computer Modern set of fonts provides all these classes of families. However, since they were produced before the NFSS attribute system of classification was established, the CM font nomenclature does not conform perfectly with this scheme. The NFSS system frees the user from having to think about the CM font names, for specifying the attributes is sufficient. Of course, the NFSS installation must provide the font definition .fd files which translate any set of attributes into a real font name, or into some acceptable substitute.

G.2.2 Classification of CM fonts

All the T_EX font names begin with the letters `cm`, which stands for ‘Computer Modern’, followed by one to four letters describing the style of font, and finally one or two digits specifying the design size in points. This is the root name of the font which must be given in the `\newfont` command (Section 4.1.5) if it is to be activated directly.

The CM fonts can be classified as text, math, decorative, or other special symbol fonts, as described in the rest of this section. Each type of font has an encoding scheme shown in the accompanying layout tables.

Text fonts

The Computer Modern fonts appropriate for straightforward text can be classified into the three families Roman, sans serif, and typewriter. Within each of these families there are upright, slanted, italic, small caps, and bold variants.

Table G.1 presents the names of these fonts together with the NFSS family/series/shape assignments from Appendix A. They all have the same coding (OT1). The `*` in each name is the design size specification which takes on values of 5, 6, 7, 8, 9, 10, 12, 17. Only `cmr*` is available in all these sizes, while some are only to be found in size 10. (This table contains much the same information as in Table A.3 on page 370 but in a different form.)

One sees several apparent inconsistencies in these font names, such as `cmti*` for the italic upright font. Why is this not `cmri*`? The answer is that this is a *text italic* font, as opposed to the *math italic* font `cmmi*` described below. These inconsistencies have arisen because the CM fonts were not created with the NFSS classification system in mind, since that was established a decade later.

Table G.1: Computer Modern text fonts

Style	Family= Series/shape	Roman cmr	Sans serif cmss	Typewriter cmtt
Upright	m/n	cmr*	cmss*	cmtt*
” slanted	m/sl	cmsl*	cmssi*	cmstt*
” italic	m/it	cmti*	—	cmiti*
” small caps	m/sc	cmcsc*	—	cmtcsc*
Bold	b/m	cmb*	—	—
Bold extended	bx/m	cmbx*	cmssbx*	—
” ” slanted	bx/sl	cmbxsl*	—	—
” ” italic	bx/it	cmbxti*	—	—

Further inconsistencies exist in the encoding schemes for the CM text fonts. They are all nominally OT1, but there are slight deviations among them. The proper OT1 encoding is displayed in Layout 1 on the next page for font `cmr10`. The text italic fonts are identical to the upright ones, except that the dollar sign in position 36 is replaced by the pound sign (Layout 3 for `cmti10`). The slanted fonts, on the other hand, are exactly the same as the upright ones. Other deviations are to be found in the small caps (Layout 2) and all the typewriter fonts (Layout 4).

Math fonts

The Computer Modern fonts provide three types of mathematical fonts, each with its own encoding scheme.

The *mathematical italic* fonts `cmmi*` contain Latin and Greek letters, in upper and lower case, plus a number of extra symbols. Since variable names in formulas are set in *italics*, these are basically italic fonts. The encoding scheme is designated OML, for *old math letters*, and is displayed in Layout 5. It is available in design sizes 5–12 pt in normal weight, but only in 10 pt size in bold face, `cmmib10`. These fonts are used for the letters math alphabet of Section A.3.4.

Symbol fonts `cmsy*` provide the rest of the math symbols for formulas, except for those that appear in variable sizes. The encoding scheme is named OMS for *old math symbols* and is shown in Layout 6. It comes in sizes 5–10 pt in normal weight, and in 10 pt size in bold face, `cmsy10`. The symbols math alphabet uses these fonts.

Variable sized symbols are to be found in the font `cmex10`, with encoding OMX, for *old math extension*. Layout 7 illustrates this set. There is no bold version of this font. It belongs to the `largesymbols` math alphabet of Section A.3.4.

	0	1	2	3	4	5	6	7
'00x	Γ ₀	Δ ₁	Θ ₂	Λ ₃	Ξ ₄	Π ₅	Σ ₆	Υ ₇
'01x	Φ ₈	Ψ ₉	Ω ₁₀	ff ₁₁	fi ₁₂	fl ₁₃	ffi ₁₄	ffl ₁₅
'02x	ı ₁₆	ı ₁₇	˘ ₁₈	˘ ₁₉	˘ ₂₀	˘ ₂₁	˘ ₂₂	˘ ₂₃
'03x	˘ ₂₄	ß ₂₅	æ ₂₆	œ ₂₇	ø ₂₈	Æ ₂₉	Œ ₃₀	Ø ₃₁
'04x	˘ ₃₂	! ₃₃	” ₃₄	# ₃₅	\$ ₃₆	% ₃₇	& ₃₈	' ₃₉
'05x	(₄₀)	)₄₁	* ₄₂	+ ₄₃	, ₄₄	- ₄₅	· ₄₆	/ ₄₇
'06x	0 ₄₈	1 ₄₉	2 ₅₀	3 ₅₁	4 ₅₂	5 ₅₃	6 ₅₄	7 ₅₅
'07x	8 ₅₆	9 ₅₇	: ₅₈	; ₅₉	i ₆₀	= ₆₁	ı ₆₂	? ₆₃
'10x	@ ₆₄	A ₆₅	B ₆₆	C ₆₇	D ₆₈	E ₆₉	F ₇₀	G ₇₁
'11x	H ₇₂	I ₇₃	J ₇₄	K ₇₅	L ₇₆	M ₇₇	N ₇₈	O ₇₉
'12x	P ₈₀	Q ₈₁	R ₈₂	S ₈₃	T ₈₄	U ₈₅	V ₈₆	W ₈₇
'13x	X ₈₈	Y ₈₉	Z ₉₀	[₉₁	“ ₉₂	]₉₃	^ ₉₄	· ₉₅
'14x	‘ ₉₆	a ₉₇	b ₉₈	c ₉₉	d ₁₀₀	e ₁₀₁	f ₁₀₂	g ₁₀₃
'15x	h ₁₀₄	i ₁₀₅	j ₁₀₆	k ₁₀₇	l ₁₀₈	m ₁₀₉	n ₁₁₀	o ₁₁₁
'16x	p ₁₁₂	q ₁₁₃	r ₁₁₄	s ₁₁₅	t ₁₁₆	u ₁₁₇	v ₁₁₈	w ₁₁₉
'17x	x ₁₂₀	y ₁₂₁	z ₁₂₂	- ₁₂₃	— ₁₂₄	” ₁₂₅	˘ ₁₂₆	” ₁₂₇

Font Layout 1: The character font `cmr10`. This is the standard character assignment for the OT1 encoding scheme.

	0	1	2	3	4	5	6	7
'00x	Γ ₀	Δ ₁	Θ ₂	Λ ₃	Ξ ₄	Π ₅	Σ ₆	Υ ₇
'01x	Φ ₈	Ψ ₉	Ω ₁₀	↑ ₁₁	↓ ₁₂	˘ ₁₃	ı ₁₄	ı ₁₅
'02x	ı ₁₆	ı ₁₇	˘ ₁₈	˘ ₁₉	˘ ₂₀	˘ ₂₁	˘ ₂₂	˘ ₂₃
'03x	˘ ₂₄	ss ₂₅	Æ ₂₆	Œ ₂₇	ø ₂₈	Æ ₂₉	Œ ₃₀	Ø ₃₁
'04x	˘ ₃₂	! ₃₃	” ₃₄	# ₃₅	\$ ₃₆	% ₃₇	& ₃₈	' ₃₉
'05x	(₄₀)	)₄₁	* ₄₂	+ ₄₃	, ₄₄	- ₄₅	· ₄₆	/ ₄₇
'06x	0 ₄₈	1 ₄₉	2 ₅₀	3 ₅₁	4 ₅₂	5 ₅₃	6 ₅₄	7 ₅₅
'07x	8 ₅₆	9 ₅₇	: ₅₈	; ₅₉	< ₆₀	= ₆₁	> ₆₂	? ₆₃
'10x	@ ₆₄	A ₆₅	B ₆₆	C ₆₇	D ₆₈	E ₆₉	F ₇₀	G ₇₁
'11x	H ₇₂	I ₇₃	J ₇₄	K ₇₅	L ₇₆	M ₇₇	N ₇₈	O ₇₉
'12x	P ₈₀	Q ₈₁	R ₈₂	S ₈₃	T ₈₄	U ₈₅	V ₈₆	W ₈₇
'13x	X ₈₈	Y ₈₉	Z ₉₀	[₉₁	“ ₉₂	]₉₃	^ ₉₄	· ₉₅
'14x	‘ ₉₆	A ₉₇	B ₉₈	C ₉₉	D ₁₀₀	E ₁₀₁	F ₁₀₂	G ₁₀₃
'15x	H ₁₀₄	I ₁₀₅	J ₁₀₆	K ₁₀₇	L ₁₀₈	M ₁₀₉	N ₁₁₀	O ₁₁₁
'16x	P ₁₁₂	Q ₁₁₃	R ₁₁₄	S ₁₁₅	T ₁₁₆	U ₁₁₇	V ₁₁₈	W ₁₁₉
'17x	X ₁₂₀	Y ₁₂₁	Z ₁₂₂	- ₁₂₃	— ₁₂₄	” ₁₂₅	˘ ₁₂₆	” ₁₂₇

Font Layout 2: The character font `cmcsc10`. The differences from Layout 1 are symbols 11-15, 25, 60, and 62. The ligatures that normally appear in 11-15 have been replaced by some extra symbols.

	0	1	2	3	4	5	6	7
'00x	Γ ₀	Δ ₁	Θ ₂	Λ ₃	Ξ ₄	Π ₅	Σ ₆	Υ ₇
'01x	Φ ₈	Ψ ₉	Ω ₁₀	ff ₁₁	fi ₁₂	fl ₁₃	ffi ₁₄	fff ₁₅
'02x	ι ₁₆	∫ ₁₇	˘ ₁₈	˙ ₁₉	˚ ₂₀	˛ ₂₁	˜ ₂₂	˝ ₂₃
'03x	ς ₂₄	β ₂₅	æ ₂₆	œ ₂₇	ø ₂₈	Æ ₂₉	Œ ₃₀	Ø ₃₁
'04x	- ₃₂	! ₃₃	" ₃₄	# ₃₅	£ ₃₆	% ₃₇	€ ₃₈	' ₃₉
'05x	(₄₀)	)₄₁	* ₄₂	+ ₄₃	, ₄₄	- ₄₅	· ₄₆	/ ₄₇
'06x	0 ₄₈	1 ₄₉	2 ₅₀	3 ₅₁	4 ₅₂	5 ₅₃	6 ₅₄	7 ₅₅
'07x	8 ₅₆	9 ₅₇	: ₅₈	; ₅₉	<i>i</i> ₆₀	= ₆₁	¿ ₆₂	? ₆₃
'10x	@ ₆₄	A ₆₅	B ₆₆	C ₆₇	D ₆₈	E ₆₉	F ₇₀	G ₇₁
'11x	H ₇₂	I ₇₃	J ₇₄	K ₇₅	L ₇₆	M ₇₇	N ₇₈	O ₇₉
'12x	P ₈₀	Q ₈₁	R ₈₂	S ₈₃	T ₈₄	U ₈₅	V ₈₆	W ₈₇
'13x	X ₈₈	Y ₈₉	Z ₉₀	[₉₁	" ₉₂	]₉₃	^ ₉₄	· ₉₅
'14x	‘ ₉₆	<i>a</i> ₉₇	<i>b</i> ₉₈	<i>c</i> ₉₉	<i>d</i> ₁₀₀	<i>e</i> ₁₀₁	<i>f</i> ₁₀₂	<i>g</i> ₁₀₃
'15x	<i>h</i> ₁₀₄	<i>i</i> ₁₀₅	<i>j</i> ₁₀₆	<i>k</i> ₁₀₇	<i>l</i> ₁₀₈	<i>m</i> ₁₀₉	<i>n</i> ₁₁₀	<i>o</i> ₁₁₁
'16x	<i>p</i> ₁₁₂	<i>q</i> ₁₁₃	<i>r</i> ₁₁₄	<i>s</i> ₁₁₅	<i>t</i> ₁₁₆	<i>u</i> ₁₁₇	<i>v</i> ₁₁₈	<i>w</i> ₁₁₉
'17x	<i>x</i> ₁₂₀	<i>y</i> ₁₂₁	<i>z</i> ₁₂₂	- ₁₂₃	— ₁₂₄	" ₁₂₅	˜ ₁₂₆	¨ ₁₂₇

Font Layout 3: The character font `cmti10`. The only difference from Layout 1 is symbol 36 (£ instead of \$). All other *text italic* fonts have this same pattern.

	0	1	2	3	4	5	6	7
'00x	Γ ₀	Δ ₁	Θ ₂	Λ ₃	Ξ ₄	Π ₅	Σ ₆	Υ ₇
'01x	Φ ₈	Ψ ₉	Ω ₁₀	† ₁₁	‡ ₁₂	' ₁₃	ı ₁₄	ˆ ₁₅
'02x	ı ₁₆	∫ ₁₇	˘ ₁₈	˙ ₁₉	˚ ₂₀	˛ ₂₁	˜ ₂₂	˝ ₂₃
'03x	ς ₂₄	β ₂₅	æ ₂₆	œ ₂₇	ø ₂₈	Æ ₂₉	Œ ₃₀	Ø ₃₁
'04x	□ ₃₂	! ₃₃	" ₃₄	# ₃₅	\$ ₃₆	% ₃₇	& ₃₈	' ₃₉
'05x	(₄₀)	)₄₁	* ₄₂	+ ₄₃	, ₄₄	- ₄₅	· ₄₆	/ ₄₇
'06x	0 ₄₈	1 ₄₉	2 ₅₀	3 ₅₁	4 ₅₂	5 ₅₃	6 ₅₄	7 ₅₅
'07x	8 ₅₆	9 ₅₇	: ₅₈	; ₅₉	< ₆₀	= ₆₁	> ₆₂	? ₆₃
'10x	@ ₆₄	A ₆₅	B ₆₆	C ₆₇	D ₆₈	E ₆₉	F ₇₀	G ₇₁
'11x	H ₇₂	I ₇₃	J ₇₄	K ₇₅	L ₇₆	M ₇₇	N ₇₈	O ₇₉
'12x	P ₈₀	Q ₈₁	R ₈₂	S ₈₃	T ₈₄	U ₈₅	V ₈₆	W ₈₇
'13x	X ₈₈	Y ₈₉	Z ₉₀	[₉₁	\ ₉₂	]₉₃	^ ₉₄	_ ₉₅
'14x	‘ ₉₆	<i>a</i> ₉₇	<i>b</i> ₉₈	<i>c</i> ₉₉	<i>d</i> ₁₀₀	<i>e</i> ₁₀₁	<i>f</i> ₁₀₂	<i>g</i> ₁₀₃
'15x	<i>h</i> ₁₀₄	<i>i</i> ₁₀₅	<i>j</i> ₁₀₆	<i>k</i> ₁₀₇	<i>l</i> ₁₀₈	<i>m</i> ₁₀₉	<i>n</i> ₁₁₀	<i>o</i> ₁₁₁
'16x	<i>p</i> ₁₁₂	<i>q</i> ₁₁₃	<i>r</i> ₁₁₄	<i>s</i> ₁₁₅	<i>t</i> ₁₁₆	<i>u</i> ₁₁₇	<i>v</i> ₁₁₈	<i>w</i> ₁₁₉
'17x	<i>x</i> ₁₂₀	<i>y</i> ₁₂₁	<i>z</i> ₁₂₂	{ ₁₂₃	|₁₂₄	} ₁₂₅	˜ ₁₂₆	¨ ₁₂₇

Font Layout 4: The character font `cmitt10`. All `tt` fonts are set up with the same pattern. The differences from Layout 1 lie in symbols 11–15, 60, 62, 92, 123, 124, and 125. Furthermore, the italic typewriter fonts also have £ in place of \$.

The term *old* in these encoding names refers to the original encoding as introduced by Donald Knuth, in the same way that the text encoding OT1 indicated the old, or original, text encoding with 128 characters per font. The new encoding schemes contain 256 characters. For text, the encoding is named T1 (Section G.4.3); such extended math fonts do not yet exist.

The extra \mathcal{AMS} fonts in Section 12.4.1 add additional bold face sizes for `cmmb*` and `cmbsy*` as well as some more sizes for `cmex*`.

Decorative fonts

Three families of decorative or special fonts are available in a single design size and limited attributes. They all exhibit OT1 encoding.

`cmfr` *Funny Roman* family, consists of two fonts, `cmff10` leaning to the left and `cmfi10` which leans to the right. Both are series `m` with shapes `n` and `it` respectively.

`cmfib` *Fibonacci* family, contains one font `cmfib8` derived from the Fibonacci series of numbers. It has series `m` and shape `n`.

`cmdunh` *Dunhill* family, with one font `cmdunh10` with series `m` and shape `n`. This font is demonstrated in the sample letterhead on page 364.

Logo fonts

The fonts `logo8`, `logo9`, `logo10`, `logos110`, and `logobf10` contain only the nine letters A, E, F, M, N, O, P, S, and T, for generating the logos

```
METAFONT  METAFONT  METAFONT
METAPOST  METAPOST  METAPOST
```

The L^AT_EX `lasy` fonts

Package: As an extension of the `cmsy*` fonts for mathematical symbols, L^AT_EX provides some additional symbols with the font `lasy*` in design sizes 5–10 pt. It contains the 15 symbols: $\langle \rangle \wedge \vee \triangleleft \triangle \triangleright \triangleright \cup \otimes \square \diamond \rightsquigarrow \square \square$.

`latexsym`
`amsfonts`

These symbols are not defined unless one of the packages `latexsym` or `amsfonts` has been loaded.

Fonts for making pictures

The special picture elements for use in the L^AT_EX `picture` environment are stored in fonts named `line10`, `lcircle10`, `linew10`, and `lcirclew10`. The first two are used for lines, ovals, and circles when `\thinlines` is in effect. The sloping lines and arrow heads are to be found in `line10`

	0	1	2	3	4	5	6	7
'00x	Γ 0	Δ 1	Θ 2	Λ 3	Ξ 4	Π 5	Σ 6	Υ 7
'01x	Φ 8	Ψ 9	Ω 10	α 11	β 12	γ 13	δ 14	ϵ 15
'02x	ζ 16	η 17	θ 18	ι 19	κ 20	λ 21	μ 22	ν 23
'03x	ξ 24	π 25	ρ 26	σ 27	τ 28	υ 29	ϕ 30	χ 31
'04x	ψ 32	ω 33	ε 34	ϑ 35	ϖ 36	ϱ 37	ς 38	φ 39
'05x	\leftarrow 40	\leftarrow 41	\rightarrow 42	\rightarrow 43	\curvearrowright 44	\curvearrowright 45	\triangleright 46	\triangleleft 47
'06x	o 48	1 49	2 50	3 51	4 52	5 53	6 54	7 55
'07x	8 56	9 57	. 58	, 59	< 60	/ 61	> 62	* 63
'10x	∂ 64	A 65	B 66	C 67	D 68	E 69	F 70	G 71
'11x	H 72	I 73	J 74	K 75	L 76	M 77	N 78	O 79
'12x	P 80	Q 81	R 82	S 83	T 84	U 85	V 86	W 87
'13x	X 88	Y 89	Z 90	b 91	q 92	# 93	~ 94	^ 95
'14x	ℓ 96	a 97	b 98	c 99	d 100	e 101	f 102	g 103
'15x	h 104	i 105	j 106	k 107	l 108	m 109	n 110	o 111
'16x	p 112	q 113	r 114	s 115	t 116	u 117	v 118	w 119
'17x	x 120	y 121	z 122	v 123	j 124	\wp 125	$\bar{\cdot}$ 126	$\hat{\cdot}$ 127

Font Layout 5: The font `cmmi10`. This corresponds to the OML encoding scheme, as does `cmmib10`. It contains lower case Greek letters in positions 11-39 and math symbols in 40-47, 60-64, and 123-127.

	0	1	2	3	4	5	6	7
'00x	- 0	· 1	× 2	* 3	÷ 4	◇ 5	± 6	∓ 7
'01x	⊕ 8	⊖ 9	⊗ 10	⊘ 11	⊙ 12	◯ 13	◦ 14	• 15
'02x	≲ 16	≡ 17	⊆ 18	⊇ 19	≤ 20	≥ 21	≲ 22	≳ 23
'03x	~ 24	≈ 25	⊂ 26	⊃ 27	≪ 28	≫ 29	≲ 30	≳ 31
'04x	← 32	→ 33	↑ 34	↓ 35	↔ 36	↗ 37	↘ 38	≈ 39
'05x	⇐ 40	⇒ 41	↑ 42	↓ 43	↔ 44	↖ 45	↗ 46	∝ 47
'06x	! 48	∞ 49	∈ 50	∋ 51	△ 52	▽ 53	/ 54	! 55
'07x	∇ 56	∃ 57	¬ 58	∅ 59	ℜ 60	ℑ 61	⊤ 62	⊥ 63
'10x	ℵ 64	\mathcal{A} 65	\mathcal{B} 66	\mathcal{C} 67	\mathcal{D} 68	\mathcal{E} 69	\mathcal{F} 70	\mathcal{G} 71
'11x	\mathcal{H} 72	\mathcal{I} 73	\mathcal{J} 74	\mathcal{K} 75	\mathcal{L} 76	\mathcal{M} 77	\mathcal{N} 78	\mathcal{O} 79
'12x	\mathcal{P} 80	\mathcal{Q} 81	\mathcal{R} 82	\mathcal{S} 83	\mathcal{T} 84	\mathcal{U} 85	\mathcal{V} 86	\mathcal{W} 87
'13x	\mathcal{X} 88	\mathcal{Y} 89	\mathcal{Z} 90	∪ 91	∩ 92	⊕ 93	∧ 94	∨ 95
'14x	⊢ 96	⊣ 97	⊥ 98	⊥ 99	⌈ 100	⌋ 101	{ 102	} 103
'15x	⟨ 104	⟩ 105	| 106	|| 107	↑ 108	↓ 109	\ 110	! 111
'16x	√ 112	∏ 113	∇ 114	∫ 115	⊔ 116	⊓ 117	⊆ 118	⊇ 119
'17x	§ 120	† 121	‡ 122	¶ 123	♣ 124	◇ 125	♥ 126	♠ 127

Font Layout 6: The font `cmsy10`. The `cmsy` fonts, adhering to the OMS encoding scheme, contain many math symbols as well as the calligraphic letters $\mathcal{A} \dots \mathcal{Z}$ in positions 65-90. The bold face version `cmsy10` is set up on the same pattern.

	0	1	2	3	4	5	6	7
'00x	(0)	1	[2]	3	| 4	| 5	| 6	| 7
'01x	{ 8 }	9	< 10 >	11	| 12	|| 13	/ 14 \	15
'02x	(16)	17	(18)	19	[20 ]	| 21	| 22	| 23
'03x	[24 ]	| 25	{ 26 }	27	< 28 >	29	/ 30 \	31
'04x	(32)	33	[34 ]	| 35	| 36	| 37	[38 ]	| 39
'05x	{ 40 }	} 41	< 42 >	43	/ 44 \	45	/ 46 \	47
'06x	(48 )	) 49	[50 ]	| 51	| 52	| 53	| 54	| 55
'07x	(56 )	) 57	(58 )	) 59	{ 60 }	} 61	' 62	| 63
'10x	(64 )	) 65	| 66	| 67	< 68 >	69	⊔ 70	⊔ 71
'11x	ℱ 72	ℳ 73	⊙ 74	⊙ 75	⊕ 76	⊕ 77	⊗ 78	⊗ 79
'12x	Σ 80	Π 81	∫ 82	∪ 83	∩ 84	⊕ 85	∧ 86	∨ 87
'13x	Σ 88	Π 89	∫ 90	∪ 91	∩ 92	⊕ 93	∧ 94	∨ 95
'14x	Π 96	Π 97	ˆ 98	ˆ 99	ˆ 100	˜ 101	˜ 102	˜ 103
'15x	[104 ]	| 105	| 106	| 107	[108 ]	| 109	{ 110 }	} 111
'16x	√ 112	√ 113	√ 114	√ 115	√ 116	| 117	⌈ 118	⌋ 119
'17x	↑ 120	↓ 121	↷ 122	↶ 123	↷ 124	↶ 125	↗ 126	↘ 127

Font Layout 7: The font cmex10, containing the mathematical symbols that appear in varying sizes. This is the OMX encoding scheme.

	0	1	2	3	4	5	6	7
'00x	Ъ 0	Љ 1	Ц 2	Э 3	І 4	Є 5	Ђ 6	Ћ 7
'01x	ъ 8	љ 9	ц 10	э 11	і 12	є 13	ђ 14	ћ 15
'02x	Ю 16	Ж 17	Й 18	Ё 19	Ѵ 20	Ѳ 21	Ѕ 22	Ј 23
'03x	ю 24	ж 25	й 26	ё 27	ѵ 28	ѳ 29	ѕ 30	ј 31
'04x	“ 32	! 33	” 34	Ђ 35	“ 36	% 37	’ 38	’ 39
'05x	(40	) 41	* 42	Ђ 43	, 44	- 45	. 46	/ 47
'06x	0 48	1 49	2 50	3 51	4 52	5 53	6 54	7 55
'07x	8 56	9 57	: 58	; 59	« 60	ı 61	» 62	? 63
'10x	˘ 64	А 65	Б 66	Ц 67	Д 68	Е 69	Ф 70	Г 71
'11x	Х 72	И 73	Ј 74	К 75	Л 76	М 77	Н 78	О 79
'12x	П 80	Ч 81	Р 82	С 83	Т 84	У 85	В 86	Ш 87
'13x	Ш 88	Ы 89	З 90	[91	“ 92	] 93	Ь 94	Ъ 95
'14x	‘ 96	а 97	б 98	ц 99	д 100	е 101	ф 102	г 103
'15x	х 104	и 105	ј 106	к 107	л 108	м 109	н 110	о 111
'16x	п 112	ч 113	р 114	с 115	т 116	у 117	в 118	ш 119
'17x	ш 120	ы 121	з 122	– 123	— 124	№ 125	ь 126	ъ 127

Font Layout 8: The character font `wncyr10`, one of the Cyrillic fonts from the University of Washington. Its coding scheme is designated OT2.

while the circles and oval segments (Section 13.1.4) are in `lcircle10`. The second pair of fonts with the added `w` contain thicker lines, for use with `\thicklines`.

G.2.3 *AMS* Cyrillic fonts

The Cyrillic fonts that are part of the `amsfonts` collection are described in Section 12.4.2. They conform to the font encoding scheme OT2, displayed in Layout 8. They are available as upright (`wncyr*`), bold (`wncyb*`), small caps (`wncysc*`), and upright sans serif (`wncyss*`) fonts. As for the CM fonts, `*` represents the design size in points.

The NFSS system assigns these fonts to families `cmr` and `cms`; that is, they are treated as members of the Computer Modern set. This is not as absurd as it sounds since they are intended to be used with the CM fonts.

G.3 The METAFONT program

METAFONT is a program for designing and developing character fonts, written by Donald E. Knuth as a companion to his \TeX program (Knuth, 1986c, 1986d, 1986e). It is this program that made the uniform high quality typographic output possible for \TeX at a time when most printers had their own built-in fonts of varying standards.

The printer driver programs have the task of converting the DVI output from T_EX into instruction code for a particular printer. To do this, they need to know how to print each of the symbols used in the document. These symbols are represented as a set of black and white dots (*pixels*) that is adjusted to the output resolution. Clearly to produce the letter *A* in a given size at 600 dpi (*dots per inch*) requires many more dots than at 150 dpi (16 times). This information is contained in the corresponding .pk files, in compressed format.

However, designing fonts as a set of dots, and that for any number of resolutions, and taking into account idiosyncrasies of individual printers, is an impossible task. Rather, the fonts are defined with .mf files, containing instructions on how to *draw* the symbols with a pen of a given shape. This is the most general definition, describing the ideal form. METAFONT then translates this ideal into the practical realization, the pixels, for any specified resolution. Aspects of the various printers, such as relative pixel size and shape, may also be included, so that the resulting patterns are both resolution and printer dependent. The font metric .tfm files are also produced in this process.

Today it is hardly necessary for most users to know anything more about METAFONT other than that it exists. The drivers and previewers are now so constructed that when they notice that the required .pk file is missing, they invoke METAFONT themselves to generate it. In this way the collection of pixel files grows as needed and includes only those that are actually used. (Originally huge sets of pixel files had to be supplied to cover every remote possibility.)

Another reason for the decline in the awareness of METAFONT is the increasing use of the type 1 fonts for PostScript and PDF output (Chapter 10).

Donald Knuth has announced that he wishes to withdraw from any further development of either of these programs, being prepared merely to correct any definite errors they may contain. To emphasize this decision, he will from now on give version numbers to T_EX that converge to π (3.14159. . .) and to METAFONT that approach the value of e (2.71828. . .). At present, T_EX is at version 3.14159 and METAFONT at 2.718. As a consequence of this decision, any further major developments to these two programs, such as undertaken by user groups, will be under new names, since Knuth has kept the copyright to the existing names.

G.4 Extended Computer fonts

The Computer Modern fonts were developed in the early days of T_EX when it could only handle 128 characters per font. The modern T_EX program can deal with 256 characters in each font, requiring a new set of standard fonts to exploit this feature.

G.4.1 Limitations and deficiencies of the CM fonts

Most of the diacritical marks (accents) used in European languages written with the Latin alphabet are contained in, or may be generated by, T_EX's Computer Modern (CM) fonts. A basic set of naked accents is available for combination with other letters, such as the acute accent ´ with the letter *e* to make *é*. Other combinations may be constructed for diacritical marks that are not predefined in T_EX or L^AT_EX.

Fashioning diacritical characters as a combination of letters and special symbols has one great disadvantage for the T_EX processing: words containing such characters cannot take part in the automatic word division since the hyphenation patterns include only pure letters. The accented letters, such as those in German and French and most other languages, must be treated as *single* characters in the hyphenation patterns, and must appear as single letters in the character set.

In addition to diacritical characters, a number of special letters are employed in some European languages, such as ß, Æ, æ, Œ, œ, Ø, and ø, which are provided in standard T_EX with the CM fonts (Section 2.5.6). However, other special letters, such as Ð, ñ, Þ, þ, and ð, are missing completely and cannot be easily constructed from existing ones.

G.4.2 The Cork proposal

At the 1990 International T_EX Conference in Cork, Ireland, an extension of the Latin alphabet and its assignments within the 256 character positions was proposed and accepted. This extension includes the majority of special and diacritical letters as single characters for many languages written with the Latin alphabet. Hyphenation patterns for such languages may include the special and diacritical letters as single letters for optimal word division by T_EX and L^AT_EX.

Character fonts conforming to the Cork scheme are to bear the identifying letters *ec* in their names for 'Extended Computer' in place of the *cm* for 'Computer Modern'.

G.4.3 The realization of EC fonts

The Cork proposal for extending the T_EX fonts to 256 characters was first implemented by Norbert Schwarz, who produced an initial set of META-FONT source files. He also selected the designation *dc* to emphasize that this was a preliminary realization of the EC fonts. Some work was still needed to fine-tune the design of several symbols.

After issuing versions 1.2 and 1.3 of the DC fonts in 1995 and 1996, Jörg Knappen released the first set of true EC fonts in January, 1997. Font Layout 9 presents his font *ecrm1000*, the extended version of *cmr10*. The EC fonts are now considered to be stable in that neither their encoding

	0	1	2	3	4	5	6	7
'00x	` 0	´ 1	ˆ 2	˜ 3	¨ 4	” 5	° 6	˘ 7
'01x	˘ 8	ˉ 9	˙ 10	˚ 11	€ 12	‚ 13	‹ 14	› 15
'02x	“ 16	” 17	„ 18	« 19	» 20	– 21	— 22	23
'03x	‰ 24	ı 25	ı 26	ff 27	fi 28	fl 29	ffi 30	ffl 31
'04x	32	! 33	" 34	# 35	\$ 36	% 37	& 38	' 39
'05x	(40	) 41	* 42	+ 43	, 44	- 45	. 46	/ 47
'06x	0 48	1 49	2 50	3 51	4 52	5 53	6 54	7 55
'07x	8 56	9 57	: 58	; 59	< 60	= 61	> 62	? 63
'10x	@ 64	A 65	B 66	C 67	D 68	E 69	F 70	G 71
'11x	H 72	I 73	J 74	K 75	L 76	M 77	N 78	O 79
'12x	P 80	Q 81	R 82	S 83	T 84	U 85	V 86	W 87
'13x	X 88	Y 89	Z 90	[91	\ 92	] 93	^ 94	- 95
'14x	‘ 96	a 97	b 98	c 99	d 100	e 101	f 102	g 103
'15x	h 104	i 105	j 106	k 107	l 108	m 109	n 110	o 111
'16x	p 112	q 113	r 114	s 115	t 116	u 117	v 118	w 119
'17x	x 120	y 121	z 122	{ 123	| 124	} 125	~ 126	- 127
'20x	Ä 128	Å 129	Ć 130	Č 131	Ď 132	Ě 133	Ě 134	Č 135
'21x	Ĺ 136	Ľ 137	Ł 138	Ń 139	Ň 140	Đ 141	Ŏ 142	Ř 143
'22x	Ř 144	Ś 145	Š 146	Ş 147	Ť 148	Ŧ 149	Ů 150	Ű 151
'23x	Ÿ 152	Ž 153	Ž 154	Ž 155	IJ 156	Í 157	đ 158	§ 159
'24x	ă 160	ą 161	ć 162	č 163	ď 164	ě 165	ę 166	ğ 167
'25x	í 168	ı 169	ł 170	ń 171	ň 172	ŋ 173	ő 174	ı 175
'26x	ř 176	ś 177	š 178	ş 179	ť 180	ŧ 181	ű 182	û 183
'27x	ÿ 184	ź 185	ż 186	ż 187	ij 188	i 189	ı 190	£ 191
'30x	À 192	Á 193	Â 194	Ã 195	Ä 196	Å 197	Æ 198	Ç 199
'31x	È 200	É 201	Ê 202	Ë 203	Ì 204	Í 205	Î 206	Ï 207
'32x	Ð 208	Ñ 209	Ò 210	Ó 211	Ô 212	Õ 213	Ö 214	Œ 215
'33x	Ø 216	Û 217	Ú 218	Û 219	Ü 220	Ý 221	Þ 222	Š 223
'34x	à 224	á 225	â 226	ã 227	ä 228	å 229	æ 230	ç 231
'35x	è 232	é 233	ê 234	ë 235	ì 236	í 237	î 238	ï 239
'36x	ð 240	ñ 241	ò 242	ó 243	ô 244	õ 245	ö 246	œ 247
'37x	ø 248	ù 249	ú 250	û 251	ü 252	ý 253	þ 254	ß 255

Font Layout 9: The extended font ecrm1000 with T1 encoding.

nor their metrics (the `.tfm` files) will be changed in future. Thus their behavior as far as \TeX and \LaTeX are concerned is finalized. The actual printed characters might be modified slightly in later updates.

The EC font names are of the form `ecxxnnnn`, where `xx` represents two letters specifying the font characteristics, and `nnnn` the design size in hundredths of points. Thus `ecrm1000` is the upright Roman font in size 10 points.

The METAFONT source files are available for the following extended fonts (without the size specification):

<code>ecrm</code>	<code>ecrb</code>	<code>eccc</code>	<code>ecci</code>	<code>ecvi</code>	<code>ecss</code>	<code>ecdh</code>
<code>ecbx</code>	<code>ecti</code>	<code>ecxc</code>	<code>ectt</code>	<code>ecvi</code>	<code>ecsi</code>	
<code>ecbl</code>	<code>ecui</code>	<code>ecsc</code>	<code>ecit</code>	<code>ectc</code>	<code>ecsx</code>	
<code>ecrb</code>	<code>ecbi</code>	<code>ecoc</code>	<code>ecvt</code>	<code>ecst</code>	<code>ecso</code>	

Comparing these with the root names of the CM fonts from Table G.1 on page 491, one may easily recognize the correspondence. For example, `ecbx*` is the extended bold font corresponding to the CM font `cmbx*`.

It is intended that the EC fonts should exist in most design sizes. The present distribution contains almost all the fonts in sizes from 5 to 35.83 pt, that is, with size specifications:

0500	0600	0700	0800	0900	1000	1095
1200	1440	1728	2074	2488	2986	3583

In contrast to the CM text fonts which exhibit differences in the symbol assignments among them, as illustrated in Layouts 1–4, the EC fonts *all* have exactly the same encoding scheme, as presented in Layout 9.

The EC fonts are now part of the standard \LaTeX installations.

A parallel set of fonts called *text companion*, or TC, fonts is also provided. These contain special symbols for text that are normally found in the CM math fonts, if at all, such as currency symbols and degree signs. These fonts are still somewhat experimental so that the symbol assignments are not yet stable. The current contents are shown in Layout 10.

G.4.4 Invoking the EC and TC fonts

The EC fonts correspond to the NFSS encoding scheme T1 (Section A.1). The simplest way to activate them is to place

```
\usepackage[T1]{fontenc}
```

in the preamble of the document. All this really does is to make T1 the standard encoding by redefining `\encodingdefault` to be T1, and it loads the file `t1enc.def` which redefines the accent and special letter commands by means of the encoding commands of Section A.3.7.

	0	1	2	3	4	5	6	7
'00x	˘ 0	˘ 1	ˆ 2	˜ 3	¨ 4	˘ 5	˚ 6	ˇ 7
'01x	˘ 8	˘ 9	˙ 10	˘ 11	˘ 12	˘ 13	14	15
'02x	16	17	¨ 18	19	20	— 21	— 22	23
'03x	← 24	→ 25	ˆ 26	ˆ 27	ˆ 28	ˆ 29	30	31
'04x	ˆ 32	33	34	35	\$ 36	37	38	' 39
'05x	40	41	* 42	43	, 44	= 45	· 46	/ 47
'06x	o 48	1 49	2 50	3 51	4 52	5 53	6 54	7 55
'07x	8 56	9 57	58	59	< 60	— 61	> 62	63
'10x	64	65	66	67	68	69	70	71
'11x	72	73	74	75	76	U 77	78	○ 79
'12x	80	81	82	83	84	85	86	Ω 87
'13x	88	89	90	¶ 91	92	¶ 93	↑ 94	↓ 95
'14x	˘ 96	97	* 98	o 99	† 100	101	102	103
'15x	104	105	106	107	108	∞ 109	♯ 110	111
'16x	112	113	114	115	116	117	118	119
'17x	120	121	122	123	124	125	~ 126	= 127
'20x	˘ 128	˘ 129	˘ 130	˘ 131	† 132	‡ 133	¶ 134	‰ 135
'21x	• 136	°C 137	\$ 138	¢ 139	f 140	© 141	W 142	ℱ 143
'22x	© 144	P 145	£ 146	R 147	‡ 148	↓ 149	d 150	™ 151
'23x	‰ 152	¶ 153	B 154	№ 155	% 156	e 157	o 158	SM 159
'24x	{ 160	} 161	¢ 162	£ 163	∩ 164	¥ 165	ı 166	§ 167
'25x	¨ 168	© 169	ª 170	© 171	¬ 172	© 173	® 174	— 175
'26x	˚ 176	± 177	² 178	³ 179	´ 180	µ 181	¶ 182	· 183
'27x	※ 184	¹ 185	º 186	√ 187	¼ 188	½ 189	¾ 190	€ 191
'30x	192	193	194	195	196	197	198	199
'31x	200	201	202	203	204	205	206	207
'32x	208	209	210	211	212	213	× 214	215
'33x	216	217	218	219	220	221	222	223
'34x	224	225	226	227	228	229	230	231
'35x	232	233	234	235	236	237	238	239
'36x	240	241	242	243	244	245	÷ 246	247
'37x	248	249	250	251	252	253	254	255

Font Layout 10: The text companion font tcrm1000 with the TS1 encoding scheme.

Package: `textcomp` To obtain access to the symbols in the TC fonts, one can load the `textcomp` package, which not only redefines several existing symbol commands, it also adds many new ones. For example, `\copyright`, which is normally defined to be `\textcircled{c}`, is changed to print character 169 from an appropriate TC font. Character 191 is the symbol for the European currency unit, the euro, printed with `\texteuro`; however, better ways of producing it are presented in Section 2.5.8.

G.4.5 Special character commands

Inspecting Font Layout 9, one notices that the EC fonts contain not only many single characters that are formed out of two CM symbols (like $\text{Å} = \text{A} + \text{ˆ}$) but also several characters that have no correspondence in the CM font layout at all. The first type is accommodated by internally redefining the action of accent and special character commands. The second set requires new commands that are recognized only when the T1 encoding is active. These are

```

the ogonek accent \k{o}: o
special letters \DH = Đ \DJ = Đ \NG = Ŋ \TH = Þ
               \dh = đ \dj = đ \ng = ŋ \th = þ
special symbols \guillemotleft = « \guillemotright = »
               \guilsinglleft = < \guilsinglright = >
               \quotedblbase = „ \quotesinglbase = ,
               \textquotedbl = "

```

When issued in OT1 encoding, these commands print an error message.

Note: The `\guillemotleft` and `\guillemotright` are not misprints even though the proper word for the French quotations marks is *guillemet*. The PostScript fonts contain these erroneous names for these symbols and this mistake has propagated to such an extent that it can never be removed from all the software that includes it. A *guillemot* is in fact an Arctic bird, not a French quotation mark.

G.5 PostScript fonts

PostScript fonts, also known as outline or type 1 fonts, are treated exactly the same way as the METAFONT fonts as far as L^AT_EX is concerned: during the processing, a `.tfm` file is read in for each font specifying the character sizes and other properties. This is all that L^AT_EX needs to know, for it is the task of the driver program to print the actual character that fills the reserved space.

The driver makes use of the *virtual font* mechanism, which means that what L^AT_EX sees are actually artificial fonts that do not really exist on their

own. There are .tfm files for these fonts, so the L^AT_EX processing proceeds as normal. What the driver then does is to read a .vf file instead of the pixel .pk files. The instructions in the virtual font file tell the driver how to create each character: they may be drawn, taken from other fonts, or distorted. This is how PostScript slanted and small caps fonts are emulated, for such fonts do not exist in the ‘raw’ form. See Section 10.1.4 for example of how this works.

Even the font layout can be redesigned with virtual fonts. The raw PostScript fonts have an encoding scheme that conforms to neither OT1 nor T1, but which is used as a pool of symbols for constructing virtual fonts that do conform to these schemes. In particular, the Computer Modern fonts contain upper case Greek letters in the first 11 slots (Layout 1 on page 492) which are to be found in the PostScript symbol font only. The virtual font ptmr7t conforms to this by taking its characters from both the raw Times-Roman and Symbol fonts.

G.5.1 Naming scheme for PostScript fonts

In order to be compatible with all possible operating systems, it is necessary to reduce the names of the PostScript font files to a maximum of eight characters. This makes for an extremely abbreviated and cryptic nomenclature.

The most commonly used scheme is that of Karl Berry. Here, the first letter of the name specifies the supplier of the font, for example p for Adobe (stands for PostScript), or h for Bigelow & Holmes, who designed the Lucida fonts used in this book, or m for Monotype, or l for Linotype, and so on.

Table G.2: Root names of the 35 standard PostScript fonts

pagd	AvantGarde-Demi	phvrrn	Helvetica-Narrow
pagdo	AvantGarde-DemiOblique	phvron	Helvetica-Narrow-Oblique
pagk	AvantGarde-Book	pncb	NewCenturySchlbk-Bold
pagko	AvantGarde-BookOblique	pncbi	NewCenturySchlbk-BoldItalic
pbkd	Bookman-Demi	pncr	NewCenturySchlbk-Roman
pbkdi	Bookman-DemiItalic	pncri	NewCenturySchlbk-Italic
pbkl	Bookman-Light	pplb	Palatino-Bold
pbkli	Bookman-LightItalic	pplbi	Palatino-BoldItalic
pcrb	Courier-Bold	pplr	Palatino-Roman
pcrbo	Courier-BoldOblique	pplri	Palatino-Italic
pcrr	Courier	psyr	Symbol
pcrro	Courier-Oblique	ptmb	Times-Bold
phvb	Helvetica-Bold	ptmbi	Times-BoldItalic
phvbo	Helvetica-BoldOblique	ptmr	Times-Roman
phvbrn	Helvetica-Narrow-Bold	ptmri	Times-Italic
phvbon	Helvetica-Narrow-BoldOblique	pzcmi	ZapfChancery-MediumItalic
phvr	Helvetica	pzdr	ZapfDingbats
phvro	Helvetica-Oblique		

Table G.3: A selection of the encoding suffixes in the Berry nomenclature

Suffix	Encoding	NFSS designation	Page
7t	7-bit T _E X text encoding	OT1	492
7m	T _E X math italics encoding	OML	495
7v	T _E X math extension encoding	OMX	496
7y	T _E X math symbols encoding	OMS	495
8t	8-bit Cork encoding	T1	500
8a	Adobe standard encoding		
8r	TeXBase1Encoding		

A two-letter typeface code follows the supplier letter, such as `tm` for Times-Roman. Next come various letters to specify weight, for example `r` for regular (upright Roman) or `b` for bold, and variant, like `i` for italic, `o` for oblique (slanted). Next come a number plus letter to indicate the encoding scheme, followed by possible width code letters. The Berry names for the 35 standard PostScript fonts that should be loaded in every printer are listed in Table G.2 on the facing page, without the encoding suffixes.

The most important encoding suffixes for our purposes are listed in Table G.3. The 7-bit encodings have already been explained in Section G.2.2 and shown in Layouts 1, 5-7, while the `8t` or `T1` scheme is to be found in Layout 9 in Section G.4.3.

The other 8-bit schemes listed in Table G.3 are the raw encoding, `8r`, and the Adobe standard encoding, `8a`, which is the default for most type 1 fonts if no re-encoding is specified. This scheme plays absolutely no role in the NFSS installation for PostScript fonts.

Virtual fonts `ptmr7t` and `ptmr8t` are both constructed from the same raw font `ptmr8r`, differing only in the character assignments. There are also raw fonts that are modifications of the basic fonts. For example, `ptmro8t` is an oblique Times-Roman virtual font, based on `ptmro8r`, the raw version. However, there is no such font in the repertoire of Table G.2. This pseudo font is generated by applying a PostScript slanting operation to Times-Roman, as demonstrated in Section 10.1.4.

G.6 Computer Modern as PostScript fonts

The traditional pixel fonts produced by METAFONT have served us well in the days when the emphasis was on printed paper output. Even for PostScript output, the pixel fonts are acceptable for online viewing. However, they become very tedious when included in PDF output for

viewing: they appear very fuzzy and require a long time to draw. For this reason, PDF output, whether produced with pdfT_EX, dvipdfm, or converted from PostScript, should use type 1 fonts exclusively. To this end, the Computer Modern fonts themselves have been converted to type 1 fonts.

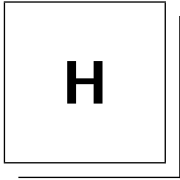
The first such undertaking was carried out by Basil Malyshev whose set of font files are known as *bakoma*. However, the set that is more often used today is the result of a joint project of Y&Y Inc. and Blue Sky Research. Originally part of their commercial T_EX installations, these fonts are now available free of charge. They are included on the T_EXLive CD under `texmf\fonts\type1\bluesky\` in several subdirectories as `.pfb` files. They bear the same names and have the same font metrics as the corresponding pixel fonts (Appendix G) and therefore do not need any additional `.tfm` files. However, one must also get the mapping file `bsr.map` from `texmf\dvips\bluesky\` and add it to the list of mapping files in `config.ps`.

The Bluesky fonts are incomplete in that certain less often used fonts are missing in some sizes. One can either include the map file `bsr-interpolated.map`, which substitutes the missing sizes with the nearest approximation, or employ the *bakoma* fonts that fill the gaps, with the map file `bakomaextra.map`. The T_EXLive CD does not include the complete *bakoma* set, but only those fonts that are missing in the Bluesky ensemble.

Together Bluesky and *bakoma* provide PostScript-encoded versions for all the Computer Modern fonts described in Section G.2, for text, math, symbols, decoration, pictures, along with the additional $\mathcal{A}\mathcal{M}\mathcal{S}$ fonts for additional symbols and Cyrillic. However, these are only for the OT1 encoding with 128 characters per font.

A more recent effort to apply PostScript to the Extended Computer (EC) fonts with the T1 encoding has been successfully completed by Vladimir Volovich with his *cm-super* collection. Each of the basic `.pfb` files contains from 468 to 585 characters, which by means of encoding vectors and mapping files can be used to emulate all the fonts in Section G.4, including the text companion fonts with TS1 encoding, and many other additional encoding schemes. They were generated from the original METAFONT `.mf` source files and should therefore produce exactly the same results as the corresponding pixel fonts.

To use them, one must install the *cm-super* package from the T_EXLive CD, which copies the `.pfb` files from `\texmf\fonts\type1\cm-super\` and the mapping and encoding files from `\texmf\dvips\cm-super\`. The metric `.tfm` files are the same as those for the pixel files and so need not be provided extra.



Command Summary

This appendix contains a brief description of all the \LaTeX commands, in alphabetical (ASCII) order, neglecting the leading backslash \backslash , along with some \TeX commands that have been explained in this book. In the following section, the commands are presented in their logical grouping in a number of tables and figures.

H.1 Brief description of the \LaTeX commands

For each command in the following summary, the section and page number is given where it is introduced and described in detail. The numbers are shown in the form: ‘(Section) – Page’: for example (2.5.1) – 13 means ‘Section 2.5.1, page 13’. If these numbers are missing, then the command has not been presented in the book but is only mentioned here.

The following notations may be added to the commands:

- [m] those permitted in math mode only;
- [a] those belonging to $\mathcal{AMS}\text{-}\LaTeX$;
- [p] those allowed only in the preamble.

$\backslash_$	..... (2.1), (2.7.1) – 19, 29
	Normal space between words after a command without arguments or after a period that is not the end of a sentence.
!	..... (9.4.2) – 226
	Field separation character within the $\backslash\text{index}$ command. For example: with $\backslash\text{index}\{\text{command!fragile}\}$ one produces an index sub-entry ‘fragile’ under the main entry ‘command’.
!‘	produces j (2.5.6) – 24
$\backslash!$ [m]	..... (5.5.1) – 145
	In math mode, a negative space of $-1/6$ quad: $xx\!x = xxx$.

"	. . . . . (2.5.2), (9.4.2), (14.2) - 23, 227, 311
	1. In normal text, this produces the double closing quote ". 2. Literal sign for MakeIndex, in order to print one of the special characters !, @, |, or ". Example: <code>\index{"!}</code> to enter character ! without it being interpreted as a separation character. 3. Delimiter for a text field in BibTeX. Example: AUTHOR = "Donald E. Knuth".
\"	. . . . . (2.5.7) - 24
	Produces an umlaut accent: <code>\"{a}</code> = ä.
#	. . . . . (8.3.2), (8.4.2) - 187, 198
	Argument replacement character in a user-defined command or environment.
##	. . . . . (8.5.6) - 204
	Replacement character for an <i>internal</i> argument within a <i>nested</i> user-defined command or environment.
\\#	. . . . . (2.5.4) - 23
	Command to produce a hash symbol: <code>\# = #</code> .
\$	. . . . . (5.1) - 119
	Toggle character for switching between text and in-line math modes. On the first appearance (text to math) it behaves the same as <code>\(</code> or <code>\begin{math}</code> , while the second call (math to text) is as <code>\)</code> or <code>\end{math}</code> .
\\$	. . . . . (2.5.4) - 23
	Command to produce a dollar sign: <code>\\$ = \$</code> .
%	. . . . . (4.11) - 118
	Comment character. The rest of the line of text following % is ignored by the TeX processing.
\%	. . . . . (2.5.4) - 23
	Command to produce a percent sign: <code>\% = %</code> .
&	. . . . . (4.8.1) - 97
	Indicates a new column in <code>array</code> and <code>tabular</code> environments.
\&	. . . . . (2.5.4) - 23
	Command to produce an ampersand symbol: <code>\& = &</code> .
\'	. . . . . (2.5.7), (4.6.4) - 24, 83
	1. Command to produce an acute accent: <code>\'a = á</code> .

2. Within the `tabbing` environment, a command to jump to the end of the current column.

() (13.1.2), (14.2) - 289, 312

For a picture command in `picture` environment, specifies a coordinate pair. In `BiBTEX`, an alternative form for the outermost grouping of the entry type.

\(. (5.1) - 119

Switches from text to in-line math mode to produce formulas within a line of text. It functions the same as `\begin{math}` and as a `$` sign in text mode.

\) (5.1) - 119

Switches back from in-line math mode to text mode. It functions the same as `\end{math}` and as a `$` sign in math mode.

\+ (4.6.3) - 82

Within the `tabbing` environment, increments the left margin by one tab stop (moves it to the right).

\, (2.7.1), (5.5.1) - 29, 145

Small space, the size of 1/6 quad, for use in text and math mode:
`xx\,x = xx x.`

- (2.5.3) - 23

As `-`, produces the hyphen `-` for compound words and word division, as `--`, the en dash `-`, and as `---`, the em dash `—`.

\- (2.8.1), (4.6.3) - 35, 82

1. Denotes possible word division. If a word contains at least one `\-` the normal word division rules are suspended for that word and division may occur *only* at those locations.
2. Within the `tabbing` environment, decrements the left margin by one tap stop (moves it to the left).

\. (2.5.7) - 24

Command to produce a dot accent: `\.o = ô.`

\/ (2.5.10) - 26

Command to break up ligatures: `shelf\ /fu l = shelfful.`

\: [m] (5.5.1) - 145

In math mode, a medium space, the size of 2/9 quad: `xx\:x = xx x.`

\; [m] (5.5.1) - 145

In math mode, a large space, the size of 5/18 quad: `xx\;x = xx x.`

- `\<` (4.6.3) - 82
 Within the `tabbing` environment, moves to the left by one tab stop.
- `\=` (2.5.7), (4.6.1) - 24, 81
1. Command to produce a macron accent: `\=o = ȯ`.
 2. Within the `tabbing` environment, sets a tab stop at the current position within the line.
- `\>` (4.6.1) - 81
 Within the `tabbing` environment, moves right to the next tab stop.
- `?‘` produces $\grave{\text{z}}$ (2.5.6) - 24
- `@` (9.4.2), (14.2) - 226, 311
1. In `MakeIndex`, separates an entry in an `\index` command into a lexical (for alphabetization) and printing part. Example: `\index{sum@\sum}` means that the entry appears in the index at the location of the word ‘sum’ but what is printed is the summation sign \sum .
 2. In `LaTeX`, denotes the *entry type*. Example: `@BOOK` indicates that the following literature entries correspond to those of a book.
- `\@` (2.7.1) - 29
 Extra space at the end of a sentence ending with a capital letter.
- `[]` (2.1) - 18
 After commands or environment calls, specifies an optional argument.
- `\[` (5.1) - 120
 Switches from text mode to displayed math mode for putting a formula on a line by itself. Has the same effect as `\begin{displaymath}` or `$$` in text mode.
- `\\[space]` (2.7.2) - 31
 Ends the current line (without right justifying it). The optional argument `[space]` inserts additional vertical spacing of length `space` before the next line.
- `*[space]` (2.7.2) - 31
 The same as `\\` but prevents a page break from occurring between the current and next line.
- `\]` (5.1) - 120
 Switches back from displayed math mode to text mode. Has the same effect as `\end{displaymath}` or `$$` in math mode.

- $\hat{[m]}$ (5.2.2) - 121
 Exponents and superscripts in equations: $x^2 = x^2$, $x^{-2n} = x^{-2n}$.
- $\hat{\ } (2.5.7) - 24$
 Command to produce a circumflex accent: $\hat{o} = \hat{o}$.
- $_ [m] (5.2.2) - 121$
 Subscripts in equations: $a_n = a_n$, $a_{\{i,j,k\}} = a_{i,j,k}$.
- $_ (2.5.4) - 23$
 Command to produce the underbar sign: $t_v = t.v$.
- $\` (2.5.7), (4.6.4) - 24, 83$
 1. Command to produce a grave accent: $\`o = \grave{o}$.
 2. Within the `tabbing` environment, pushes the following text up against the right margin of the line.
- $\{ \} (2.1), (2.2), (14.2) - 18, 20, 311$
 1. After a command or environment call, specifies a mandatory argument.
 2. Grouping a section of text to create a nameless environment.
 3. In L^AT_EX, delimiting the name of an entry type, as well as an alternative delimiter for the text field.
- $\{$ produces a left curly brace: $\{ = \{ (2.5.4) - 23$
- $| [m]$ produces $| (5.3.4), (5.4.1) - 126, 132$
- $| (9.4.2) - 227$
 In `MakeIndex`, the command character within a `\index` command.
 1. After the command `\newcommand{\ii}[1]{\textit{#1}}` has been defined, `\index{entry|ii}` produces the page number for ‘entry’ in the index in italic type.
 2. The cross-reference command `\see` from `makeidx.sty` can be invoked with `\index{bison|see{buffalo}}` to produce cross-references within the index.
- $\| [m]$ produces $\| (5.3.6) - 127$
- $\} produces a right curly brace: \} = \} (2.5.4) - 23$
- $\~ (2.7.1) - 29$
 A normal space between words, but without the possibility that the line will be broken there. Example: `Prof.~Jones` ensures that ‘Prof.’ and ‘Jones’ both remain on the same line.
- $\tilde (2.5.7) - 24$
 Command to produce a tilde accent: $\tilde{n} = \tilde{n}$.

- `\a=` (4.6.4) - 83
 Produces a macron accent within `tabbing` environment: `\a=o = ö`.
- `\a'` (4.6.4) - 83
 Produces an acute accent within `tabbing` environment: `\a'o = ó`.
- `\a'` (4.6.4) - 83
 Produces a grave accent within `tabbing` environment: `\a'o = ò`.
- `\AA` produces Å (2.5.6) - 24
`\aa` produces å (2.5.6) - 24
`\abovedisplayskip [m]` (5.5.4) - 149
 Vertical space between a *long* displayed equation and the preceding line of text. A new value may be assigned with the `\setlength` command:
`\setlength{\abovedisplayskip}{10pt plus2pt minus5pt}`
- `\abovedisplayshortskip [m]` (5.5.4) - 149
 Vertical space between a *short* displayed equation and the preceding line of text. A new value may be assigned with the `\setlength` command as in the above example.
- `\abstractname` (D.4.1) - 460
 Command containing the heading for the abstract. In English, this is 'Abstract' but may be altered for adaptation to other languages.
- `\acute{x} [m]` (5.3.9) - 129
 Acute accent over math variable x : `\acute{a} = á`
- `\Acute{x} [m][a]` (12.2.2) - 263
 With the `amsmath` package, can be used like `\acute`, but with multiple $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ math accents the positioning will be correct.
- `\addcontentsline{file}{format}{entry}` (3.4.3), (3.4.4) - 59, 60
 Manual addition of *entry* into the list file `.toc`, `.lof`, or `.lot`, according to the value of *file*, to be formatted as the heading of a sectioning command, as given by *format*, for example
`\addcontentsline{toc}{section}{References}`
- `\address{sender}` (16.1) - 351
 In the `letter` document class, enters the sender's address. Multiple lines in *sender* are separated by `\\`.
- `\addtime{secs}` (15.1.3) - 327
 In the `slides` class, if the option `clock` has been selected, a time marker, in minutes, appears at the bottom of the notes. This command adds the specified number of seconds to the marker. See also `\settime`.

- `\addtocontents{file}{entry}` (3.4.3), (3.4.4) - 59, 60
 Manual addition of *entry* into the list file .toc, .lof, or .lot, according to the value of *file*. Example:
`\addtocontents{lof}{\protect\newpage}`
- `\addtocounter{counter}{number}` (8.1.3) - 182
 Adds *number* to the current value of the number stored in *counter*.
- `\addtolength{length_name}{length}` (8.2) - 184
 Adds the quantity *length* to the current value of the length command `\length_name`.
- `\addvspace{length}` (8.2) - 185
 Inserts vertical spacing of amount *length* between paragraphs at the point where the command is given. If other vertical spacing exists, the total will not exceed *length*.
- `\AE` produces \mathring{A} (2.5.6) - 24
- `\ae` produces \mathring{a} (2.5.6) - 24
- `\aleph [m]` produces \aleph (5.3.6) - 127
- `\allowdisplaybreaks [num] [p][a]` (12.2.7) - 278
 With the `amsmath` package, allows automatic page breaks to occur within multiline math formulas. If *num* is present, it takes a value of 0-4 to increase the ease with which page breaks occur. Without this command, a manual page break can be made at the end of any formula line with `\displaybreak`.
- `\Alph{counter}` (8.1.4) - 183
 Prints the current value of *counter* as a capital letter.
- `\alph{counter}` (8.1.4) - 183
 Prints the current value of *counter* as a lower case letter.
- `\alpha [m]` produces α (5.3.1) - 125
- `\also name` (D.4.1) - 460
 Command for use in the `makeidx` package. It prints the text for a command `\seealso`. In English, this is ‘see also’ but may be altered for adaptation to other languages.
- `\amalg [m]` produces \amalg (5.3.3) - 125
- `\and` (3.3.1) - 53
 Used to separate author names within the `\author` command for generating a title page with `\maketitle`.
- `\angle [m]` produces \angle (5.3.6) - 127
- `\appendixname` (D.4.1) - 460
 Command containing the heading for the appendix. In English, this is ‘Appendix’ but may be altered for adaptation to other languages.

- `\approx [m]` produces \approx (5.3.4) - 126
- `\arabic{counter}` (8.1.4) - 183
 Prints the current value of *counter* as an Arabic number.
- `\arccos [m]` (5.3.8) - 128
 Command to produce the function name ‘arccos’ in equations.
- `\arcsin [m]` (5.3.8) - 128
 Command to produce the function name ‘arcsin’ in equations.
- `\arctan [m]` (5.3.8) - 128
 Command to produce the function name ‘arctan’ in equations.
- `\arg [m]` (5.3.8) - 128
 Command to produce the function name ‘arg’ in equations.
- `\arraycolsep` (4.8.2) - 98
 Half the width of the intercolumn spacing in the array environment.
 Value is assigned with the L^AT_EX command `\setlength`:
`\setlength{\arraycolsep}{3mm}`
- `\arrayrulewidth` (4.8.2) - 98
 The thickness of vertical and horizontal lines in the array and tabular environments. Its value is assigned to a length with `\setlength`:
`\setlength{\arrayrulewidth}{0.5mm}`
- `\arraystretch` (4.8.2) - 98
 Factor to change the spacing between lines in a table, normal value being 1. Spacing is multiplied by this factor, which is set to a new value with `\renewcommand{\arraystretch}{factor}`.
- `\ast [m]` produces $*$ (5.3.3) - 125
- `\asymp [m]` produces \asymp (5.3.4) - 126
- `\AtBeginDocument{code} [p]` (D.2.4) - 444
 Stores the *code* to be inserted into the processing stream when `\begin{document}` is executed. Commands that are only allowed in the preamble may be part of *code*. A package might include coding in this way to ensure that it is not overwritten by another package.
- `\AtEndDocument{code} [p]` (D.2.4) - 444
 Stores the *code* to be inserted into the processing stream when `\end{document}` is executed. A package might include coding in this way to have additional features printed automatically at the end of the document.

`\AtEndOfClass{code}` [p] (D.2.4) - 444

Stores the *code* to be inserted into the processing stream when the current class file has finished being read. May only be given in a class file, or in another file that is read by a class file. May be used by a local configuration file to overwrite defaults in the class file itself.

`\AtEndOfPackage{code}` [p] (D.2.4) - 444

Stores the *code* to be inserted into the processing stream when the current package file has finished being read. May only be given in a package file, or in another file that is read by a package file. May be used by a local configuration file to overwrite defaults in the package file itself.

`\author{name}` (3.3.1) - 53

Enters the author name(s) for a title page produced by the `\maketitle` command.

`\b{x}` (2.5.7) - 24

Command to produce an underbar accent: `\b{o} = o`.

`\backmatter` (3.3.5) - 57

In the book class, introduces the material that comes at the end (bibliography, index) by turning off the chapter numbering of the `\chapter` command.

`\backslash` [m] produces `\` (5.3.6) - 127

`\bar{x}` [m] (5.3.9) - 129

Macron accent over the math variable *x*: `\bar{a} = ā`.

`\Bar{x}` [m][a] (12.2.2) - 263

With the `amsmath` package, can be used like `\bar`, but with multiple \mathcal{A} -L^AT_EX math accents the positioning will be correct.

`\baselineskip` (3.2.4) - 46

Interline spacing within a paragraph. Every font has its own internal line spacing. A new value (a rubber length) may be assigned with `\setlength`:

`\setlength{\baselineskip}{12pt plus2pt minus1pt}`

`\baselinestretch` (3.2.4), (4.1.2) - 46, 63

A factor with the normal value of 1 by which the internal length `\baselineskip` is multiplied to produce the actual interline spacing. May be changed with:

`\renewcommand{\baselinestretch}{factor}`

The new value takes effect after the next change in font size!

- `\begin{envrnmnt}` (2.2) - 19
 Start of an environment with the name *envrnmnt*. This command must be coupled with `\end{envrnmnt}` to terminate the environment. The environment name in both these commands must be identical.
- `\begin{abstract}` (3.3.2) - 55
 Start of the environment `abstract` to produce an abstract. With document class `article`, font size `\small` and the quotation environment are selected. With `report`, the abstract appears on a separate page with normal font size and line width. In both cases, the heading **Abstract** is centered above the text.
- `\begin{align} [a]` (12.2.6) - 274
 With the `amsmath` package, switches to displayed math mode to produce a set of aligned equations. Line are terminated by `\\` commands. The lines are split into columns aligned on the first, third, fifth . . . & characters. Each line receives an equation number unless the ***-form of the environment has been selected.
- `\begin{alignat}{num} [a]` (12.2.6) - 275
 Is the same as the `align` environment except that no spacing is inserted automatically between the column pairs. The argument *num* is the number of column pairs = $(1 + n_{\&})/2$ where $n_{\&}$ is the number of & signs in one row. Explicit spacing may be placed between column pairs, especially if the left part of that pair is otherwise empty.
- `\begin{aligned} [pos] [m][a]` (12.2.6) - 276
 With the `amsmath` package, is like the `align` environment but is used as an element within math mode. The optional argument *pos* determines the vertical positioning relative to neighboring elements: `t` or `b` for top or bottom, no argument for centering.
- `\begin{appendix}` (3.3.4) - 57
 Start of the environment `appendix` to produce an appendix. The main section counter is reset to zero and its numbering appears as capital letters.
- `\begin{array} [pos] {col} [m]` (4.8.1), (5.4.3) - 95, 134
 Start of the environment `array` to produce matrices and arrays in math mode. The column definition *col* contains a formatting character for each column. Thus `\begin{array}{lcr}` produces an array with three columns: one *left justified*, one *centered*, and one *right justified*. The optional parameter *pos* determines how the array is aligned vertically with text outside it on the same line: `t` with the top line, `b` with the bottom line, while the default is with the center. See also `\begin{tabular}`
- `\begin{center}` (4.2.1) - 67
 Start of the environment `center`. Each line of text terminated by `\\` appears centered. See also `\centering`.

- `\begin{command_name}` (2.2) - 20
 Most declaration commands, such as the font styles and sizes, can be used as environment names. For example, `\begin{small}` switches to font size `\small` until the countercommand `\end{small}` is given.
- `\begin{alltt}` (4.9.1) - 111
 When the `alltt` package has been loaded, this environment prints out original text in typewriter typeface, maintaining line breaks, special symbols, and so on, except for `\{ }` which function as usual. This allows commands to be executed within the typewriter text.
- `\begin{bmatrix} [m][a]` (12.2.4) - 266
 Like the `matrix` environment, but enclosed in square brackets `[]`.
- `\begin{Bmatrix} [m][a]` (12.2.4) - 266
 Like the `matrix` environment, but enclosed in curly braces `{ }`.
- `\begin{cases} [m][a]` (12.2.6) - 277
 With the `amsmath` package, writes math expressions on several lines, terminated by `\`, in left-justified columns, separated by `&`, with a curly brace enclosing all lines at the left, the whole being centered vertically.
- `\begin{description}` (4.3.3) - 70
 Start of the environment `description` to produce an indented list with labels. The label text is the argument `label` in the command `\item[label]`.
- `\begin{displaymath}` (5.1) - 120
 Switches from text to displayed math mode for producing a formula on a line by itself. Functions the same as `\[`.
- `\begin{document}` (1.5.2) - 12
 Start of the outermost environment of a text document. This command terminates the preamble. It is obligatory for every L^AT_EX document, as is its counterpart `\end{document}` for ending the document.
- `\begin{enumerate}` (4.3.2) - 70
 Start of the environment `enumerate` to produce a numbered, indented listing. The style of numbering depends on the depth of nesting; at the first level, it consists of a running Arabic number that is incremented with each call to `\item`.
- `\begin{eqnarray} [m]` (5.4.7) - 138
 Switches from text to displayed math mode to produce a set of equations or a multiline formula in the form of a three-column table `{rc}`. The individual lines of the formula are ended with the command `\`; the fields within a line are separated by `&` characters. Each line is given a sequential equation number unless the command `\nonumber` appears within it.

- `\begin{eqnarray*}` [m] (5.4.7) - 138
Is the same as the `eqnarray` environment except that no equation numbers are printed.
- `\begin{equation}` [m] (5.1) - 120
Switches from text to displayed math mode to produce a formula on a line by itself, including an automatic sequential equation number.
- `\begin{falign}` [a] (12.2.6) - 275
With the `amsmath` package, is the same as the `align` environment except that spacing is inserted between the column pairs to fill up the entire line.
- `\begin{figure}[loc]` (7.1) - 169
Float environment for entering text for a figure. The optional argument *loc* can be any combination of the letters *h*, *t*, *b*, and *p* to determine the various positioning possibilities. Default is *tbp*. The character *!* may additionally be given to ignore all float spacing and number restrictions set by the float style parameters.
- `\begin{figure*}[loc]` (7.1) - 169
The same as the `figure` environment except that the figure is inserted over the width of two columns when the option `twocolumn` or the command `\twocolumn` has been selected. The standard form `figure` will only fill the width of one column.
- `\begin{filecontents}{file_name}` [p] (D.2.9) - 448
An environment that may be given only before `\documentclass`, it writes its lines literally to a file of the specified name, if that file does not already exist. It also adds comment lines stating its source. In this way, non-standard files may be included in the main document file for shipment to other installations. If a file with the stated name already exists, it is not overwritten, but a warning message is issued.
- `\begin{filecontents*}{file_name}` [p] (D.2.9) - 448
Is the same as the `filecontents` environment, except that no comment lines are written to the file. The file will contain exactly the contents of the environment, and nothing more.
- `\begin{flushleft}` (4.2.2) - 67
Start of the `flushleft` environment in which each line of text is left justified, that is, it begins flush with the left margin but is not expanded to match the right edge. The equivalent declaration is `\raggedright`.
- `\begin{flushright}` (4.2.2) - 67
Start of the `flushright` environment in which each line of text is right justified, that is, the right-hand side is flush with the right margin, but the line is not expanded to start exactly at the left edge. The equivalent declaration is `\raggedleft`.

- `\begin{gather} [a]` (12.2.6) – 273

With the `amsmath` package, switches to displayed math mode to produce several lines of equations, all centered with no alignment. Lines are terminated by `\\` commands. Each line receives an equation number, unless the `*`-form of the environment has been selected.
- `\begin{gathered} [pos] [m][a]` (12.2.6) – 276

With the `amsmath` package, is like the `gather` environment but is used as an element within math mode. The optional argument `pos` determines the vertical positioning relative to neighboring elements: `t` or `b` for top or bottom, no argument for centering.
- `\begin{itemize}` (4.3.1) – 69

Start of the `itemize` environment for producing labeled, indented listings. The type of label depends on the depth of nesting; at the first level it is a `•` generated by each `\item` command.
- `\begin{longtable}` (4.8.4) – 108

With the `longtable` package, begins a table with the same syntax as `tabular` but which will continue to other pages as necessary. The head and footlines on the continued pages can be specified, terminated with `\endhead`, `\endfirsthead`, `\endfoot`, `\endlastfoot`.
- `\begin{letter}{recipient}` (16.1) – 352

Start of a letter with the document class `letter`. Name and address of the *recipient* are given within the second pair of brackets; lines of text within this argument are ended with the command `\\`.
- `\begin{list}{standard_label}{list_decl}` (4.4) – 74

Start of a generalized list environment. The label is defined by *standard_label*, which is generated by each `\item` command. The desired list declarations are contained in *list_decl* (see page 75).
- `\begin{lrbbox}{boxname}` (4.7.1) – 87

Functions in a way similar to the command `\sbox`, except that it is the text of the environment that is stored in the LR box named `\boxname`, which has previously been created with `\newsavebox{\boxname}`. The contents of the box may be printed as often as desired with `\usebox{\boxname}`.
- `\begin{math}` (5.1) – 119

Switches from text to in-line math mode to produce formulas within a line of text. This environment has the same effect as `\C` or `\$` in text mode.
- `\begin{matrix} [m][a]` (12.2.4) – 266

With the `amsmath` package, is the same as the `array` environment except that the column specifier argument may be omitted, without

which up to 10 centered columns may be entered. This maximum may be changed with the counter `MaxMatrixCols`. The environments `pmatrix`, `bmatrix`, `Bmatrix`, `vmatrix`, and `Vmatrix` function the same as `matrix` but are enclosed in braces `()`, `[]`, `{}`, `||` and `|||`, respectively.

`\begin{minipage}[pos][height][inner_pos]{width}`
 (4.7.3), (4.7.5) – 88, 90

Environment to format text within a ‘minipage’ of width *width*. Its vertical positioning with respect to the surrounding text is determined by the optional argument *pos*: `t` for alignment with its top line, `b` with its bottom line, and centered with no argument. The other two optional arguments are: *height* to give the total height, and *inner_pos* to specify how the text is to be positioned inside it. Possible values are `t` for top, `b` for bottom, `c` for centered, and `s` to be stretched out to fill the whole vertical space. The default is the value of the external positioning *pos* option. The *height* argument may contain the parameters `\height`, `\depth`, `\width`, and `\totalheight`.

`\begin{multicols}{num_cols}[header][pre_space]`
 (3.2.8), (B.5.4) – 51, 395

This environment is provided by the `multicol` package in the tools collection (Section B.5.4). It switches to printing the text in *num_cols* columns, with *header* printed in one column across the top. A new page is inserted only if the remaining space on the current page is less than `\premulticols` or the optional argument *pre_space*. A new page is inserted at the end if the remaining space is less than `\postmulticols`. The columns on the last page are balanced. Column separation and rule are set by the lengths `\columnsep` and `\columnseprule`.

With the starred version `multicols*`, the columns of text are not balanced on the last page of the environment.

`\begin{multiline}[a]` (12.2.6) – 271

With the `amsmath` package, switches to displayed math mode to produce a single equation over several lines. Line breaks are forced by `\\` commands. The first line is to the far left, the last to the right, all others centered. With `\shoveleft{form}` and `\shoveright{form}`, single lines consisting of *form* may be pushed to the left or right. The single equation number appears at the right of the last line, or at the left of the first line, depending on class options `reqno` (default) and `leqno`, respectively. With the **-form* of the environment, the equation number is suppressed.

`\begin{note}` (15.1.2) – 326

In `slides` class, the environment for producing a note for the current slide. Notes are numbered with the current slide number followed by a hyphen and running number, for example 8-1, 8-2, etc.

- `\begin{overlay}` (15.1.2) – 325
 In `slides` class, the environment for producing an overlay for the current slide. Overlays are numbered with the current slide number followed by a lower case letter, for example 3-a, 3-b, etc. See also `\begin{slide}`.
- `\begin{picture}(x_dimen,y_dimen)` (13.1.2) – 288
 Environment to generate a picture with the width `x_dimen` and height `y_dimen`, where the unit of length has previously been specified by the declaration `\unitlength`.
- `\begin{picture}(x_dimen,y_dimen)(x_offset,y_offset)` (13.1.6) – 301
 Most general form of the call to the `picture` environment. The picture is displaced to the left by `x_offset` and downwards by `y_offset`.
- `\begin{pmatrix}[m][a]` (12.2.4) – 266
 Like the `matrix` environment, but enclosed in round parentheses ().
- `\begin{quotation}` (4.2.3) – 67
 Start of the `quotation` environment in which text is indented on both sides relative to the normal page margins. Paragraphs within the environment are marked with an additional indentation of the first line.
- `\begin{quote}` (4.2.3) – 67
 The same as the `quotation` environment except that the first line of a paragraph is not indented but instead additional line spacing comes between paragraphs.
- `\begin{slide}` (15.1.2), (15.2.1) – 325, 331
 In `slides` and `seminar` classes, the main environment for producing a slide.
- `\begin{sloppypar}` (2.8.3) – 36
 Inside this environment word spacings are allowed to stretch more generously than usual so that paragraphs are broken up into lines with fewer word divisions. See also `\sloppy`. The countercommand is `\fussy`.
- `\begin{split}[m][a]` (12.2.6) – 272
 With the `amsmath` package, is used within a `math` environment such as `equation` to write a formula over several lines. Line breaks are forced with `\\` commands and the lines are horizontally aligned on the `&` alignment marker. Any equation number is generated by the outer environment. It is either centered with the class option `centertags` (default) or with `tbtags` it appears at the right of the last line, or at the left of the first line, depending on class options `reqno` (default) and `lreqno`, respectively.

`\begin{subarray}{pos}{1st line}\dots\last line}` [m][a] (12.2.2) - 261

With the `amsmath` package, sets multiline text for superscripts and subscripts, like `\substack`, but the parameter *pos* may take on values `c` or `l` for centered or left-justified lines.

`\begin{subequations}` [a] (12.2.7) - 277

With the `amsmath` package, numbers equations within it with a fixed main number and sequence of lower case letters attached, as 7a, 7b, 7c,

`\begin{tabbing}` (4.6.1) - 81

Start of the `tabbing` environment in which special tabbing commands become operational: `\=` sets a tab stop, `\>` jumps to the next stop, `\<` goes back a stop, `\|` terminates and starts a new line, `\+` sets the left margin one tab stop further, `\-` moves the left margin back one stop.

`\begin{table}[loc]` (4.8.5), (7.1) - 109, 169

Float environment for entering text for a table. The optional argument *loc* can be any combination of the letters `h`, `t`, `b`, and `p` to determine the various positioning possibilities. Default is `tbp`. The character `!` may additionally be given to ignore all float spacing and number restrictions set by the float style parameters.

`\begin{table*}[loc]` (7.1) - 169

The same as the `table` environment except that the table is inserted over the width of two columns when the option `twocolumn` or the command `\twocolumn` has been selected. The standard form `table` will only fill the width of one column.

`\begin{tabular}[pos]{cols}` (4.8.1) - 95

Start of the `tabular` environment for producing tables. The argument *cols* contains a formatting character for each column in the table: `c` for centered text, `l` for left, `r` for right justification, or `p{wd}` for a column of width *wd* in which the text may extend over several lines.

When the entry `@{text}` appears between any two of the above column formatting characters, *text* is inserted in every row between those two columns. Where the character `|` appears, a vertical line is drawn in every row.

The optional argument *pos* specifies how the table is to be vertically aligned with the surrounding text: with no argument, it is centered, otherwise with `t` the top line, with `b` the bottom line is aligned with the external baseline.

The text entries of the individual columns are separated by `&` and the rows are terminated by `\\`.

- `\begin{tabular*}{width}[pos]{cols}` (4.8.1) - 95
 The same as `\begin{tabular}` except that the total width of the table is given by the argument *width*. This may only be achieved successfully if there is rubber spacing between the columns. This may be added with `@{\extracolsep\fill}` somewhere within the *cols* format definition.
- `\begin{thebibliography}{sample_label}` (9.3.1) - 217
 Environment to generate a list of literature references. The *sample_label* is the longest reference marker that will appear. Each entry in the bibliography starts with the command `\bibitem` which prints the marker for that entry; lines after the first are indented by an amount equal to the width of *sample_label*.
- `\begin{theindex}` (9.4.1) - 225
 Environment to produce a keyword index in two-column format. Entries are made with the `\item`, `\subitem`, `\subsubitem`, or `\indexspace` commands.
- `\begin{theorem_type}[extra_title]` (4.5) - 80
 Environment to invoke a theorem-like structure that has previously been defined by the user with the `\newtheorem` command. The name of the environment, *theorem_type*, something like `theorem` or `axiom`, is the first argument of the `\newtheorem` command. The *extra_title* is text that added after the name and number of the structure in () parentheses.
- `\begin{titlepage}` (3.3.1) - 52
 Environment to produce a title page without a page number. The user has total control over the composition of this page.
- `\begin{trivlist}` (4.4.5) - 79
 Environment to generate a trivial list *without* a sample label and list declarations. The parameters `\leftmargin`, `\labelwidth`, and `\itemsep` are all set to 0 pt while `\listparindent = \parindent` and `\parsep = \parskip`.
- `\begin{verbatim}` (4.9) - 110
 Environment to print out source text, that is, as from a typewriter. Blank lines, line breaking, and commands are all output literally without any interpretation or formatting.
- `\begin{verbatim*}` (4.9) - 110
 The same as the `verbatim` environment except that blanks are printed as `_` to make them visible.
- `\begin{verse}` (4.2.4) - 68
 Environment for setting rhymes, poems, verses, etc. Stanzas are separated by blank lines, individual lines by the `\\` command.

- `\begin{vmatrix}` [m][a] (12.2.4) – 266
Like the `matrix` environment, but enclosed in vertical lines `| |`.
- `\begin{Vmatrix}` [m][a] (12.2.4) – 266
Like the `matrix` environment, but enclosed in double vertical lines `|| ||`.
- `\belowdisplayskip` [m] (5.5.4) – 149
Vertical spacing between a *long* displayed formula and the following text. A new value may be assigned with the `\setlength` command:
`\setlength{\belowdisplayskip}{\abovedisplayskip}`
sets `\belowdisplayskip` to the same value as `\abovedisplayskip`. See further examples under `\abovedisplayskip`.
- `\belowdisplayshortskip` [m] (5.5.4) – 149
Vertical spacing between a *short* displayed formula and the following text. Value is set with the `\setlength` command as in the above example.
- `\beta` [m] produces β (5.3.1) – 125
- `\bfdefault` (A.3.1) – 372
This command defines the series attribute that is selected with the `\bfseries` command. It may be redefined with `\renewcommand`:
`\renewcommand{\bfdefault}{b}`
- `\bfseries` (4.1.3), (A.2) – 64, 371
This declaration switches to a font in the current family and shape, but with the **bold** series attribute.
- `\bibitem[label]{key} entry_text` (9.3.1), (9.3.4) – 217, 221
Command to enter the text for a literature reference in the `thebibliography` environment. The reference word *key* is used in the main body of the text with citation commands to refer to this entry. In standard \LaTeX , the bibliography list will be sequentially numbered, except for those entries with an optional *label*, in which case *label* replaces the number. In author-year bibliographies, the *label* must have a special form to transfer author and year texts to the citation commands.
- `\bibliography{file.list}` (9.3.2), (14.1) – 219, 309
For producing a bibliography with the aid of the \BibTeX program; *file.list* is the root name of one or more files containing the literature databases to be searched.
- `\bibliographystyle{style}` (9.3.2), (14.1) – 219, 310
In conjunction with the \BibTeX program, this command selects the style in which the bibliography entries are to be written. Choices for *style* are `plain`, `unsrt`, `alpha`, and `abbrv`, or `plainnat`, `unsrnat`, `abbrvnat` with `natbib`. Many other contributed styles also exist.

`\bibname` (D.4.1) – 460

Command containing the heading for the bibliography in book and report document classes. In English, this is ‘Bibliography’ but may be altered for adaptation to other languages.

`\bigbrsymbol [m]` (5.5.3) – 148

A bracket symbol larger than normal, but smaller than `\Big`. Example: `\bigC`.

`\Bigbrsymbol [m]` (5.5.3) – 148

A bracket symbol larger than `\big`, but smaller than `\bigg`. Example: `\Big[`.

`\bigcap [m]` produces \cap (5.3.7) – 128

`\bigcirc [m]` produces \bigcirc (5.3.3) – 125

`\bigcup [m]` produces \cup (5.3.7) – 128

`\biggbrsymbol [m]` (5.5.3) – 148

A bracket symbol larger than `\Big`, but smaller than `\Bigg`. Example: `\bigg|`.

`\Biggbrsymbol [m]` (5.5.3) – 148

The largest bracket symbol. Example: `\Bigg\langl e`.

`\bigodot [m]` produces \odot (5.3.7) – 128

`\bigoplus [m]` produces \oplus (5.3.7) – 128

`\bigotimes [m]` produces \otimes (5.3.7) – 128

`\bigtriangledown [m]` produces ∇ (5.3.3) – 125

`\bigtriangleup [m]` produces \triangle (5.3.3) – 125

`\bigskip` (2.7.3) – 32

Inserts large vertical spacing of the amount `\bigskipamount`. See also `\medskip` and `\smallskip`.

`\bigskipamount`

Standard value for the amount of vertical spacing that is inserted with the command `\bigskip`. May be changed with the `\setlength` command:

`\setlength{\bigskipamount}{5ex plus1.5ex minus2ex}`

`\bigsqcup [m]` produces \sqcup (5.3.7) – 128

`\biguplus [m]` produces \uplus (5.3.7) – 128

`\bigvee [m]` produces \vee (5.3.7) – 128

`\bigwedge [m]` produces \wedge (5.3.7) – 128

`\binom{over}{under} [m][a]` (12.2.3) – 264

With the `amsmath` package, prints a binomial expression:

`\[\binom{n}{k}\]` yields $\binom{n}{k}$.

- `\bmod [m]` (5.3.8), (12.2.5) – 129, 268
 Command to produce the function name ‘mod’ in the form

$$a \bmod b = a \text{ mod } b$$
- `\boldmath` (5.4.9) – 143
 Switches to bold face for math mode. This command must be given in text mode, however, before going into math mode. To set only part of a formula in bold face, use `\mbox{\boldmath$...$}` to return temporarily to text mode.
- `\boldsymbol{symbol} [m][a]` (12.2.1) – 258
 When one of the packages `amsmath` or `amsbsy` has been loaded, this command prints *symbol* in bold face. Unlike `\mathbf`, it also affects math symbols and lower case Greek letters.
- `\bot [m]` produces \perp (5.3.6) – 127
- `\botfigrule` (7.3) – 173
 A command that is executed before a float at the bottom of a page. It is normally defined to do nothing, but may be redefined to add a rule between the float and the main text. It must not add any net vertical spacing.

$$\begin{aligned} &\renewcommand{\botfigrule}{\vspace*{-.4pt}} \\ &\rule{\columnwidth}{.4pt} \end{aligned}$$
- `\bottomfraction` (7.3) – 172
 Maximum fraction of a page that may be taken up by floats at the bottom. May be set to a new value with:

$$\renewcommand{\bottomfraction}{decimal_frac}.$$
- `bottomnumber` (7.3) – 171
 Maximum number of floats that may appear at the bottom of a page. Set to a new number with `\setcounter{bottomnumber}{num}`.
- `\bowtie [m]` produces \bowtie (5.3.4) – 126
- `\Box [m]` produces \square (5.3.3) – 125
- `\boxed{formula} [m][a]` (12.2.5) – 270
 With the `amsmath` package, sets the mathematical *formula* in a box.
- `\breve{x} [m]` (5.3.9) – 129
 Brevé accent over the math variable x : $\breve{a} = \check{a}$.
- `\Breve{x} [m][a]` (12.2.2) – 263
 With the `amsmath` package, can be used like `\breve`, but with multiple $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ math accents the positioning will be correct.
- `\bullet [m]` produces \bullet (5.3.3) – 125
- `\c{x}` (2.5.7) – 24
 Produces a cedilla under x : $\c{C} = \mathring{C}$.

- `\cap [m]` produces \cap (5.3.3) - 125
- `\caption[short_form]{caption_text}` (7.4) - 173
 - Produces a numbered title or caption with the text *caption_text* within the float environments `figure` or `table`. The *short_form* is the abbreviated text appearing in the list of figures or tables, which is the same as the *caption_text* if it is omitted.
- `\captionlanguage` (D.4.1), (11.1) - 459, 255
 - A command used in several language adaptations to redefine the headings of special sections such as ‘Chapter’ and ‘Contents’. It occurs in packages like `german` as well as in the `babel` system. This command is normally part of the definition of the `\selectlanguage` command.
- `\cc{list}` (16.1) - 353
 - Command within document class `letter` to generate ‘cc’, copies, followed by a list of names *list* at the end of the letter.
- `\ccname` (D.4.1) - 460
 - Command in the `letter` document class containing the word to be printed by the `\cc` command. In English, this is ‘cc’ but may be altered for adaptation to other languages.
- `\cdot [m]` produces \cdot (5.3.3) - 125
- `\cdots [m]` produces \cdots (5.2.6) - 123
- `\centering` (4.2.1) - 67
 - Declaration to switch to centered lines of text, each input line being terminated by `\.`. See also `\begin{center}`.
- `\centerline{text}` (4.2.1) - 67
 - An additional T_EX command that sets *text* centered on a horizontal line by itself.
- `\cfrac[pos]{over}{under} [m][a]` (12.2.3) - 265
 - With the `amsmath` package, produces a continued fraction. The optional argument *pos* may be `l` or `r` to have the numerator left or right justified on the horizontal rule, otherwise it is centered.
- `\chapter[short title]{title}` (3.3.3) - 55
 - Starts a new chapter on a new page, with an automatic sequential chapter number and *title* as header. If the optional *short title* is given, it appears in place of *title* in the table of contents and in the running head at the top of the pages.
- `\chapter*{title}` (3.3.3) - 55
 - Starts a new chapter on a new page, with *title* as header, but without a chapter number. The entry does not appear in the table of contents.

- `\chaptername` (D.4.1) - 460
 Command containing the chapter heading. In English, this is ‘Chapter’ but may be altered for adaptation to other languages.
- `\check{x}` [m] (5.3.9) - 129
 Háček accent over the math variable x : `\check{a}` = \check{a} .
- `\Check{x}` [m][a] (12.2.2) - 263
 With the `amsmath` package, can be used like `\check`, but with multiple $\mathcal{A}\mathcal{M}\mathcal{S}$ - \LaTeX math accents the positioning will be correct.
- `\CheckCommand{com_name} [narg] [opt] {def}` (D.2.5) - 445
 Tests that the current definition of `com_name` is as expected. If not, an error message is issued. This is used to ensure that important commands have not been altered by other packages.
- `\chi` [m] produces χ (5.3.1) - 125
- `\circ` [m] produces \circ (5.3.3) - 125
- `\circle{diameter}` (13.1.4) - 295
 Picture element command to produce a circle with diameter *diameter* in the `picture` environment. To be used as an argument in a `\put` or `\multiput` command.
- `\circle*{diameter}` (13.1.4) - 295
 Like `\circle` but produces a solid circle, filled in black.
- `\cite[note]{key}` (9.3.3), (14.1) - 219, 310
 Literature citation using the identifier *key* to produce a reference label in the text. The optional *note* text is included with the label.
- `\citep[pre-note] [post-note] {key}` (9.3.4) - 221
 With the `natbib` package, inserts a parenthetical literature citation as ‘[Jones et al., 1999]’, using the identifier *key*. The optional note texts are included within the parentheses, before and after; if only one is present, it is a *post-note*. In numerical citation mode, the citation number is printed as ‘[21]’, just as with the standard `\cite` command. Multiple keys may be given.
- `\citet{key}` (9.3.4) - 221
 With the `natbib` package, inserts an in-text literature citation as ‘Jones et al. [1999]’, using the identifier *key*. In numerical citation mode, it prints the author’s name before the citation number, as ‘Jones et al. [21]’.
- `\ClassError{class_name}{error_text}{help} [p]` (D.2.7) - 446
 Writes an error message *error_text* to the monitor and transcript file, labeled with the class name, and halts processing, waiting for a user response as for a \LaTeX error. If `H{return}` is typed, the *help* text is printed. Both *error_text* and *help* may contain `\MessageBreak` for a new line, `\space` for a forced space, and `\protect` before commands that are to have their names printed literally and not interpreted.

`\ClassInfo{class_name}{info_text} [p]` (D.2.7) - 447

Is like `\ClassWarningNoLine` except that the text *info_text* is only written to the transcript file, and not to the monitor.

`\ClassWarning{class_name}{warning_text} [p]` (D.2.7) - 446

Writes *warning_text* to the monitor and transcript file, labeled with the class name and the current line number of the input file. Processing continues. The *warning_text* is formatted in the same way as that for `\ClassError`.

`\ClassWarningNoLine{class_name}{warning_text} [p]` . . . (D.2.7) - 446

Is like `\ClassWarning` except that the current line number of the input file is not printed.

`\cleardoublepage` (2.7.4) - 34

Ends the current page and outputs all unprocessed floats on to one or more float pages. The next page will be a *right-hand* one, with an odd page number.

`\clearpage` (2.7.4) - 33

Ends the current page and outputs all unprocessed floats on to one or more float pages.

`\cline{n-m}` (4.8.1) - 97

In `tabular` environment, produces a horizontal rule from the beginning of column *n* to the end of column *m*. Example: `\cline{2-5}`.

`\closing{regards}` (16.1) - 353

End of the text in the `letter` environment; *regards* stands for the desired terminating text.

`\clubsuit [m]` produces ♣ (5.3.6) - 127

`\color col_spec` (6.2) - 167

A command made available with the `color` package. It is a declaration that switches the color in which the text is printed to that specified. It remains in effect until the end of the current environment or until countermanded by another `\color` command. The *col_spec* is either the name of a color defined (or predefined) by `\definecolor` or of the form `[model]{specs}`, where the arguments have the same meaning as they do for `\definecolor`. Examples:

```
\color[rgb]{0.5,0.5,0} \color{magenta}
```

`\colorbox col_spec{text}` (6.2) - 167

A command made available with the `color` package. The *text* is set in an LR box with the specified color as the background color. The *col_spec* is the same as for `\color`.

- `\columnsep` (3.1.1) - 40
 Declaration for the amount of intercolumn spacing in two-column page formatting. May be changed with the `\setlength` command:
`\setlength{\columnsep}{1pt}`
- `\columnseprule` (3.1.1) - 40
 Declaration for the thickness of the vertical rule separating the columns in two-column page formatting. Value is set with the `\setlength` command:
`\setlength{\columnseprule}{1pt}`
- `\cong [m]` produces \cong (5.3.4) - 126
- `\contentsline{sec.type}{\numberline{sec.num}title.text}{page}`
 Command that appears in the `.toc` file for every entry in the table of contents, which is read when the `\tableofcontents` command is given. Such commands may be altered or added to the `.toc` file by means of the text editor. The entry `sec.type` stands for the sectioning level, such as `section`, while `sec.num` is its number (for example, 2.3) and `page` is the page number where the entry appears.
- `\contentsname` (D.4.1) - 459
 Command containing the heading for the table of contents. In English, this is ‘Contents’ but may be altered for adaptation to other languages.
- `\coprod [m]` produces \coprod (5.3.7) - 128
- `\copyright` produces © (2.5.5) - 23
- `\cos [m]` (5.3.8) - 128
 Command to produce the function name ‘cos’ in formulas.
- `\cosh [m]` (5.3.8) - 128
 Command to produce the function name ‘cosh’ in formulas.
- `\cot [m]` (5.3.8) - 128
 Command to produce the function name ‘cot’ in formulas.
- `\coth [m]` (5.3.8) - 128
 Command to produce the function name ‘coth’ in formulas.
- `\csc [m]` (5.3.8) - 128
 Command to produce the function name ‘csc’ in formulas.
- `\cup [m]` produces \cup (5.3.3) - 125
- `\CurrentOption [p]` (D.2.3) - 443
 A command that may only be used in the definition of options, especially for default options. It contains the name of the option being processed.

`\d{x}` (2.5.7) - 24
 Produces a ‘dot under’ accent: `\d{o}` = o.

`\dag` produces † (2.5.5) - 23

`\dagger [m]` produces † (5.3.3) - 125

`\dashbox{dash}(x_dimen, y_dimen) [pos]{text}` . . . (13.1.4) - 291

Picture element command to produce a dashed frame with width *x_dimen* and height *y_dimen*, using a dash length of *dash* in the `picture` environment. Without the optional *pos*, the contents *text* are centered within the frame, otherwise they are positioned at the left (l), right (r), top (t), or bottom (b), or a combination thereof, such as `lt`. This command is used as an argument in a `\put` or `\multiput` command.

`\dashv [m]` produces \dashv (5.3.6) - 127

`\date{date_text}` (3.3.1), (16.1) - 52, 353

1. The command `\maketitle` normally prints the current date on the title page. The declaration `\date` will replace the date with whatever text is given in *date_text*.
2. Prints the text *date_text* instead of the automatic current date in a letter.

`\datelanguage` (11.1) - 255

A command used in several language adaptations to redefine the `\today` command according to the requirements of *language*. It occurs in `german` package as well as in the `babel` system. It may also be used for ‘dialects’, such as `\dateUSenglish` and `\dateenglish`. This command is normally part of the definition of the `\selectlanguage` command.

`\dblfigrule` (7.3) - 173

A command that is executed after a two-column float at the top of a page. It is normally defined to do nothing, but may be redefined to add a rule between the float and the main text. It must not add any net vertical spacing.

```
\renewcommand{\dblfigrule}{\vspace*{-.4pt}
\rule{\textwidth}{.4pt}}
```

`\dblfloatpagefraction` (7.3) - 172

For two-column page formatting, the fraction of a float page that must be filled with floats before a new page is called. A new value is assigned with

```
\renewcommand{\dblfloatpagefraction}{decimal.frac}
```

`\dbinom{over}{under} [m][a]` (12.2.3) - 264

With the `amsmath` package, produces a binomial as `\binom` does, but in `\displaystyle` size.

`\dblfloatsep` (7.3) - 172

For two-column page formatting, the vertical spacing between floats that extend over both columns. A new value is set with the `\setlength` command:

`\setlength{\dblfloatsep}{12pt plus 2pt minus 4pt}`

`\dbltextfloatsep` (7.3) - 172

For two-column page formatting, the vertical spacing between floats extending over both columns at the top of the page and the following text. A new value is set with the `\setlength` command.

`\dbltopfraction` (7.3) - 172

For two-column page formatting, the maximum fraction of a page that may be occupied at the top by floats extending over both columns. A new value is assigned with

`\renewcommand{\dbltopfraction}{decimal.frac}`.

`dbltopnumber` (7.3) - 172

For two-column page formatting, the maximum number of floats that may appear at the top of a page extending over both columns. A new value is assigned with

`\setcounter{dbltopnumber}{num}`.

`\ddag` produces ‡ (2.5.5) - 23

`\ddagger [m]` produces ‡ (5.3.3) - 125

`\ddot{x}` [m][a] (12.2.2) - 263

With the `amsmath` package, a triple dot accent in math formulas:
`\ddot{a}` = \ddot{a} .

`\ddddot{x}` [m][a] (12.2.2) - 263

With the `amsmath` package, a four-dot accent in math formulas:
`\ddddot{a}` = \ddddot{a} .

`\ddot{x}` [m] (5.3.9) - 129

A double dot accent in mathematical formulas: `\ddot{a}` = \ddot{a} .

`\Ddot{x}` [m][a] (12.2.2) - 263

With the `amsmath` package, can be used like `\ddot{}`, but with multiple \mathcal{A} - \mathcal{X} math accents the positioning will be correct.

`\ddots` [m] produces \ddots (5.2.6) - 123

`\DeclareErrorFont{code}{fam}{ser}{shp}{sz} [p]` (A.3.6) - 376

If no valid font can be found, even after substituting the attributes as given by `\DeclareFontSubstitution`, the font declared with this command is selected as a last resort.

- `\DeclareFixedFont{\cmd}{code}{fam}{ser}{shp}{sz}` [p] (A.3.2) – 373

Defines *\cmd* to be a font *declaration* that selects a font with the fixed attributes given in the definition.
- `\DeclareFontEncoding{code}{text_set}{math_set}` [p] (A.3.6) – 376

Declares *code* to be the name of a new encoding scheme; *text_set* is a set of commands that is to be executed when switching to text mode, *math_set* a set for math mode.
- `\DeclareFontEncodingDefaults{text_set}{math_set}` [p] (A.3.6) – 376

Declares the sets of commands to be executed by all encodings when switching to text and math modes; the additional commands specific to each encoding are executed afterwards.
- `\DeclareFontFamily{code}{fam}{opt}` [p] (A.3.6) – 376

Declares *fam* to be a new font family with the encoding *code*; the encoding must previously have been declared. The commands in *opt* are executed every time this family is selected.
- `\DeclareFontShape{code}{fam}{ser}{shp}{def}{opt}` [p] (A.3.6) – 377

Associates external font names with the given font attribute values; the actual definition *def* relates font sizes to font names, as explained on page 377. The commands in *opt* are executed every time this shape is selected.
- `\DeclareFontSubstitution{code}{fam}{ser}{shp}` [p] (A.3.6) – 376

Declares the font attributes that are to be substituted in case there is no valid font corresponding to the set of attributes selected. The order of substitution is *shape*, *series*, and *family*; the encoding is never substituted.
- `\DeclareGraphicsExtensions{ext_list}` [p] (6.1.7) – 165

Establishes the list of default extensions for graphics files that can be imported with the `\includegraphics` command and the `graphics` or `graphicx` packages; *ext_list* is a comma-separated list of file extensions, such as `.eps`, `.ps`.
- `\DeclareGraphicsRule{ext}{type}{bb}{cmd}` [p] (6.1.7) – 165

Associates a graphics file extension *ext* with a graphics file type and a file extension (*bb*) where the bounding box information is to be read, and an operating command (*cmd*) that is to be executed on the file to make it available for importation. For example

```
\DeclareGraphicsRule{.eps.gz}{eps}
  {.eps.bb}{'gunzip -c #1}
```

Here the command must be prefixed with `'` and `#1` represents the name of the file to be processed.

`\DeclareMathAccent`{*\cmd*}{*type*}{*sym_fnt*}{*pos*} [p] . (A.3.4) – 375

Declares *\cmd* to be a math accent command, printed with the character in position *pos* of the symbol font with the internal name *sym_fnt*. The *type* is either `\mathord` or `\mathalpha`; in the latter case the symbol changes with math alphabet.

`\DeclareMathAlphabet`{*\cmd*}{*code*}{*fam*}{*ser*}{*shp*} [p]
 (A.3.3) – 373

Defines *\cmd* to be a math alphabet for setting letters in math mode; the font selected *in all math versions* is that with the specified font attributes. If a different font is to be invoked for certain math versions, they are defined individually with `\SetMathAlphabet` afterwards. However, if the shape attribute is left empty, the alphabet command is indeed created, but remains undefined in *all* versions, requiring an explicit `\SetMathAlphabet` declaration for each one.

`\DeclareMathDelimiter`{*\cmd*}{*type*}{*sym_fnt1*}{*pos1*}{*sym_fnt2*}{*pos2*} [p] (A.3.4) – 375

Declares *\cmd* to be a math delimiter in two sizes: the smaller variant is the character in position *pos1* of the symbol font with the internal name *sym_fnt1*, while the larger is from position *pos2* of font *sym_fnt2*.

`\DeclareMathOperator`{*\cmd*}{*name*} [p][a] (12.2.5) – 268

With the `amsopn` or `amsmath` packages, defines *\cmd* to be a math mode command to print the text *name* as a function name in an upright font with appropriate spacing. With the **-form*, the raising and lowering operators `^` and `_` produce limits, above or below the name.

`\DeclareMathRadical`{*\cmd*}{*sym_fnt1*}{*pos1*}{*sym_fnt2*}{*pos2*} [p] (A.3.4) – 375

Declares *\cmd* to be a math radical symbol: the smaller variant is the character in position *pos1* of the symbol font with the internal name *sym_fnt1*, while the larger is from position *pos2* of font *sym_fnt2*.

`\DeclareMathSizes`{*text*}{*math_text*}{*script*}{*sscript*} [p] (A.3.4) – 375

Sets the point sizes for the three math styles `\textstyle`, `\scriptstyle`, and `\scriptscriptstyle` when the text is being printed in point size *text*. The unit `pt` is not included.

`\DeclareMathSymbol`{*\symbol*}{*type*}{*sym_fnt*}{*pos*} [p] (A.3.4) – 375

Declares *\symbol* to be a command that prints the character in position *pos* with the symbol font with the internal name *sym_fnt*. This same symbol is printed in all math alphabets, but may be different for other math versions if the symbol font has been `\Set . . .` to have different attributes in that math version.

`\DeclareMathVersion{ver}` [p] (A.3.3) – 374

Declares *ver* to be a new math version for math alphabets and symbol fonts. Initially, the version will use those fonts defined by `\Declare...` commands, which may be redefined for this math version with appropriate `\Set...` commands.

`\DeclareOldFontCommand{\cmd}{text_specs}{math_specs}` [p]
 (A.3.2) – 373

Defines `\cmd` to be a font *declaration* that invokes *text_specs* in text mode, and *math_specs* in math mode. The new command behaves in math mode as a 2.09 font declaration, although *math_specs* must be a math font command without its argument. It is meant to define commands to be compatible with L^AT_EX 2.09 and should generally be avoided.

`\DeclareOption{option}{code}` [p] (D.2.3) – 442

In a class or package file, this command defines the set of commands (*code*) that is to be associated with the given *option*. These commands are executed when `\ExecuteOptions` or `\ProcessOptions` is called. After the latter, all definitions are erased, to save memory. The *code* is internally stored in a command named `\ds@option`.

`\DeclareOption*{code}` [p] (D.2.3) – 442

In a class or package file, this command defines the default set of commands that is associated with every undefined option. Special commands that may be used within *code* are `\CurrentOption` (the name of the option) and `\OptionNotUsed`. Example:

```
\DeclareOption*{\InputIfFileExists
  {\CurrentOption.sty}{\OptionNotUsed}}
```

`\DeclareRobustCommand{\cmd}[narg][opt]{def}` . . . (D.2.5) – 445

Defines or redefines the command `\cmd` in the same way as `\newcommand` except that the result is robust: it may be used in the argument of another command without a `\protect` command before it.

`\DeclareRobustCommand*{\cmd}[narg][opt]{def}` . . (D.2.6) – 445

The same as `\DeclareRobustCommand` except that the arguments to `\cmd` must be 'short', not containing any new paragraphs.

`\DeclareSymbolFont{sym_fnt}{code}{fam}{ser}{shp}` [p]
 (A.3.4) – 374

Declares the math font with the given attributes to be a symbol font that may be addressed by other commands with the name *sym_fnt*. The symbol font applies to all math versions unless redefined with a `\SetSymbolFont` command.

- `\DeclareSymbolFontAlphabet`{*\cmd*}{*sym.fnt*} [p] . . . (A.3.4) – 375
 Defines *\cmd* to be a math alphabet that uses the font declared with a `\DeclareSymbolFont` command to have the internal name *sym.fnt*. This is preferred over `\DeclareMathAlphabet` if there is a defined symbol font with the necessary attributes for the math alphabet.
- `\DeclareTextAccent`{*\cmd*}{*code*}{*pos*} [p] (A.3.7) – 379
 Defines *\cmd* to be an accent command when encoding *code* is active; it uses the symbol in font position *pos* as the accent.
- `\DeclareTextAccentDefault`{*\cmd*}{*code*} [p] (A.3.7) – 380
 Declares the default encoding that is to be taken if the accent command *\cmd* is called in an encoding for which it is not explicitly defined.
- `\DeclareTextCommand`{*\cmd*}{*code*} [*narg*] [*opt*]{*def*} [p]
 (A.3.7) – 379
 Defines *\cmd* in the same way as `\newcommand` except the definition is only valid when encoding *code* is active.
- `\DeclareTextCommandDefault`{*\cmd*} [*narg*] [*opt*]{*def*} [p]
 (A.3.7) – 380
 Creates a default definition for the command *\cmd* for all encodings for which it is not explicitly defined.
- `\DeclareTextComposite`{*\cmd*}{*code*}{*let*}{*pos*} [p] . . . (A.3.7) – 379
 Defines *\cmd* followed by the letter *let* to be the single character in font position *pos* when encoding *code* is active. It thus defines the action of accent commands in T1 encoding when the accented letter exists as a separate symbol. For example:
`\DeclareTextComposite{\'}{T1}{e}{233}`
 The command must already have been defined for the encoding with either `\DeclareTextAccent` or `\DeclareTextCommand` (with one argument).
- `\DeclareTextCompositeCommand`{*\cmd*}{*code*}{*let*}{*def*} [p]
 (A.3.7) – 379
 Is the same as `\DeclareTextComposite` except that any definition may be assigned to the command/letter combination, and not just a single symbol.
- `\DeclareTextFontCommand`{*\cmd*}{*font.specs*} [p] . . . (A.3.2) – 373
 Defines *\cmd* to be a text font command that sets its argument with the *font.spec* specifications. Example:
`\DeclareTextFontCommand{\textbf}{\bfseries}`
- `\DeclareTextSymbol`{*\cmd*}{*code*}{*pos*} [p] (A.3.7) – 379
 Defines *\cmd* to print the symbol in font position *pos* when encoding *code* is active.

`\DeclareTextSymbolDefault{\cmd}{code}` [p] (A.3.7) – 380

Declares the default encoding that is to be taken if the symbol command `\cmd` is called in an encoding for which it is not explicitly defined.

`\definecolor{name}{model}{specs}` (6.2) – 167

A command made available with the `color` package. It associates the name of a color (*name*) with the specifications *specs* according to a certain *model*. Possible values for *model* are `rgb` (red, green, blue), `cmk` (cyan, magenta, yellow, black), `gray`, and `named`. In each case, *specs* is a comma-separated list of numbers between 0 and 1 specifying the strength of the relevant component. In the case of the `named` model, *specs* is an internal name for the color that is known by the driver program. Examples:

```
\definecolor{lightgrn}{cmk}{0.25,0,0.75.0}
\definecolor{brown}{named}{RawSienna}
```

A number of colors are predefined in all color drivers: red, green, blue, yellow, cyan, magenta, black, and white.

`\deg` [m] (5.3.8) – 128

Command to produce the function name ‘deg’ in formulas.

`\DeleteShortVerb{c}` (4.9.1, B.5.3) – 111, 393

When the standard package `shortvrb` has been loaded, this command counteracts the effects of a previous `\MakeShortVerb{c}`, allowing the character *c* to have its original meaning once more.

`\Delta` [m] produces Δ (5.3.1) – 125

`\delta` [m] produces δ (5.3.1) – 125

`\depth` (4.7.1) – 86

A length parameter equal to the depth of a box (baseline to bottom); it may only be used in the *width* specification of `\makebox`, `\framebox`, or `\savebox`, or in the *height* specification of a `\parbox` or `minipage` environment.

```
\framebox[20\depth]{text}
```

`\det` [m] (5.3.8) – 128

Command to produce the function name ‘det’ in formulas. Can be combined with a lower limit by means of the subscript command.

`\dfrac{numerator}{denominator}` [m][a] (12.2.3) – 264

With the `amsmath` package, produces a fraction as `\frac` does, but in `\displaystyle` size.

`\DH` (G.4.5) – 503

When T1 encoding is active, prints the character Đ.

- `\dh` (G.4.5) - 503
 When T1 encoding is active, prints the character δ .
- `\Diamond [m]` produces \diamond (5.3.3) - 125
`\diamond [m]` produces \diamond (5.3.3) - 125
`\diamondsuit [m]` produces \blacklozenge (5.3.6) - 127
`\dim [m]` (5.3.8) - 128
 Command to produce the function name 'dim' in formulas.
- `\discretionary{before}{after}{without}` (2.8.1) - 35
 Hyphenation suggestion within a word. The word may be divided such that *before* is at the end of one line, and *after* at the start of the next line. If no division occurs, *without* is printed.
- `\displaybreak[num] [m][a]` (12.2.7) - 278
 With the `amsmath` package, allows a manual page break in a multiline math formula when given just before `\;`; if *num* is present, it takes on values of 0-4 with increasing encouragement for a break, where 4 is the same as no value, a forced page break. Automatic page breaks are impossible in multiline formulas unless `\allowdisplaybreaks` has been issued in the preamble.
- `\displaystyle [m]` (5.5.2) - 146
 Switches to font size `\displaystyle` as the active font within a math formula.
- `\div [m]` produces \div (5.3.3) - 125
`\DJ` (G.4.5) - 503
 When T1 encoding is active, prints the character \DJ .
- `\dj` (G.4.5) - 503
 When T1 encoding is active, prints the character \dj .
- `\documentclass[options]{class}[version] [p]` (3.1) - 37
 Normally the first command in a \LaTeX document, determining the overall characteristics. Standard values for *class* are:
`article`, `report`, `book`, `letter`, and `slides`
 of which only one may be selected. In addition, various options may be chosen, their names separated by commas. Possibilities are:
`10pt`, `11pt`, `12pt`,
`letterpaper`, `legalpaper`, `executivepaper`,
`a4paper`, `a5paper`, `b5paper`, `landscape`,
`onecolumn`, `twocolumn`,
`oneside`, `twoside`,
`notitlepage`, `titlepage`,
`leqno`, `fleqn`, `openbib`,
`draft`, `final`

These and any additional options are all global, meaning that they also apply to any packages specified with a following `\usepackage` command.

The optional *version* is a date, given in the form *yyyy/mm/dd*, as for example 1994/08/01. If the date of the class file read in is earlier than this, a warning message is printed.

`\doublebox{text}` (4.7.9) - 94

With the `fancybox` package, is a variant of `\fbox`, drawing a doubled box around *text*; the thicknesses and separation of the lines depend on the length `\fboxrule`.

`\dot{x}` [m] (5.3.9) - 129

A dot accent in mathematical formulas: `\dot{a}` = \dot{a} .

`\Dot{x}` [m][a] (12.2.2) - 263

With the `amsmath` package, can be used like `\dot`, but with multiple \mathcal{A} - \mathcal{M} - \mathcal{S} -L^AT_EX math accents the positioning will be correct.

`\doteq` [m] produces \doteq (5.3.4) - 126

`\dotfill` (2.7.1) - 30

Fills up the space in a line with a dotted leader: `..... = \dotfill`.

`\dots` produces \dots (5.2.6) - 123

`\dots` [m][a] (12.2.2) - 264

With the `amsmath` package, places continuation dots in math mode automatically at a height determined by the following symbol.

`\dotsb` [m][a] produces dots for binary operator: \dots (12.2.2) - 264

`\dotsc` [m][a] produces dots for commas: \dots (12.2.2) - 264

`\dotsi` [m][a] produces dots for integral signs: \dots (12.2.2) - 264

`\dotsm` [m][a] produces dots for multiplication: \dots (12.2.2) - 264

`\doublerulesep` (4.8.2) - 98

The distance between double rules inside the `tabular` and `array` environments. New value assigned with `\setlength` outside of the environment.

`\Downarrow` [m] produces \Downarrow (5.3.5) - 127

`\downarrow` [m] produces \downarrow (5.3.5) - 127

`\ell` [m] produces ℓ (5.3.6) - 127

`\em` (4.1.1) - 62

This declaration switches to an emphatic font, one that has the current family and series, but with a different shape attribute. It normally toggles between an upright and an italic shape.

- `\emph{text}` (4.1.1) - 62
 This command sets its argument in an emphatic font, one that has the current family and series, but with a different shape attribute. It normally toggles between an upright and an italic shape.
- `\emptyset [m]` produces \emptyset (5.3.6) - 127
- `\encl{enclosures}` (16.1) - 353
 Command in the document class `letter` to add the word ‘encl.’ with the list *enclosures* at the end of a letter. For International L^AT_EX, the actual word printed is contained in the command `\enclname`.
- `\enclname` (D.4.1) - 460
 Command in the `letter` document class containing the word to be printed by the `\encl` command. In English, this is ‘encl’ but may be altered for adaptation to other languages.
- `\end{environment}` (2.2) - 19
 Command to terminate an environment started with a command `\begin{environment}`.
- `\endfirsthead` (4.8.4) - 108
 Within the `longtable` environment of the `longtable` package, this command ends those specifications that are to be added to the top of the table (the head) on the first page only.
- `\endfoot` (4.8.4) - 108
 Within the `longtable` environment of the `longtable` package, this command ends those specifications that are to be added at the bottom of the table (the foot) before it is continued to other pages.
- `\endhead` (4.8.4) - 108
 Within the `longtable` environment of the `longtable` package, this command ends those specifications that are to be added to the top of the table (the head) when it is continued to other pages.
- `\endlastfoot` (4.8.4) - 108
 Within the `longtable` environment of the `longtable` package, this command ends those specifications that are to be added at the bottom of the table (the foot) on the last page.
- `\enlargethispage{size}` (2.7.4) - 34
 The `\textheight` parameter is temporarily increased by the length *size*, in order to improve a bad page break. On the following pages, `\textheight` will have its normal value once more.
- `\enlargethispage*` (2.7.4) - 34
 Is the same as `\enlargethispage` except that any additional spacing between the lines is removed as necessary to maximize the amount of text on the page.

`\ensuremath{math cmds}` (8.3.1) - 186

Sets *math cmds* in math mode; may be called in both text and math modes. Its main use is to define new commands that require math mode but can be called from either mode.

`\epsilon [m]` produces ϵ (5.3.1) - 125

`\eqref{marker} [a]` (12.2.7) - 278

With the `amsmath` package, is a variation on the `\ref` command, and prints the equation number defined with `\label{marker}` in parentheses, as (5.6).

`\equiv [m]` produces \equiv (5.3.4) - 126

`\eta [m]` produces η (5.3.1) - 125

`\euro` (2.5.8) - 25

With the `eurosym` package, prints the euro symbol € from the `eurosym` METAFONT fonts. With the `eurosans` package, it prints the symbol from the Adobe (PostScript) euro fonts. In both cases, the symbol is sans serif but changes to bold face or slanted to match the current font.

`\EUR` (2.5.8) - 25

With the `europs` package, prints the euro symbol € from the Adobe (PostScript) euro fonts, such that it matches the font family and other attributes. `\EUROfc` prints the invariable symbol €.

`\evensidemargin` (3.2.5) - 48

Sets the left margin for the even-numbered pages. It is effective in the document class `book` and, when the option `twoside` has been selected, in the other classes. A new value is assigned with the `\setlength` command:

`\setlength{\evensidemargin}{2.5cm}`

`\ExecuteOptions{option_list} [p]` (D.2.3) - 443

In a class or package file, this command executes all the option definitions in *option_list*. This is normally invoked just prior to `\ProcessOptions` to establish certain options as default.

`\exists [m]` produces \exists (5.3.6) - 127

`\exp [m]` (5.3.8) - 128

Command to produce the function name ‘exp’ in formulas.

`\extracolsep{extra_width}` (4.8.1) - 96

Tabular command for setting extra spacing between all the following columns in a table. This command is inserted as an @-expression into the column definition field of the `tabular` environment:

`\begin{tabular}{l r @{\extracolsep{2.5mm}} l cr}`

- `\fbox{text}` produces a frame around `text` (4.7.1) - 86
- `\fancypage{cmds1}{cmds2}` (4.7.9) - 95
 With the fancybox package, places a framed box around the contents of all subsequent pages; *cmds1* exclude the head and footlines, *cmds2* includes them. The arguments set box parameters like `\fboxrule` but must end with a box command like `\shadowbox`. Usually one set of *cmds* is left blank.
- `\fboxrule` (4.7.8) - 93
 The line thickness for the frames drawn by `\fbox` and `\framebox` commands. A new value is assigned with the `\setlength` command:
`\setlength{\fboxrule}{1pt}`
- `\fboxsep` (4.7.8) - 93
 The distance between the frame and text in the `\fbox` and `\framebox` commands. A new value is assigned with the `\setlength` command:
`\setlength{\fboxsep}{1mm}`
- `\colorbox col_spec1 col_spec2{text}` (6.2) - 167
 A command made available with the color package. Like `\colorbox`, the *text* is set in an LR box with the *col_spec2* as the background color, but with a frame of color *col_spec1* around it. The *col_specs* are either both defined names or employ the same model. Examples:
`\colorbox[rgb]{1,0,0}{0,1,0}{Text}`
`\colorbox{red}{green}{Text}`
- `\figurename` (D.4.1) - 459
 Command containing the name for a figure caption. In English, this is 'Figure' but may be altered for adaptation to other languages.
- `\fill` (2.4.2) - 22
 A rubber length with a natural size of zero that can stretch to any size necessary to fill up the horizontal or vertical space available.
- `\flat [m]` produces `b` (5.3.6) - 127
- `\floatpagefraction` (7.3) - 172
 The fraction of a float page that must be filled with floats before a new page is called. A new value is assigned with
`\renewcommand{\floatpagefraction}{decimal.frac}`
- `\floatsep` (7.3) - 172
 The vertical spacing between floats that appear at the top or bottom of a page. A new value is set with the `\setlength` command:
`\setlength{\floatsep}{12pt plus 2pt minus 4pt}`
- `\flushbottom` (3.2.5) - 48
 A declaration that puts vertical spacing between paragraphs so that the last line on every page is at the same position. Standard for the book document class and for the twoside option.

- `\fnsymbol{counter}` (8.1.4) – 183
 Prints the current value of the given *counter* as a ‘footnote symbol’:
 * † ‡ § ¶ || ** †† ‡‡
- `\fontencoding{enc}` (A.1) – 368
 This command selects the font encoding scheme. Possible values of *enc* are OT1 for the standard and T1 for the Cork encodings. Other values are also possible.
- `\fontfamily{fam}` (A.1) – 368
 This command selects the ‘family’ of fonts. Possible values of *fam* for standard L^AT_EX with the Computer Modern fonts are *cmr*, *cmss*, *cmtt*, and *cmfi*.
- `\fontseries{ser}` (A.1) – 368
 This command selects the ‘series’ of fonts within a ‘family’. Possible values of *ser* for standard L^AT_EX are *m* (medium) and *bx* (bold extended).
- `\fontshape{form}` (A.1) – 368
 This command selects the ‘shape’ of fonts. Possible values of *form* are *n* (normal), *it* (italic), *sl* (slanted), *sc* (small caps), and *u* (‘unslanted’ italic).
- `\fontsize{sz}{line_sp}` (A.1) – 368
 This command selects the font size. The argument *sz* specifies the size of the characters in points (without the dimension *pt*) and *line_sp* determines the value of the interline spacing (`\baselineskip`), with an explicit dimension. Example: `\fontsize{12}{14pt}`.
- `\footnote[num]{footnote_text}` (4.10.1), (4.10.2) – 112, 114
 Produces a footnote containing the text *footnote_text*. The optional argument *num* will be used as the footnote number in place of the next number in the automatic sequence.
- `\footnotemark[num]` (4.10.3) – 114
 Produces a footnote marker in the current text. The optional argument *num* will be used as the footnote number in place of the next number in the automatic sequence. May be used within structures where `\footnote` is not normally permitted, such as LR boxes, tables, math formulas.
- `\footnoterule` (4.10.6) – 118
 This is an internal command to produce the horizontal rule between the regular text on a page and the footnote text at the bottom. May be changed with, e.g.,
`\renewcommand{\footnoterule}`
`{\rule{width}{hght}\vspace{-hght}}`

- `\footnotesep` (4.10.6) - 117
 The vertical spacing between two footnotes. A new value is assigned with the `\setlength` command:
`\setlength{\footnotesep}{6.5pt}`
- `\footnotesize` (4.1.2) - 62
 Switches to the font size `\footnotesize`, which is smaller than `\small` but larger than `\scriptsize`.
- `\footnotetext[num]{footnote_text}` (4.10.3) - 114
 Produces a footnote with the text *footnote_text* but without generating a marker in the current text. The marker that is used for the footnote itself at the bottom of the page derives from the current value of the counter `footnote`, which remains unchanged, or from the value of the optional argument *num*. This command may be used together with the `\footnotemark` command to insert footnotes into structures where they are otherwise not allowed, such as LR boxes, tables, and math formulas. The `\footnotetext` command must be given *outside* of that structure.
- `\footskip` (3.2.5) - 48
 The distance from the bottom edge of the text body to the lower edge of the footline. A value is assigned with the `\setlength` command:
`\setlength{\footskip}{25pt}`
- `\forall [m]` produces \forall (5.3.6) - 127
- `\foreignlanguage{language}{text}` (11.1) - 254
 In the `babel` system, sets a short *text* in the selected *language*.
- `\frac{numerator}{denominator} [m]` (5.2.3) - 122
 Math command for generating fractions.
- `\frame{text}` (13.1.4) - 298
 Produces a frame without any intervening spacing around `text`. Mainly used as a picture element in a `\put` or `\multiput` command within the `picture` environment.
- `\framebox[width][pos]{text}` (4.7.1) - 86
 Produces a frame of width *width* around *text*. By default, the text is centered within the frame, but may be left or right justified by giving the optional argument *pos* as `l` or `r`. It may also have the value `s`, to stretch the text to the given width.
- `\framebox(x_dimen,y_dimen)[pos]{text}` (13.1.4) - 291
 Picture element command to produce a frame of width *x_dimen* and height *y_dimen* within the `picture` environment. Without the optional argument *pos*, the text is centered vertically and horizontally.

The text may be left or right justified, and/or aligned at the top or bottom, by setting *pos* to a combination of the letters l, r, t, and b, such as tr for top, right; *pos* may also contain s to stretch the text to the full width. The command is to be used as the argument of a \put or \multiput command.

\frenchspacing (2.7.1) - 29

After this command has been given, no additional horizontal spacing is inserted at the end of a sentence. The countercommand is \nonfrenchspacing.

\frontmatter (3.3.5) - 57

In the book class, introduces the material that comes at the beginning (preface, table of contents) by turning off the chapter numbering of the \chapter command and switching to Roman numbers for the pagination.

\frown [m] produces \frown (5.3.4) - 126

\fussy (2.8.3) - 36

Countercommand of \sloppy that allows larger interword spacings than normal. After \fussy has been given, the normal spacings apply once more.

\Gamma [m] produces Γ (5.3.1) - 125

\gamma [m] produces γ (5.3.1) - 125

\gcd [m] (5.3.8) - 128

Command to produce the function name 'gcd' in formulas. A lower limit may be given as a subscript.

\ge [m] produces \geq (5.3.4) - 126

\genfrac{left}{right}{thkns}{mathsz}{over}{under} [m][a]
 (12.2.3) - 265

With the amsmath package, produces a generalized fraction with delimiters *left* and *right*, line thickness *thkns*, math font size *mathsz* 0-3, and with *over* on top of *under*. If *mathsz* is empty, the sizing is automatic.

\geq [m] produces \geq (5.3.4) - 126

\gets [m] produces \leftarrow (5.3.5) - 127

\gg [m] produces \gg (5.3.4) - 126

\glossary{glossary_entry} (9.4.4) - 230

Write a \glossaryentry command to the .glo file if \makeglossary has been issued in the preamble; else it does nothing.

\glossaryentry{glossary_entry}{page_number} (9.4.4) - 230

The form in which the entry is written to the .glo file by the \glossary command.

- `\graphpaper[num] (x, y) (lx, ly)` (13.1.5) - 301
 A command added with the `graphpap` package for use in the `picture` environment. It plots a labeled grid system with the lower left corner at (x, y) , lx wide and ly high. Grid lines are drawn every num units, with the fifth ones thicker. If num is not specified, it is assumed to be 10. All arguments must be integers, not decimal fractions.
- `\grave{x}` [m] (5.3.9) - 129
 A grave accent over the math variable x : `\grave{a}` = \hat{a} .
- `\Grave{x}` [m][a] (12.2.2) - 263
 With the `amsmath` package, can be used like `\grave`, but with multiple $\mathcal{AMS-L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ math accents the positioning will be correct.
- `\guillemotleft` (G.4.5) - 503
 When T1 encoding is active, prints the symbol «.
- `\guillemotright` (G.4.5) - 503
 When T1 encoding is active, prints the symbol ».
- `\guilsinglleft` (G.4.5) - 503
 When T1 encoding is active, prints the symbol ‹.
- `\guilsinglright` (G.4.5) - 503
 When T1 encoding is active, prints the symbol ›.
- `\H{x}` (2.5.7) - 24
 Hungarian double acute accent: `\H{o}` = \acute{o} .
- `\hat{x}` [m] (5.3.9) - 129
 Circumflex over the math variable x : `\hat{a}` = \hat{a} .
- `\Hat{x}` [m][a] (12.2.2) - 263
 With the `amsmath` package, can be used like `\hat`, but with multiple $\mathcal{AMS-L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ math accents the positioning will be correct.
- `\hbar` [m] produces \hbar (5.3.6) - 127
- `\headheight` (3.2.5) - 48
 The height of the head at the top of each page. A new value is assigned with the `\setlength` command:
`\setlength{\headheight}{25pt}`
- `\headsep` (3.2.5) - 48
 Vertical spacing between the lower edge of the page head and the top of the main text. A new value is assigned with the `\setlength` command:
`\setlength{\headsep}{0.25in}`

`\headtoname` (D.4.1) - 460

Command in the `letter` document class containing the text that precedes the recipient's name in the headline after the first page. In English, this is 'To' but may be altered for adaptation to other languages.

`\heartsuit [m]` produces ♥ (5.3.6) - 127

`\height` (4.7.1) - 86

A length parameter equal to the natural height of a box (distance from the baseline to the top); it may only be used in the *width* specification of `\makebox`, `\framebox`, or `\savebox`, or in the *height* specification of a `\parbox` or a `minipage` environment.

`\framebox[6\height]{text}`

`\hfill` (2.7.1) - 30

A horizontal rubber spacing with a natural length of zero that can be stretched to any value. Used to fill up a horizontal line with blank spacing. This command is an abbreviation for `\hspace{\fill}`.

`\hline` (4.8.1) - 97

Produces a horizontal line in the `array` and `tabular` environments over the width of the entire table.

`\hoffset` 602, 603

Horizontal offset of the output page from the printer border set by the printer driver. This printer border is normally 1 inch from the left edge of the paper. The standard value of `\hoffset` is 0 pt so that the left reference margin of the page is identical with the printer margin. A new value is assigned with the `\setlength` command:

`\setlength{\hoffset}{-1in}`

`\hom [m]` (5.3.8) - 128

Command to produce the function name 'hom' in formulas.

`\hookleftarrow [m]` produces \leftrightarrow (5.3.5) - 127

`\hookrightarrow [m]` produces \curvearrowright (5.3.5) - 127

`\hrulefill` (2.7.1) - 30

Fills up the space in a line with a rule: _____ = `\hrulefill`.

`\hspace{width}` (2.7.1) - 29

Produces horizontal spacing of length *width*. It is ignored if it occurs at the beginning or end of a line.

`\hspace*{width}` (2.7.1) - 29

Produces horizontal spacing of length *width* even at the beginning or end of a line.

- `\huge` (4.1.2) - 62
Switches to the font size `\huge`, which is smaller than `\Huge` but larger than `\LARGE`.
- `\Huge` (4.1.2) - 62
Switches to the largest font size available `\Huge`, which is larger than `\huge`.
- `\hyperlink{name}{link}` (10.2.4) - 247
With the `hyperref` package, makes the contents of `link` to be a link to the target with the name `name`, established with the `\hypertarget` command. The `link` may be text, a symbol, or a graphics loaded with `\includegraphics`. The link is framed with a colored box, unless the option `colorlinks` has been set to `true`, in which case the `link` is set in a text color determined by the option `linkcolor`.
- `\hypertarget{name}{text}` (10.2.4) - 247
With the `hyperref` package, prints the `text` argument as normal, but makes it a target for internal links, named `name`. The `text` may be empty.
- `\hypersetup{key = value, ...}` (10.2.4) - 241
With the `hyperref` package, allows parameters (`key`) to be assigned values (`value`); the parameters may also be set as options in the `\usepackage` loading command, by with `\hypersetup`, these values may be changed within the document. The list of possible keys and values is given on pages 242-246.
- `\hyphenation{hyphenation.list} [p]` (2.8.2) - 35
Sets up a list of hyphenation exceptions. The `hyphenation.list` consists of a collection of words containing hyphens at the places where word division may occur: `hy-phen-a-tion per-mit-ted`.
- `\i` produces i (2.5.7) - 24
- `\idotsint [m][a]` produces $\int \cdots \int$ (12.2.2) - 260
- `\iff [m]` produces \iff (5.3.5) - 127
- `\IfFileExists{file.name}{true}{false}` (D.2.8) - 447
Tests if the file `file.name` can be found in the places where \LaTeX looks for files; if so, the code `true` is executed; otherwise, `false`. This is like `\InputIfFileExists` except the file is not input.
- `\iflanguage{language}{yes.text}{no.text}` (11.1) - 254
In the multilingual `babel` system, tests if `language` is the currently selected language and, if so, executes `yes.text`, otherwise `no.text`.

`\[ifthen]ifthenelse{test}{then_text}{else_text}` (8.3.5) - 193

A conditional command available when the standard package `ifthen` has been loaded. If the logical statement *test* evaluates to *true* then *then_text* is inserted, otherwise *else_text*. The logical statement may be relational (two numbers with one of `<` `=` `>` between them), an even-odd test (`\isodd{number}`), a comparison of two texts (`\equal{text1}{text2}`), a comparison of two lengths (`\lengthtest{length1 op length2}`, *op* is one of `<` `=` `>`), or a test of a boolean switch (`\boolean{switch}`). Switches are created with `\newboolean{switch}` and set with `\setboolean{switch}{value}`, where *value* is `true` or `false`. Logical statements may be combined with logical operators `\and`, `\or`, and `\not`, and grouped with `\(` and `\)`.

`\Im [m]` produces \Im (5.3.6) - 127

`\imath [m]` produces \imath (5.3.6) - 127

`\in [m]` produces \in (5.3.4) - 126

`\include{file}` (9.1.2) - 209

Inserts the contents of the file with the root name *file* and extension `.tex` into the current text at the point where the command appears. A new page is always started! Together with `\includeonly`, this command allows portions of the document to be processed as though the rest of the text were present.

`\includegraphics[llx,lly][urx,ury]{file_name}` (6.1.2) - 155

A command made available with the `graphics` package that imports external graphics stored in the file *file_name*. The coordinates of the bounding box are given by *llx*, *lly* (lower left corner) and by *urx*, *ury* (upper right corner). It is the contents of this bounding box that are used for further manipulation: scaling, rotating. It is also the (manipulated) bounding box that is used to reserve space in the text; any graphics that extend beyond the limits of this box will also be printed, but overlapping any other material that may be beside it.

The bounding box coordinates may have units attached to them; the default units are big points `bp` (72 per inch).

If the bounding box coordinates are omitted, the information is obtained in some other manner, depending on the type of graphics file. For an encapsulated PostScript file, this information is taken from the graphics file itself.

If *llx* and *lly* are not specified, they are assumed to be 0. That is, if only one set of optional coordinates are given, they refer to the upper right corner.

`\includegraphics*[llx,lly][urx,ury]{file_name}` (6.1.2) - 155

The same as `\includegraphics` except that any graphics extending beyond the bounding box are *not* included: the figure is clipped.

- `\includegraphics[key=value,...]{file_name}` (6.1.3) - 157
 With the `graphicx` package, this command has a different syntax in which the scaling, rotating, clipping are effected through `key=value` pairs, like `width=7cm, angle=90, scale=.5`.
- `\includeonly{file_list} [p]` (9.1.2) - 209
 Only those files whose names are in `file_list`, separated by commas, will be read in by the `\include` commands. The `\include` commands for other file names are ignored. Nevertheless, all the auxiliary files are read in so that the page and section numbers will be correct, as are the cross-reference markers.
- `\indent` (3.2.4) - 46
 The first line of the *next* paragraph is to be indented.
- `\index{index_entry}` (9.4.2), (9.4.2) - 225, 226
 Writes a `\indexentry` command to the `.idx` file if the `\makeindex` command has been issued in the preamble; otherwise it does nothing. The `MakeIndex` program (Section 9.4.3) can process this file if the entries are in the forms
`\index{main_entry}`
`\index{main_entry!sub_entry}`
`\index{main_entry!sub_entry!sub_sub_entry}`
 making up a `theindex` environment with the entries alphabetically ordered and organized with `\item`, `\subitem`, and `\subsubitem` commands.
- `\indexentry{index_entry}{page_number}` (9.4.2) - 226
 The form in which the entry is written to the `.idx` file by the `\index` command.
- `\indexname` (D.4.1) - 459
 Command containing the heading for the index. In English, this is ‘Index’ but may be altered for adaptation to other languages.
- `\indexspace` (9.4.1) - 225
 Command within the `index` environment to produce a blank line.
- `\inf [m]` (5.3.8) - 128
 Command to produce the function name ‘inf’ in formulas. A lower limit may be set as a subscript.
- `\infty [m]` produces ∞ (5.3.6) - 127
- `\intertext{insert_text} [m][a]` (12.2.1) - 259
 When the package `amsmath` is loaded, this command inserts text as a left-justified line between lines of an equation, without affecting their horizontal alignment.

- `\input{file}` (9.1.1) – 207
 Inserts the contents of the file with the root name *file* and extension `.tex` into the current text at the point where the command appears. The file that is read in may also contain further `\input` commands.
- `\InputIfFileExists{file_name}{true}{false}` (D.2.8) – 447
 Tests if the file *file_name* can be found in the places where L^AT_EX looks for files; if so, the code *true* is executed and the file is input; otherwise, *false* is executed.
- `\int [m]` produces \int (5.2.5) – 123
`\iint [m][a]` produces \iint (12.2.2) – 260
`\iiint [m][a]` produces \iiint (12.2.2) – 260
`\iiiiint [m][a]` produces \iiiiint (12.2.2) – 260
- `\intertextsep` (7.3) – 172
 The vertical spacing between floats in the middle of a page and the surrounding text. A new value is assigned with the `\setlength` command:
`\setlength{\intertextsep}{10pt plus2pt minus3pt}`
- `\invisible` (15.1.2) – 326
 In `slides` class, a declaration that makes the following text be printed in ‘invisible ink’, that is, it takes up as much space as though it were there. It remains in effect until the end of the environment, or end of the curly braces, in which it was issued, or until `\visible` is given. It is used for making overlays.
- `\iota [m]` produces ι (5.3.1) – 125
`\itdefault` (A.3.1) – 372
 This command defines the shape attribute that is selected with the `\itshape` command. It may be redefined with `\renewcommand`:
`\renewcommand{\itdefault}{it}`
- `\item[label]` (4.3), (4.4.1) – 69, 74
 Produces a label and the start of an item text in a list environment. Without the optional argument, the label is generated according to the type of environment, for example numbers for the `enumerate` environment. The optional argument inserts *label* in place of this standard item label.
- `\item` (9.4.1) – 225
 Produces a main entry in the `index` environment.
- `\itemindent` (4.4.2) – 77
 The amount by which the label and the text of the first line after each `\item` is indented in a list environment. The standard value is 0 pt, but a new value may be assigned with the `\setlength` command:
`\setlength{\itemindent}{1em}`

- `\itemsep` (4.4.2) - 75
 The amount of vertical spacing in addition to `\parsep` that is inserted between the `\item` texts in a list environment. A new value may be assigned with the `\setlength` command:

$$\setlength{\itemsep}{2pt plus 1pt minus 1pt}$$
- `\itshape` (4.1.3), (A.2) - 64, 371
 This declaration switches to a font in the current family and series, but with the *italic* shape attribute.
- `\j` produces j (2.5.7) - 24
`\jmath [m]` produces j (5.3.6) - 127
`\Join [m]` produces \bowtie (5.3.6) - 127
`\jot` (5.5.4) - 149
 The amount of vertical spacing between the formula lines of an `eqnarray` or `eqnarray*` environment. Standard value is 3 pt. A new value may be assigned with the `\setlength` command:

$$\setlength{\jot}{4.5pt}$$
- `\k{x}` (G.4.5) - 503
 When T1 encoding is active, prints the ogonek accent $\k{A} = \mathring{A}$.
- `\kappa [m]` produces κ (5.3.1) - 125
`\ker [m]` (5.3.8) - 128
 Command to produce the function name 'ker' in formulas.
- `\kill` (4.6.2) - 82
 Removes the preceding sample line in a `tabbing` environment that was given only to set the tabs and not to be printed at this point.
- `\L` produces \mathbb{L} (2.5.6) - 24
`\l` produces \mathbb{l} (2.5.6) - 24
`\label{marker}` (9.2.1) - 213
 Sets a marker in the text at this position with the name *marker*. It may be referred to either earlier or later in the document with the command `\ref{marker}` to output the counter that was then current, such as the section, equation, or figure number, or with the command `\pageref{marker}` to print the page number where the marker was set.
- `\labelenum n` (4.3.5) - 73
 A set of commands to produce the standard labels for the nesting levels of the `enumerate` environments, where *n* is one of *i*, *ii*, *iii*, or *iv*. For example,

$$\renewcommand{\labelenumii}{\arabic{enumii}.}$$
 changes the standard labels of the second-level `enumerate` environment to be 1.), 2.), etc.

`\labelitem n` (4.3.5) - 73

A set of commands to produce the standard labels for the nesting levels of the `itemize` environments, where n is one of `i`, `ii`, `iii`, or `iv`. For example,

`\renewcommand{\labelitemi}{\Rightarrow}`

changes the standard labels of the outermost `itemize` environment to \Rightarrow .

`\labelsep` (4.4.2) - 77

In a `list` environment, the distance between the label box and the list text. A new value is assigned with the `\setlength` command:

`\setlength{\labelsep}{5pt}`

`\labelwidth` (4.4.2) - 77

In a `list` environment, the width of the box reserved for the label. A new value is assigned with the `\setlength` command:

`\setlength{labelwidth}{2.2cm}`

`\Lambda [m]` produces Λ (5.3.1) - 125

`\lambda [m]` produces λ (5.3.1) - 125

`\langle [m]` produces \langle (5.4.1) - 132

`\language{num}` (11.1) - 255

In T_EX versions 3.0 and later, the set of hyphenation patterns number num is made active. The patterns must be previously loaded into the format file by an `initex` run in which `\language{num}` was given before those patterns were read in.

`\large` (4.1.2) - 62

Switches to the font size `\large`, which is smaller than `\Large` but larger than `\normalsize`.

`\Large` (4.1.2) - 62

Switches to the font size `\Large`, which is smaller than `\LARGE` but larger than `\large`.

`\LARGE` (4.1.2) - 62

Switches to the font size `\LARGE`, which is smaller than `\huge` but larger than `\Large`.

`\LaTeX` produces L^AT_EX (2.1) - 18

`\LaTeXe` produces L^AT_EX 2_ε (2.1) - 19

`\lceil [m]` produces \lceil (5.4.1) - 132

`\ldots` produces \dots (5.2.6) - 123

`\le [m]` produces \leq (5.3.4) - 126

`\leadsto [m]` produces \rightsquigarrow (5.3.5) - 127

- `\leftlbrack [m]` (5.4.1) - 131
 Adjusts the size of the bracket symbol *lbrack* to fit the height of the formula between the `\left` ... `\right` pair. For example, `\left[`. If there is to be no matching bracket, the `\left` and `\right` commands must still be given to specify the part of the formula to be sized, but the missing bracket is given as a period (for example, `\right.`).
- `\Leftarrow [m]` produces \Leftarrow (5.3.5) - 127
`\leftarrow [m]` produces \leftarrow (5.3.5) - 127
`\leftharpoondown [m]` produces \leftharpoondown (5.3.5) - 127
`\leftharpoonup [m]` produces \leftharpoonup (5.3.5) - 127
`\lefteqn [m]` (5.4.7) - 140
 A command inside the `eqnarray` environment that outputs its argument as though it had zero width, thus having no effect on the column widths. It is used mainly for the first row of a multi-row formula.
- `\leftmargin` (4.4.2) - 76
 In a `list` environment, the amount by which the left edge of the text is indented relative to the surrounding text. A new value is assigned with the `\setlength` command. For nested `list` environments, different values for the indentation can be specified by adding `i` ... `vi` to the declaration name, such as

$$\setlength{\leftmarginiii}{0.5cm}$$
 See also (4.3.4) - 71.
- `\Leftrightarrow [m]` produces \Leftrightarrow (5.3.5) - 127
`\leftrightarrow [m]` produces \leftrightarrow (5.3.5) - 127
`\leftroot{shift} [m][a]` (12.2.5) - 269
 With the `amsmath` package, used in the index to a `\sqrt` command to shift it slightly to the left. The *shift* is a number specifying how many units to move it. Example:

$$\sqrt{\leftroot{-1}\uproot{3}\beta}\{k}$$
- `\leq [m]` produces \leq (5.3.4) - 126
`\lfloor [m]` produces \lfloor (5.4.1) - 132
`\lg [m]` (5.3.8) - 128
 Command to produce the function name 'lg' in formulas.
- `\lhd [m]` produces \lhd (5.3.3) - 125
`\lim [m]` (5.3.8) - 128
 Command to produce the function name 'lim' in formulas. A lower limit may be set as a subscript.
- `\liminf [m]` (5.3.8) - 128
 Command to produce the function name 'liminf' in formulas. A lower limit may be set as a subscript.

- `\limits [m]` (5.2.5), (5.3.7) – 123, 128
 Places the upper and lower limits above and below the appropriate symbols where these would normally go just after them.
- `\limsup [m]` (5.3.8) – 128
 Command to produce the function name ‘lim sup’ in formulas. A lower limit may be set as a subscript.
- `\line($\Delta x, \Delta y$){length}` (13.1.4) – 293
 A picture element command within a `picture` environment for drawing horizontal and vertical lines of any length as well as slanted lines at a limited number of angles. For horizontal and vertical lines, the *length* argument is the actual length in units of `\unitlength`. For slanted lines, *length* is the length of the projection on to the x-axis (horizontal displacement). The slope is determined by the $(\Delta x, \Delta y)$ arguments, which take on integral values such that $-6 \leq \Delta x \leq 6$ and $-6 \leq \Delta y \leq 6$. This command is the argument of a `\put` or `\multiput` command.
- `\linebreak[n]` (2.7.2) – 31
 A recommendation to break the line of text at this point such that it fills the horizontal space available (left and right justified). The urgency of the recommendation is given by the integral number *n* between 0 and 4, with the higher numbers meaning a stronger recommendation. A value of 4 is the same as the command without the optional argument and means an obligatory line break.
- `\linethickness{thickness}` (13.1.4) – 300
 Sets the thickness of the horizontal and vertical lines in the `picture` environment. The argument *thickness* is a length specification with units, for example, 1.2mm.
- `\linewidth` (3.2.5) – 47
 A length that is set to the current text line width, whether in one column of a two-column page, in a minipage or parbox. This must never be changed, but is used when that width is needed, say to set the width of an included graphics with

$$\includegraphics[width=0.8\linewidth]{..}$$
- `\listfigurename` (D.4.1) – 459
 Command containing the heading for the list of figures. In English, this is ‘List of Figures’ but may be altered for adaptation to other languages.
- `\listfiles [p]` (9.1.1), (D.2.9) – 208, 447
 When given in the preamble, causes a list of all files read in during the processing to be printed to the monitor and to the transcript file at the end of the run. The list includes version number, date, and any additional information entered with one of the `\Provides...` commands.

- `\listoffigures` (3.4.4) - 59
 Produces a list of figures with the entries from all the `\caption` commands in figure environments.
- `\listoftables` (3.4.4) - 59
 Produces a list of tables with the entries from all the `\caption` commands in table environments.
- `\listparindent` (4.4.2) - 77
 Depth of indentation for the first line of a paragraph inside a `list` environment. A new value may be assigned with the `\setlength` command:
`\setlength{\listparindent}{1em}`
- `\listtablename` (D.4.1) - 459
 Command containing the heading for the list of tables. In English, this is ‘List of Tables’ but may be altered for adaptation to other languages.
- `\ll [m]` produces \ll (5.3.4) - 126
`\ln [m]` (5.3.8) - 128
 Command to produce the function name ‘ln’ in formulas.
- `\LoadClass[options]{class}[version] [p]` (D.2.2) - 442
 This command may only be invoked within a class file to load another class file. It may only be called once within any class file. The file loaded must have the extension `.cls`. Any options specified in the `\documentclass` command are *not* passed over as global options.
 The optional *version* is a date, given in the form *yyyy/mm/dd*, as for example 1994/08/01. If the date of the class file is earlier than this, a warning message is printed.
- `\LoadClassWithOptions{class}[version] [p]` (D.2.2) - 442
 Like `\LoadClass` except all the currently specified options are automatically passed to *class*.
- `\location{number}` (16.1) - 352
 In the `letter` document class, enters the sender’s room number. In the standard \LaTeX `letter` class, *number* is only output if `\address` has not been called. It is intended to be used in company letterheads.
- `\log [m]` (5.3.8) - 128
 Command to produce the function name ‘log’ in formulas.

- `\Longleftarrow [m]` produces \Leftarrow (5.3.5) - 127
- `\longleftarrow [m]` produces \leftarrow (5.3.5) - 127
- `\Longleftrightarrow [m]` produces \Leftrightarrow (5.3.5) - 127
- `\longleftrightarrow [m]` produces \longleftrightarrow (5.3.5) - 127
- `\longmapsto [m]` produces \mapsto (5.3.5) - 127
- `\Longrightarrow [m]` produces \Rightarrow (5.3.5) - 127
- `\longrightarrow [m]` produces \rightarrow (5.3.5) - 127
- `\lq` produces ‘, identical to the ‘ symbol.
- `\lvert [m][a]` produces | (left delimiter) (12.2.5) - 270
- `\lVert [m][a]` produces || (left delimiter) (12.2.5) - 270
- `\mainmatter` (3.3.5) - 57
- In the book class, introduces the main body of text after the front matter, by resetting the page numbering to 1 with Arabic numbers, and by reactivating the chapter numbering with the `\chapter` command. It undoes the effects of `\frontmatter`.
- `\makebox [width] [pos] {text}` (4.7.1) - 86
- Produces a box of width *width* containing *text* centered horizontally, unless *pos* is given to specify that it is to be left (l) or right (r) justified. It may also have the value s, to stretch the text to *width*.
- `\makebox (x.dimen, y.dimen) [pos] {text}` (13.1.4) - 291
- Picture element command to produce a box of width *x.dimen* and height *y.dimen* within the `picture` environment. Without the optional argument *pos*, the text is centered vertically and horizontally. The text may be left or right justified, and/or aligned at the top or bottom, by setting *pos* to a combination of the letters l, r, t, and b, such as tr for top, right; *pos* may also contain s to stretch the text to the full width. The command is used as the argument of a `\put` or `\multiput` command.
- `\makeglossary [p]` (9.4.4) - 230
- Command to activate the `\glossary` commands in the text.
- `\makeindex [p]` (9.4.2) - 226
- Command to activate the `\index` commands in the text.
- `\makelabel {text}` (4.4.1) - 75
- An internal command that is called by the `\item` command to produce the actual label *text* within a list environment.
- `\makelabels` (16.1) - 355
- Produces address labels in the `letter` document class using the entries from the `\begin{letter}` environment.
- `\MakeLowercase {text_cmd}` (D.3.2) - 455
- Converts *text_cmd* (text and commands) to lower case.

- `\MakeShortVerb{c}` (4.9.1, B.5.3) – 111, 393
 When the standard package `shortvrb` has been loaded, this command makes the character *c* a shorthand form for `\verb{c}`: everything that appears between two occurrences of *c* is printed literally, in typewriter type. With `\DeleteShortVerb{c}`, the character is restored to its normal meaning. Example: `\MakeShortVerb{\}`
- `\maketitle` (3.3.1) – 54
 Produces a title page using entries in the `\author` and `\title` commands, and optionally those in the `\date` and `\thanks` commands.
- `\MakeUppercase{text_cmd}` (D.3.2) – 455
 Converts *text_cmd* (text and commands) to upper case.
- `\mapsto [m]` produces \mapsto (5.3.5) – 127
- `\marginpar[left_text]{right_text}` (4.10.5) – 117
 Produces a marginal note at the right of the text containing *right_text*. With two-sided formatting, the marginal note goes into the left margin on the even pages, in which case the optional *left_text* will be written instead. For two-column text, the marginal notes always go into the ‘outer’ margin, and again *left_text* will be used for the left margin.
- `\marginparpush` (4.10.6) – 118
 The minimum vertical separation between two marginal notes. A new value may be assigned with the `\setlength` command.
- `\marginparsep` (4.10.6) – 118
 The spacing between the edge of the text and a marginal note. A new value may be assigned with the `\setlength` command.
- `\marginparwidth` (4.10.6) – 118
 The width of the box reserved for marginal notes. A new value may be assigned with the `\setlength` command.
- `\markboth{left_head}{right_head}` (3.2.1) – 43
 Sets the text entries for the left and right page headlines in two-sided formatting when the page style `myheadings` has been selected, or when the automatic entries of page style `headings` are to be changed.
- `\markright{head}` (3.2.1) – 43
 Sets the text entry for the page headline when the page style `myheadings` has been selected, or when the automatic entry of page style `headings` is to be manually changed. In two-sided formatting, only the right headline is set with this command.
- `\mathbf{text} [m]` (5.4.2), (A.3.3) – 133, 373
 This command sets *text* in a bold font (`\bfseries`) within math mode. Spaces are ignored as usual.

- `\mathcal{text}` [m] (5.3.2), (5.4.2), (A.3.3) – 125, 133, 373
 This command sets *text* in calligraphic letters within math mode:
 $\mathcal{ABC} = \mathcal{ABC}$.
- `\mathindent` (3.1.1) – 40
 The indentation of displayed formulas from the left margin when the option `fleqn` has been selected. A new value may be assigned with the `\setlength` command:
 $\setlength{\mathindent}{25pt}$
- `\mathit{text}` [m] (5.4.2), (A.3.3) – 133, 373
 This command sets *text* in a text italic font (`\itshape`) within math mode. It differs from `\mathnormal` in that the spacing between the letters is as in regular text. Compare *mathit* and *mathnormal*.
- `\mathnormal{text}` [m] (5.3.1), (5.4.2), (A.3.3) – 125, 133, 373
 This command sets *text* in the normal (italic) math font within math mode. In this font, capital Greek letters are also set in italics:
 $\Gamma\mathnormal{\Gamma} = \Gamma\Gamma$.
- `\mathring{x}` [m] (5.3.9) – 129
 A ring accent in mathematical formulas: $\mathring{a} = \mathring{a}$.
- `\mathrm{text}` [m] (5.4.2), (A.3.3) – 133, 373
 This command sets *text* in a Roman font (`\rmfamily`) within math mode. Spaces are ignored as usual.
- `\mathsf{text}` [m] (5.4.2), (A.3.3) – 133, 373
 This command sets *text* in a sans serif font (`\sffamily`) within math mode. Spaces are ignored as usual.
- `\mathtt{text}` [m] (5.4.2), (A.3.3) – 133, 373
 This command sets *text* in a typewriter font (`\ttfamily`) within math mode. Spaces are ignored as usual.
- `\mathversion{ver}` (A.3.3) – 373
 Selects the current math version. Possible values are `bold` and `normal`; new values may be created with the `\DeclareMathVersion` command.
- `\max` [m] (5.3.8) – 128
 Command to produce the function name ‘max’ in formulas. A lower limit may be set as a subscript.
- `\mbox{text}` produces an LR box around *text* (4.7.1) – 86
- `\mddefault` (A.3.1) – 372
 This command defines the series attribute that is selected with the `\mdseries` command. It may be redefined with `\renewcommand`:
 $\renewcommand{\mddefault}{m}$

- `\mdseries` (4.1.3), (A.2) - 64, 371
 This declaration switches to a font in the current family and shape, **but with the medium series attribute.**
- `\medskip` (2.7.3) - 32
 Inserts large vertical spacing of the amount `\medskipamount`. See also `\bigskip` and `\smallskip`.
- `\medskipamount`
 Standard value for the amount of vertical spacing that is inserted with the command `\medskip`. May be changed with the `\setlength` command:

$$\setlength{\medskipamount}{3ex plus1ex minus1ex}$$
- `\medspace [m][a]` (12.2.5) - 269
 With the `amsmath` package, this is an alias for `\:`, a medium space in a math formula.
- `\MessageBreak` (D.2.7) - 446
 Forces a new line in the texts of error, warning, and information messages. These are the only places where it may be invoked, otherwise it does nothing.
- `\mho [m]` produces \O (5.3.6) - 127
- `\mid [m]` produces $|$ (5.3.4) - 126
- `\min [m]` (5.3.8) - 128
 Command to produce the function name ‘min’ in formulas. A lower limit may be set as a subscript.
- `\mod{arg} [m][a]` (12.2.5) - 268
 With the `amsopn` or `amsmath` packages, command to produce the function name ‘mod’ in formulas in the form:

$$y\mod\{a+b\} = y \bmod a + b$$
- `\models [m]` produces \models (5.3.4) - 126
- `\mp [m]` produces \mp (5.3.3) - 125
- `\mspace{mu} [m][a]` (12.2.5) - 269
 With the `amsmath` package, inserts spacing in math formulas; *mu* is a math space in units of mu (=1/18 em): `\mspace{-4mu}`.
- `\mu [m]` produces μ (5.3.1) - 125
- `\multicolumn{n}{col}{text}` (4.8.1) - 97
 Merges the next *n* columns in the array and `tabular` environments, formatting the text entry *text* according to the single column definition *col*, which may be `l`, `c`, `r` as well as `|`.

`\multiput(x,y)(Δx,Δy){n}{pic_elem}` (13.1.3) - 289

Multiple positioning command in the `picture` environment. The object `pic_elem` is placed n times, at (x,y) , $(x+Δx,y+Δy)$, . . . $(x+(n-1)Δx,y+(n-1)Δy)$.

`\multlinegap [m][a]` (12.2.6) - 271

A length that determines the left and right margins of formulas produced with the $\mathcal{A}\mathcal{M}\mathcal{S}$ -L^AT_EX `\multline` environment; initial value is 10 pt but may be reset by the user.

`\nabla [m]` produces ∇ (5.3.6) - 127

`\name{sender}` (16.2) - 356

In the `letter` document class, enters the sender's name.

`\natural [m]` produces \natural (5.3.6) - 127

`\nearrow [m]` produces \nearrow (5.3.5) - 127

`\NeedsTeXFormat{format}[version] [p]` (D.2.1) - 440

Declares the L^AT_EX format that is necessary for processing the file. This should be the first statement in the file. At the moment, the only legitimate value for `format` is `LaTeX2e`. The `version`, if included, must be given as a date in the form `yyyy/mm/dd`, specifying the earliest possible release date of the format that is consistent with all the features employed in the file. Example:

`\NeedsTeXFormat{LaTeX2e}[1994/06/01]`

`\neg [m]` produces \neg (5.3.6) - 127

`\negmedspace [m][a]` (12.2.5) - 269

With the `amsmath` package, this inserts a negative medium space in a math formula.

`\negthickspace [m][a]` (12.2.5) - 269

With the `amsmath` package, this inserts a negative thick space in a math formula.

`\negthinspace [m][a]` (12.2.5) - 269

With the `amsmath` package, this is an alias for `\!`, a negative thin space in a math formula.

`\neq [m]` produces \neq (5.3.4) - 127

`\newboolean{switch}` (8.3.5) - 194

Requires the standard L^AT_EX package `ifthen`. Creates a new boolean switch. The value of the switch is set with `\setboolean{switch}{value}`, where `value` is `true` or `false`. Its value is tested with `\boolean{switch}`, which may be used as a logical statement in the `test` part of `\ifthenelse` and `\whiledo`.

`\newcommand{com_name}[narg][opt]{def}` (8.3) - 185

Defines a user command with the name `\com_name` to be `def`. The first optional argument $narg \leq 9$ specifies how many variable arguments the command is to have, which appear in the `def` as the replacement characters `#1` to `#narg`. If the second optional argument is present, the first argument of the new command is optional, and takes on the value `opt` if it is not explicitly given.

`\newcommand*{com_name}[narg][opt]{def}` (D.2.6) - 445

The same as `\newcommand` except that the arguments to `\com_name` must be ‘short’, not containing any new paragraphs.

`\newcounter{counter_name}[in_counter]` (8.1.2) - 182

Establishes a new counter with the name `counter_name`. The optional argument `in_counter` is the name of an existing counter which, when incremented, resets the new counter to zero; that is, the new counter is a sub-counter of `in_counter`.

`\newenvironment{env_name}[narg][opt]{beg_def}{end_def}`
 (8.4) - 195

Defines a user environment with the name `env_name` which has the `\begin` definition `beg_def` and the `\end` definition `end_def`. The optional argument $narg \leq 9$ specifies how many variable arguments the environment is to have, which appear in the `beg_def` as the replacement characters `#1` to `#narg`. If the second optional argument is present, the first argument of the `\begin` command is optional, and takes on the value `opt` if it is not explicitly given.

`\newenvironment*{env_name}[narg][opt]{beg_def}{end_def}`
 (D.2.6) - 445

The same as `\newenvironment` except that the arguments to `\begin{env_name}` must be ‘short’, not containing any new paragraphs.

`\newfont{\font_cmd}{\font_name scaled size}` (4.1.5) - 66

Establishes the relation between the font file name `file_name` magnified by the scaling factor `size` and a font selection command `\font_cmd`. After `\font_cmd` has been called, `\baselineskip`, the interline spacing, still has its previous value.

`\newlength{\length_cmd}` (8.2) - 185

Creates a new length command with the name `\length_cmd` and initializes it to 0 pt. New values may be assigned as for all length commands with the `\setlength` command:

`\setlength{\length_cmd}{length}`

The quantity `length` must have units (cm, pt, etc.) and may be a rubber length.

- `\newline` (2.7.2) - 31
 Terminates and starts a line of text *without* right justifying it.
- `\newpage` (2.7.4) - 33
 Terminates and starts a new page, leaving the rest of the page blank.
- `\newsavebox{\boxname}` (4.7.1) - 87
 Creates a storage box with the name `\boxname` in which LR boxes may be saved with the `\savebox` command.
- `\newtheorem{type}[num_like]{title}`
`\newtheorem{type}{title}[in_ctr]` (4.5) - 80
 Defines a new theorem-like environment named *type* which when called prints a theorem declaration with the name *title* in **bold face**, followed by an automatic sequential number, and the actual text of the environment in *italic*. The optional argument *num.like* is the name of another theorem structure which is to share the same numbering counter. The other optional argument *in_ctr* is the name of a sectioning counter, such as `chapter`, which is to reset the theorem counter every time it is incremented. That is, the theorem counter is a sub-counter of *in_ctr*. Only one of the optional arguments may be given.
- `\NG` (G.4.5) - 503
 When T1 encoding is active, prints the character D.
- `\ng` (G.4.5) - 503
 When T1 encoding is active, prints the character η .
- `\ni [m]` produces \ni (5.3.4) - 126
- `\nocite{key}` (14.1) - 310
 The entry in the literature database with the keyword *key* will be included in the bibliography without any citation (reference) in the text. With `\nocite{*}`, *all* entries in all databases will be included.
- `\nofiles [p]` (B.6) - 396
 Issued in the preamble, this command suppresses the output of the auxiliary files `.aux`, `.glo`, `.idx`, `.lof`, `.lot`, and `.toc`.
- `\noindent` (3.2.4) - 46
 The first line of the *next* paragraph will *not* be indented.
- `\nolimits [m]` (5.3.7) - 128
 Places the upper and lower limits after the appropriate symbols where these would normally go just above or below them.

- `\nolinebreak[n]` (2.7.2) - 32
 A recommendation *not* to break the line of text at this point. The urgency of the recommendation is given by the integral number n between 0 and 4, with the higher numbers meaning a stronger recommendation. A value of 4 is the same as the command without the optional argument and means absolutely no line break here.
- `\nonfrenchspacing` (2.7.1) - 29
 Countermands `\frenchspacing`, switching back to the standard formatting in which extra word spacing is inserted at the end of a sentence.
- `\nonumber [m]` (5.4.7) - 139
 The formula line in an `eqnarray` environment in which this command appears will *not* contain an equation number.
- `\nopagebreak[n]` (2.7.4) - 33
 A recommendation *not* to break the page at this point. The urgency of the recommendation is given by the integral number n between 0 and 4, with the higher numbers meaning a stronger recommendation. A value of 4 is the same as the command without the optional argument and means absolutely no page break here.
- `\normalcolor` (6.2) - 167
 A command that normally does nothing. However, if the `color` package has been loaded, it resets the color for text to be the color that was in effect at the end of the preamble, normally black. A `\color` command in the preamble can alter this ‘standard’ color.
 This command is called by many internal \LaTeX macros, to reset the text color when printing headlines and headings. Other packages should also use it so that they are consistent with the `color` package.
- `\normalfont` (4.1.3), (A.2) - 65, 371
 This declaration switches to the font with the default family, shape, and series attributes.
- `\normalmarginpar` (4.10.5) - 117
 Countermands `\reversemarginpar`, switching back to the standard placement of marginal notes in the ‘outer’ margin.
- `\normalsize` (4.1.2) - 62
 Switches to the font size `\normalsize`, the size selected by the option in the `\documentclass` or `\documentstyle` commands. It is smaller than `\large` but larger than `\small`.
- `\not [m]` (5.3.4) - 127
 Changes the following comparison symbol into its negative counterpart:

$$\not\cong = \neq$$

`\notag{mark} [m][a]` (12.2.6) - 271

Within one of the *AMS-L^AT_EX* alignment environments, suppresses the automatic equation number.

`\notin [m]` produces \notin (5.3.4) - 127

`\nu [m]` produces ν (5.3.1) - 125

`\numberwithin{ctr}{in_ctr} [a]` (12.2.7) - 277

With the *amsmath* package, redefines the counter *ctr* to be a sub-counter of *in_ctr*, meaning it is reset every time *in_ctr* is incremented. The value of *in_ctr* is printed with that of *ctr*. This is normally used to make equations in an article to be numbered within sections:

`\numberwithin{equation}{section}`

`\narrow [m]` produces \nwarrow (5.3.5) - 127

`\O` produces \emptyset (2.5.6) - 24

`\o` produces \emptyset (2.5.6) - 24

`\oddsidemargin` (3.2.5) - 48

Sets the left margin for the odd-numbered pages in document class *book* or when the option *twoside* has been selected for other classes. In all other cases, it sets the left margin for *all* pages. A new value is assigned with the `\setlength` command:

`\setlength{\oddsidemargin}{1.5cm}`

`\odot [m]` produces \odot (5.3.3) - 125

`\OE` produces \mathbb{C} (2.5.6) - 24

`\oe` produces \mathbb{c} (2.5.6) - 24

`\oint [m]` produces \oint (5.3.7) - 128

`\Omega [m]` produces Ω (5.3.1) - 125

`\omega [m]` produces ω (5.3.1) - 125

`\ominus [m]` produces \ominus (5.3.3) - 125

`\onecolumn` (3.2.7) - 51

Starts a new page and switches from two-column to one-column page formatting.

`\onlynotes{note_nums}` (15.1.3) - 327

In *slides* class, a command to be issued in the preamble to generate only those notes whose numbers appear in *note_nums*. The command behaves the same as `\onlyslides` for slides.

`\onlyslides{slide_nums}` (15.1.3) - 327

In *slides* class, a command to be issued in the preamble to generate only those slides whose numbers appear in *slide_nums*. The numbers are separated by commas, and may include a range with a hyphen: `\onlyslides{4,10-13,23}`.

- `\opening{dear}` (16.1) - 353
 In the `letter` environment of the `letter` class, this sets the form of the salutation at the start of the letter text; for example, `\opening{Dear George,}`.
- `\oplus [m]` produces \oplus (5.3.3) - 125
- `\OptionNotUsed [p]` (D.2.3) - 443
 A command that may only be used in the definition of options, especially default options. It declares the `\CurrentOption` to be unprocessed. This is used if the processing of a default option should fail, say because some file is missing. \LaTeX is then informed that this requested option is still outstanding.
- `\oslash [m]` produces \oslash (5.3.3) - 125
- `\otimes [m]` produces \otimes (5.3.3) - 125
- `\oval(x.dimen,y.dimen) [part]` (13.1.4) - 296
 Picture element command to produce an oval with width *x.dimen* and height *y.dimen* in the `picture` environment. The optional *part* argument may take on values of `t`, `b`, `l`, and `r` to draw only the top, bottom, left, or right halves of the oval. A combination of these values may be given to draw only a quarter of the oval, such as `t l` or `l t` for the top left part. To be used as an argument in a `\put` or `\multiput` command.
- `\ovalbox{text}` (4.7.9) - 94
 With the `fancybox` package, is a variant of `\fbox`, drawing a framed box with round corners around *text*; the thickness of the lines is given by `\thinlines`.
- `\Ovalbox{text}` (4.7.9) - 94
 With the `fancybox` package, is the same as `\ovalbox` but the thickness of the lines is given by `\thicklines`.
- `\overbrace{sub-form} [m]` (5.4.4) - 136
 Produces a horizontal curly brace over the math formula *sub.form*. Any following superscript will be placed centered above the horizontal brace.
- $$\overbrace{a+b} = \overbrace{a+b}$$
- $$\overbrace{x+y+z}^{\xi\eta\zeta} = \overbrace{x+y+z}^{\xi\eta\zeta}$$
- `\overleftarrow{expr} [m][a]` (12.2.2) - 262
 With the `amsmath` package, places a long leftwards pointing arrow over the mathematical expression *expr*.
- `\overleftrightharrow{expr} [m][a]` (12.2.2) - 262
 With the `amsmath` package, places a long double arrow over the mathematical expression *expr*.

- `\overline{sub_form}` [m] (5.4.4) - 136
 Produces a horizontal bar over the math formula *sub_form*:

$$\overline{a-b} = \overline{a - b}$$
- `\overrightarrow{expr}` [m][a] (12.2.2) - 262
 With the `amsmath` package, places a long rightwards pointing arrow over the mathematical expression *expr*.
- `\overset{char}{\symbol}` [m][a] (12.2.2) - 262
 With the `amsmath` package, places *char* over the math symbol `\symbol` in superscript size.
- `\P` produces ¶ (2.5.5) - 23
- `\PackageError{pkg_name}{error_text}{help}` [p] (D.2.7) - 446
 Writes an error message *error_text* to the monitor and transcript file, labeled with the package name, and halts processing, waiting for a user response as for a L^AT_EX error. If `H(return)` is typed, the *help* text is printed. Both *error_text* and *help* may contain `\MessageBreak` for a new line, `\space` for a forced space, and `\protect` before commands that are to have their names printed literally and not interpreted.
- `\PackageInfo{pkg_name}{info_text}` [p] (D.2.7) - 447
 Is like `\PackageWarningNoLine` except that the text *info_text* is only written to the transcript file, and not to the monitor.
- `\PackageWarning{pkg_name}{warn_text}` [p] (D.2.7) - 446
 Writes *warn_text* to the monitor and transcript file, labeled with the package name and the current line number of the input file. Processing continues. The *warn_text* is formatted in the same way as that for `\PackageError`.
- `\PackageWarningNoLine{pkg_name}{warn_text}` [p] . . (D.2.7) - 446
 Is like `\PackageWarning` except that the current line number of the input file is not printed.
- `\pagebreak[n]` (2.7.4) - 33
 A recommendation to break the page at this point. The urgency of the recommendation is given by the integral number *n* between 0 and 4, with the higher numbers meaning a stronger recommendation. A value of 4 is the same as the command without the optional argument and means an obligatory page break.
- `\pagecolor col_spec` (6.2) - 167
 A command made available with the `color` package. Sets the background color starting with the current page. All following pages have the same background color until `\pagecolor` is called once more. The *col_spec* is the same as for `\color`.

- `\pagename` (D.4.1) - 460
 Command in the `letter` document class containing the text for page numbers after the first page. In English, this is 'Page' but may be altered for adaptation to other languages.
- `\pagenumbering{style}` (3.2.3) - 45
 Determines the style of the page numbering and resets the page counter to 1. Possible values for *style* are: `arabic`, `roman`, `Roman`, `alph`, and `Alph`.
- `\pageref{marker}` (9.2.1) - 213
 Prints the number of the page where *marker* has been set by a `\label{marker}` command.
- `\pagestyle{style} [p]` (3.2) - 42
 Determines the page style, that is, the contents of the head and footlines on every page. Possible values for *style* are: `plain`, `empty`, `headings`, and `myheadings`.
- `\path{directory}` (4.9.2) - 112
 With the `url` package, prints *directory* literally, in typewriter font, with line breaks after non-letters, without hyphens. It functions much the same as the `\url` command, but is *logically* distinct since it is encoding something different.
- `\paperheight` (3.2.5) - 48
 The total height of the page as specified by the page size option in the `\documentclass` command line. With the default `lettersize` option, this is 11 in; with `a4paper`, it is 29.7 cm. The additional option `landscape` interchanges the values of `\paperwidth` and `\paperheight`.
- `\paperwidth` (3.2.5) - 48
 The total width of the page as specified by the page size option in the `\documentclass` command line. With the default `lettersize` option, this is 8.5 in; with `a4paper`, it is 21 cm. The additional option `landscape` interchanges the values of `\paperwidth` and `\paperheight`.
- `\par` (2.5.1) - 23
 Ends the current paragraph and begins a new one. This command is equivalent to a blank line.
- `\paragraph[short title]{title}` (3.3.3) - 55
 The second last command in the sectioning hierarchy, coming between `\subsubsection` and `\subparagraph`. It formats *title* with the current sub-subsection number and an automatic sequential paragraph number. If the optional *short title* is given, it appears in place of *title* in the table of contents.

- `\paragraph*{title}` (3.3.3) - 55
 The same as `\paragraph` but without a number or an entry in the table of contents.
- `\parallel [m]` produces \parallel (5.3.4) - 126
- `\parbox[pos][height][inner_pos]{width}{text}` (4.7.3), (4.7.5) - 88, 90
 Produces a vertical box of width *width* in which *text* is set in lines that are left and right justified to this width. The vertical positioning with respect to the surrounding text is determined by the optional argument *pos*: `t` for alignment with its top line, `b` with its bottom line, and centered with no argument. The two additional optional arguments: *height* to give the total height, and *inner_pos* to specify how the text is to be positioned inside it. Possible values are `t` for top, `b` for bottom, `c` for centered, and `s` to be stretched out to fill the whole vertical space. The default is the value of the external positioning *pos* option. The *height* argument may contain the parameters `\height`, `\depth`, `\width`, and `\totalheight`.
- `\parindent` (3.2.4) - 46
 The amount of indentation for the first line of a paragraph. A new value may be assigned with the `\setlength` command:
`\setlength{\parindent}{1.5em}`
- `\parsep` (4.4.2) - 76
 The vertical spacing between paragraphs within a `list` environment. A new value may be assigned with the `\setlength` command:
`\setlength{\parsep}{2pt plus1pt minus1pt}`
- `\parskip` (3.2.4) - 46
 The vertical spacing between paragraphs. A new value may be assigned with the `\setlength` command:
`\setlength{\parskip}{3pt plus1pt minus2pt}`
- `\part[short title]{title}` (3.3.3) - 55
 The highest command in the sectioning hierarchy. It begins a new ‘Part’ with an automatic sequential part number and the heading *title*. The following sectioning numbers are not influenced by the part number. If the optional *short title* is given, it appears in place of *title* in the table of contents.
- `\part*{title}` (3.3.3) - 55
 The same as `\part` but without a number or an entry in the table of contents.
- `\partial [m]` produces ∂ (5.3.6) - 127
- `\partname` (D.4.1) - 460
 Command containing the part heading. In English, this is ‘Part’ but may be altered for adaptation to other languages.

`\partopsep` (4.4.2) - 75

The additional vertical spacing at the beginning and/or end of a listing when a blank line precedes or follows the environment commands. A new value may be assigned with the `\setlength` command:

`\setlength{\partopsep}{2pt plus1pt minus1pt}`

`\PassOptionsToClass{options}{class} [p]` (D.2.3) - 443

Assigns the options in the list *options* to the specified class file, which is later loaded with `\LoadClass`. This command must be called from a class file, or from another file input by a class file. It may be used in the definition of options, or in a configuration file to activate options.

`\PassOptionsToPackage{options}{package} [p]` (D.2.3) - 443

Assigns the options in the list *options* to the specified package file, which is later loaded with `\RequirePackage`. This command may be called from a class or package file. It may be used in the definition of options, or in a configuration file to activate certain options.

`\perp [m]` produces \perp (5.3.4) - 126

`\Phi [m]` produces Φ (5.3.1) - 125

`\phi [m]` produces ϕ (5.3.1) - 125

`\Pi [m]` produces Π (5.3.1) - 125

`\pi [m]` produces π (5.3.1) - 125

`\pm [m]` produces \pm (5.3.4) - 126

`\pmb{symbol} [m][a]` (12.2.1) - 258

When one of the packages `amsmath` or `amsbsy` has been loaded, this command prints *symbol* in simulated bold face. This is done by printing it several times slightly displaced.

`\pmod{arg} [m]` (5.3.8), (12.2.5) - 129, 268

Command to produce the function name ‘mod’ in formulas in the form:

$y \pmod{a+b} = y \pmod{a + b}$

`\pod{arg} [m][a]` (12.2.5) - 268

With the `amsopn` or `amsmath` packages, command to produce the function name ‘mod’ in formulas in the form:

$y \pod{a+b} = y (a + b)$

`\poptabs` (4.6.4) - 83

Restores the last set of tabular stops in the `tabbing` environment that has been saved with `\pushtabs`.

`\pounds` produces \pounds (2.5.5) - 23

`\Pr [m]` (5.3.8) - 128

Command to produce the function name ‘Pr’ in formulas. A lower limit may be set as a subscript.

- `\prec [m]` produces \prec (5.3.4) - 126
- `\preceq [m]` produces \preceq (5.3.4) - 126
- `\prime [m]` produces ' (identical to the ' symbol) (5.3.6) - 127
- `\printindex` (9.4.3) - 228

A command defined in the `makeidx.sty` file that generates the index environment after the program `MakeIndex` has processed the `.idx` file.

- `\ProcessOptions [p]` (D.2.3) - 443

In a class or package file, this command processes the requested options by executing the `\ds@` commands for each one *in the order in which they were defined*. The `\ds@` commands are then erased.

- `\ProcessOptions* [p]` (D.2.3) - 443

This is the same as `\ProcessOptions` except that the `\ds@` commands are executed *in the order in which the options were requested*.

- `\prod [m]` produces \prod (5.3.7) - 128
- `\propto [m]` produces \propto (5.3.4) - 126
- `\protect` (D.2.5) - 445

Fragile commands may be used in moving arguments when they are preceded by the `\protect` command. Example:

```
\section{The \protect\pounds{} Sign}.
```

- `\providecommand{\com_name} [narg] [opt] {def}` (8.3.1) - 187

The same as `\newcommand` except that if a command with the name `\com_name` already exists, the new definition is ignored.

- `\providecommand*{\com_name} [narg] [opt] {def}` (D.2.6) - 445

The same as `\providecommand` except that the arguments to `\com_name` must be 'short', not containing any new paragraphs.

- `\ProvidesClass{class} [version] [p]` (D.2.1) - 441

At the beginning of a class file, this statement declares the name of the class and its version, to be checked against the name and version in the `\documentclass` or `\LoadClass` command that input it. The *version* specification, if present, consists of three parts: date, version number, and additional information. Example:

```
\ProvidesClass{thesis}[1995/01/25 v3.8 U of Saigon]
```

- `\ProvidesFile{file_name} [version]` (D.2.1) - 442

At the beginning of a general file, this statement declares its name and version. No checking is done when the file is read in with `\input`, but the information is printed out if `\listfiles` has been activated. This command is not limited to the preamble as the other `\Provides..` commands are.

- `\ProvidesPackage{class}[version] [p]` (D.2.1) – 441
 At the beginning of a package file, this statement declares the name of the package and its version, to be checked against the name and version in the `\usepackage` or `\RequirePackage` command that input it. The *version* specification, if present, consists of three parts: date, version number, and additional information. Example:
`\ProvidesPackage{notes}[1995/02/13 1.2 G. Smith]`
- `\ProvideTextCommand{\cmd}{code} [narg] [opt] {def} [p]`
 (A.3.7) – 379
 Defines `\cmd` in the same way as `\providecommand` except the definition is only valid when encoding *code* is active. If the command `\cmd` is already defined for that encoding, it is not redefined.
- `\ProvideTextCommandDefault{\cmd}{code} [narg] [opt] {def} [p]`
 (A.3.7) – 380
 Is the same as `\DeclareTextCommandDefault` except that if a default encoding definition already exists for `\cmd`, then no redefinition occurs and the previous definition is retained.
- `\ps text` (16.1) – 353
 Adds a postscript to a letter in the `letter` document class.
- `\Psi [m]` produces Ψ (5.3.1) – 125
`\psi [m]` produces ψ (5.3.1) – 125
`\pushtabs` (4.6.4) – 83
 Saves the current set of tabulator stops in the `tabbing` environment. It may be recalled with the `\poptabs` command.
- `\put(x,y){pic_elem}` (13.1.3) – 289
 The positioning command within a `picture` environment. The picture element *pic_elem* is placed with its reference point at the location (x,y) .
- `\qbezier[num](x1,y1)(x2,y2)(x3,y3)` (13.1.4) – 299
 This command can be given within the `picture` environment to draw a quadratic Bézier curve from point (x_1,y_1) to (x_3,y_3) , using (x_2,y_2) as the extra Bézier point. The curve is drawn as *num* + 1 dots if the optional argument *num* is given, otherwise *num* is calculated automatically to produce a solid line. It is the same as `\bezier` except that *num* is optional.
- `\quad` (2.7.1) – 30
 Inserts horizontal spacing of size 1 em.
- `\qqquad` (2.7.1) – 30
 Inserts horizontal spacing of size 2 em.

- `\quotedblbase` (G.4.5) - 503
When T1 encoding is active, prints the symbol „
- `\quotesinglbase` (G.4.5) - 503
When T1 encoding is active, prints the symbol ,.
- `\r{x}` (2.5.7) - 24
Produces a circle accent: `\r{o}` = \circ .
- `\raggedbottom` (3.2.5) - 48
The standard page formatting for `article`, `report`, and `letter` document classes when the `twoside` option has *not* been selected. The spacing between paragraphs is fixed so that the last line will vary from page to page. The opposite command is `\flushbottom`.
- `\raggedleft` (4.2.2) - 67
After this declaration, the lines of text will only be right justified and the left margin will be uneven. The individual lines are terminated by `\`. See also `\begin{flushright}`.
- `\raggedright` (4.2.2) - 67
After this declaration, the lines of text will only be left justified and the right margin will be uneven. The individual lines are terminated by `\`. See also `\begin{flushleft}`.
- `\raisebox{lift}[height][depth]{text}` (4.7.2) - 87
An LR box containing *text* is raised an amount *lift* above the current baseline. If *lift* is negative, the box is lowered. The optional arguments state that it is to be treated as though it extended by *height* above and by *depth* below the baseline regardless of its true extents.
- `\raisetag{len}[m][a]` (12.2.6) - 271
Within one of the \mathcal{A}_{MS} -L^AT_EX alignment environments, raises the equation number or marker by *len* above its normal position.
- `\rangle [m]` produces \rangle (5.4.1) - 132
- `\rceil [m]` produces \rceil (5.4.1) - 132
- `\Re [m]` produces \Re (5.3.6) - 127
- `\ref{marker}` (9.2.1) - 213
Prints the number of the section, equation, figure, or table where *marker* has been set by a `\label{marker}` command.
- `\reflectbox{text}` (6.1.2) - 156
A command made available with the `graphics` package that reflects the contents *text* as an LR box such that left and right are reversed.

- `\refname` (D.4.1) - 460
 Command containing the heading for the bibliography in `article` document class. In English, this is ‘References’ but may be altered for adaptation to other languages.
- `\refstepcounter{counter}` (8.1.3) - 182
 Increases the value of the number stored in *counter* by one, the same as `\stepcounter`, but also makes the specified counter the relevant one for the `\label`–`\ref` cross-referencing commands.
- `\renewcommand{com_name}[narg][opt]{def}` (8.3) - 185
 The same as `\newcommand` except that the command `\com_name` must already exist, otherwise an error message is printed.
- `\renewcommand*{com_name}[narg][opt]{def}` (D.2.6) - 445
 The same as `\renewcommand` except that the arguments to `\com_name` must be ‘short’, not containing any new paragraphs.
- `\renewenvironment{env}[narg][opt]{beg}{end}` (8.4) - 195
 The same as `\newenvironment` except that the environment *env* must already exist, otherwise an error message is printed.
- `\renewenvironment*{env}[narg][opt]{beg}{end}` (D.2.6) - 445
 The same as `\renewenvironment` except that the arguments to `\begin{env}` must be ‘short’, not containing any new paragraphs.
- `\RequirePackage[options]{packages}[version][p]` (D.2.2) - 442
 This command is the equivalent of `\usepackage` within a class or package file. It loads one or more package files with the extension `.sty`. More than one package may be specified in *packages*, the names being separated by commas. Any *options* listed will be applied to all packages. Furthermore, any options listed in the `\documentclass` command will also be applied to the package files.
 The optional *version* is a date, given in the form *yyyy/mm/dd*, as for example 1994/08/01. If the date of the package file is earlier than this, a warning message is printed.
- `\RequirePackageWithOptions{package}[version][p]` (D.2.2) - 442
 Like `\RequirePackage` except all the currently specified options are automatically passed to *package*.
- `\resizebox{h.length}{v.length}{text}` (6.1.2) - 156
 A command made available with the `graphics` package that scales the contents *text* as an LR box such that the horizontal size becomes *h.length* and the vertical size *v.length*. If either size is given as `!`, the one scale factor is applied to both dimensions.

`\resizebox*{h.length}{v.length}{text}` (6.1.2) - 156

The same as `\resizebox` except that the vertical size *v.length* refers to the total height plus depth of the LR box.

`\reversemarginpar` (4.10.5) - 117

Changes the placement of marginal notes from the standard (right or ‘outer’ margin) to the opposite side. Can be countermanded with `\normalmarginpar`.

`\rfloor [m]` produces] (5.4.1) - 132

`\rhd [m]` produces ▷ (5.3.3) - 125

`\rho [m]` produces ρ (5.3.1) - 125

`\rightbrack [m]` (5.4.1) - 131

Adjusts the size of the bracket symbol *rbrack* to fit the height of the formula between the `\left` ... `\right` pair. For example, `\right]`. If there is to be no matching bracket, the `\left` and `\right` commands must still be given to specify the part of the formula to be sized, but the missing bracket is given as a period (for example, `\left.`).

`\Rightarrow [m]` produces ⇒ (5.3.5) - 127

`\rightarrow [m]` produces → (5.3.5) - 127

`\rightharpoondown [m]` produces ⇓ (5.3.5) - 127

`\rightharpoonup [m]` produces ⇑ (5.3.5) - 127

`\rightleftharpoons [m]` produces ⇌ (5.3.5) - 127

`\rightmargin` (4.4.2) - 76

In a `list` environment, the amount by which the right edge of the text is indented relative to the right side of the surrounding text. Standard value is 0 pt. A new value is assigned with the `\setlength` command:

`\setlength{\rightmargin}{0.5cm}`

`\rmdefault` (A.3.1) - 372

This command defines the family attribute that is selected with the `\rmfamily` command. It may be redefined with `\renewcommand`:

`\renewcommand{\rmdefault}{ptm}`

`\rmfamily` (4.1.3), (A.2) - 64, 371

This declaration switches to a font in the current series and shape, but with the Roman family attribute.

`\Roman{counter}` (8.1.4) - 183

Prints the current value of the *counter* as an upper case Roman numeral.

`\roman{counter}` (8.1.4) - 183

Prints the current value of the *counter* as a lower case Roman numeral.

- `\rotatebox{angle}{text}` (6.1.2) - 156
 A command made available with the `graphics` package that rotates the contents *text* as an LR box through the *angle* expressed in degrees. The rotation is counterclockwise about the left-hand end of the baseline of the box.
- `\rq` produces ' , identical to the ' symbol.
- `\rule[lift]{width}{height}` (4.7.6) - 91
 Produces a black rectangle of width *width* and height *height*, raised above the baseline by an amount *lift*, if this optional argument is given. A value of '0 pt' for either the *width* or *height* creates an invisible horizontal or vertical *strut* that may be used to make spacing.
- `\rvert [m][a]` produces | (right delimiter) (12.2.5) - 270
`\rVert [m][a]` produces || (right delimiter) (12.2.5) - 270
- `\S` produces § (2.5.5) - 23
`\SS` produces SS, the upper case version of `\ss`, ß (2.5.6) - 24
- `\savebox{\boxname}[width][pos]{text}` (4.7.1) - 87
 Functions the same as the `\makebox` command except that the box contents are not output but saved under the name `\boxname`, which has been previously defined with `\newsavebox`. The box may be set any place in the text as often as desired with the command `\usebox{\boxname}`.
- `\savebox{\boxname}(x_dim,y_dim)[pos]{sub_pic}` (13.1.4) - 300
 In the `picture` environment, a sub-picture *sub_pic* may be stored as a box of width *x_dim* and height *y_dim* under the name `\boxname`, which has been previously defined with `\newsavebox`. The *pos* argument functions as it does for the `picture` `\makebox`. The box may be set any place in the `picture` environment with the command `\usebox{\boxname}`.
- `\sb` produces a subscript, identical to the `_` symbol.
- `\sbox{\boxname}{text}` (4.7.1) - 87
 Stores *text* in an LR box named `\boxname` that has previously been created with `\newsavebox{\boxname}`. The contents of the box may be printed as often as desired with `\usebox{\boxname}`.
- `\scalebox{h_scale}[v_scale]{text}` (6.1.2) - 156
 A command made available with the `graphics` package that scales the contents *text* as an LR box with the horizontal factor *h_scale* and optionally with the (different) vertical factor *v_scale*. If *v_scale* is missing, it is the same as *h_scale*.
- `\scdefault` (A.3.1) - 372
 This command defines the shape attribute that is selected with the `\scshape` command. It may be redefined with `\renewcommand`:
`\renewcommand{\scdefault}{sc}`

- `\scriptscriptstyle [m]` (5.5.2) - 146
 Switches to font size `\scriptscriptstyle` as the active font inside a math formula.
- `\scriptsize` (4.1.2) - 62
 Switches to the font size `\scriptsize`, which is smaller than `\footnotesize` but larger than `\tiny`.
- `\scriptstyle [m]` (5.5.2) - 146
 Switches to font size `\scriptstyle` as the active font inside a math formula.
- `\scshape` (4.1.3), (A.2) - 64, 371
 This declaration switches to a font in the current family and series, but with the CAPS AND SMALL CAPS shape attribute.
- `\searrow [m]` produces \searrow (5.3.5) - 127
- `\sec [m]` (5.3.8) - 128
 Command to produce the function name ‘sec’ in formulas.
- `\section[short title]{title}` (3.3.3) - 55
 Begins a new section, formatting *title* with the current chapter number (book and report classes only) and an automatic sequential section number. If the optional *short title* is given, it appears in place of *title* in the table of contents and the running head at the top of the pages.
- `\section*{title}` (3.3.3) - 55
 The same as `\section` but without a number or an entry in the table of contents.
- `\see{reference}` (9.4.2) - 227
 A command defined in the `makeidx` package for use with the `MakeIndex` program. It is called within an `\index` command to refer to another entry in the keyword index as ‘see *reference*’. Given in the form:

$$\backslash\text{index}\{entry|\text{see}\{reference\}\}$$
 Note: the above text is correct with `|` in place of `\` for `|see`.
- `\seealso{reference}` (9.4.2) - 227
 Like `\see`, but will print the text ‘see also *reference*’ in the index. More precisely, it prints the text stored in the command `\alsoiname`. Requires the `makeidx` package.
- `\seename` (D.4.1) - 460
 A command defined in the package `makeidx` containing the text for the command `\see`. In English, this is ‘see’ but may be altered for adaptation to other languages.

- `\selectfont` (A.1) - 369
 Activates the font with the current set of attributes, making it the current font in which text is set. It should normally follow an attribute selection command. Example:
`\fontshape{s1}\selectfont`
- `\selectlanguage{language}` (11.1) - 255
 Command in multi-language packages such as `german` and in the `babel` system for changing the language. The names of titles, the form of the date command `\today`, special language-specific commands, and the hyphenation patterns are all changed. Example:
`\selectlanguage{english}`
- `\setboolean{switch}{value}` (8.3.5) - 194
 Requires the standard \LaTeX package `ifthen`. Sets the value of a boolean switch to *true* or *false*, depending on *value*, which must be true or false. The switch must have been created with `\newboolean{switch}`. Its value is tested with `\boolean{switch}`, which may be used as a logical statement in the *test* part of `\ifthenelse` and `\whiledo`.
- `\setcounter{counter}{value}` (8.1.3) - 182
 Assigns the integral number *value* to the counter *counter*.
- `\setlength{\length_cmd}{length_spec}` (8.2) - 184
 The length command with the name `\length_cmd` is assigned the length value *length_spec*, which may be a fixed or rubber length. See also (2.4.1), (2.4.2) - 21, 21
- `\SetMathAlphabet{\cmd}{ver}{code}{fam}{ser}{shp}` [p]
 (A.3.3) - 373
 Defines the math alphabet that has been declared with `\DeclareMathAlphabet` to take the specified font attributes in the math version *ver*.
- `\setminus [m]` produces `\` (5.3.3) - 125
- `\SetSymbolFont{sym_fnt}{ver}{code}{fam}{ser}{shp}` [p]
 (A.3.4) - 374
 Defines the symbol font that has been declared with `\DeclareSymbolFont` to take the specified font attributes in the math version *ver*.
- `\settime{secs}` (15.1.3) - 327
 In the `slides` class, if the option `clock` has been selected, a time marker, in minutes, appears at the bottom of the notes. This command sets the internal timer to the specified number of seconds. See also `\addtime`.

`\settodepth{\length_cmd}{text}` (8.2) - 184

The length command with the name `\length_cmd` is assigned a value equal to the depth of `text` below the baseline.

`\settoheight{\length_cmd}{text}` (8.2) - 184

The length command with the name `\length_cmd` is assigned a value equal to the height of `text` above the baseline.

`\settowidth{\length_cmd}{text}` (8.2) - 184

The length command with the name `\length_cmd` is assigned a value equal to the length of `text` as it would be set in an LR box.

`\sfdefault` (A.3.1) - 372

This command defines the family attribute that is selected with the `\sffamily` command. It may be redefined with `\renewcommand`:

`\renewcommand{\sfdefault}{phv}`

`\sffamily` (4.1.3), (A.2) - 64, 371

This declaration switches to a font in the current series and shape, but with the sans serif family attribute.

`\shadowbox{text}` (4.7.9) - 94

With the `fancybox` package, is a variant of `\fbox`, drawing a shadowed box around `text`; the thickness of the shadow is given by the length `\shadowsize`.

`\sharp [m]` produces # (5.3.6) - 127

`\shortstack[pos]{text}` (13.1.4) - 297

Formats the `text` into a single column, where the individual rows are terminated by `\`. The optional positioning argument `pos` takes on values of `l` or `r` to set the text left or right justified, otherwise it is centered. Example:

`\shortstack{aa\bbb\cc\x\yy\zzz}` aa
bbb
cc
x
yy
zzz

`\sideset{pre}{post}\symbol [m][a]` (12.2.2) - 262

With the `amsmath` package, places superscripts and subscripts snugly before (`pre`) and after (`post`) the math symbol `\symbol`. Example:

`\sideset{_\dag^*}{_\dag^*}\prod$ yields \prod_{\dagger}^*`

`\Sigma [m]` produces Σ (5.3.1) - 125

`\sigma [m]` produces σ (5.3.1) - 125

`\signature{name}` (16.1) - 351

In the `letter` document class, supplies the name of the writer that should go below the signature if this is different from the entry in `\name`.

- `\sim [m]` produces \sim (5.3.4) - 126
- `\simeq [m]` produces \simeq (5.3.4) - 126
- `\sin [m]` (5.3.8) - 128
Command to produce the function name ‘sin’ in formulas.
- `\sinh [m]` (5.3.8) - 128
Command to produce the function name ‘sinh’ in formulas.
- `\sldefault` (A.3.1) - 372
This command defines the shape attribute that is selected with the `\slshape` command. It may be redefined with `\renewcommand`:
`\renewcommand{\sldefault}{sl}`
- `\sloppy` (2.8.3) - 36
After this command has been given, word spacings are allowed to stretch more generously than usual so that paragraphs are broken up into lines with fewer word divisions. It is countermanded by `\fussy`. See also `\begin{sloppypar}`.
- `\slshape` (4.1.3), (A.2) - 64, 371
This declaration switches to a font in the current family and series, but with the *slanted* shape attribute.
- `\small` (4.1.2) - 62
Switches to the font size `\small`, which is smaller than `\normalsize` but larger than `\footnotesize`.
- `\smallskip` (2.7.3) - 32
Inserts large vertical spacing of amount `\smallskipamount`. See also `\medskip` and `\bigskip`.
- `\smallskipamount`
Standard value for the amount of vertical spacing that is inserted with the command `\smallskip`. May be changed with the `\setlength` command:
`\setlength{\smallskipamount}{1ex plus0.5ex minus0.3ex}`
- `\smash[pos]{text} [m][a]` (12.2.5) - 269
With the `amsmath` package, this \TeX command acquires an optional argument *pos* that may be `b` or `t`, to effectively zero the depth or height of the *text*. With no *pos*, both height and depth are zeroed.
- `\smile [m]` produces \smile (5.3.4) - 126
- `\sp` produces a superscript, identical to the $\hat{}$ symbol.
- `\spadesuit [m]` produces \spadesuit (5.3.6) - 127
- `\sqcap [m]` produces \sqcap (5.3.3) - 125
- `\sqcup [m]` produces \sqcup (5.3.3) - 125
- `\sqrt[n]{arg} [m]` (5.2.4) - 122
Basic math command to produce a root sign. The height and length of the sign are made to fit the contents *arg*. The optional argument *n* is the degree of the root: `\sqrt[3]{2}` = $\sqrt[3]{2}$, `\sqrt{2}` = $\sqrt{2}$.

- `\sqsubset [m]` produces \sqsubset (5.3.4) - 126
- `\sqsubseteq [m]` produces \sqsubseteq (5.3.4) - 126
- `\sqsupset [m]` produces \sqsupset (5.3.4) - 126
- `\sqsupseteq [m]` produces \sqsupseteq (5.3.4) - 126
- `\ss` produces β (2.5.6) - 24
- `\stackrel{upper}{lower} [m]` (5.4.5) - 137
 - Places one mathematical symbol *upper* on top of another *lower*, such that the upper one appears in a smaller typeface:
 - `\stackrel{\alpha}{\longrightarrow}`
- `\star [m]` produces \star (5.3.3) - 125
- `\stepcounter{counter}` (8.1.3) - 182
 - Increases the value of the number stored in *counter* by one.
- `\stretch{decimal_num}` (8.2) - 184
 - A rubber length with a natural value of 0 pt but with a stretchability that is *decimal_num* times that of `\fill`.
- `\subitem{sub_entry}` (9.4.1) - 225
 - In the `index` environment, a command to produce a second-level entry after an `\item` command.
- `\subparagraph[short title]{title}` (3.3.3) - 55
 - The last command in the sectioning hierarchy, coming after `\paragraph`. It formats *title* with the current paragraph number and an automatic sequential sub-paragraph number. If the optional *short title* is given, it appears in place of *title* in the table of contents.
- `\subparagraph*{title}` (3.3.3) - 55
 - The same as `\subparagraph` but without a number or an entry in the table of contents.
- `\subsection[short title]{title}` (3.3.3) - 55
 - The command in the sectioning hierarchy that comes between the `\section` and `\subsubsection`. It formats *title* with the current section number and an automatic sequential subsection number. If the optional *short title* is given, it appears in place of *title* in the table of contents.
- `\subsection*{title}` (3.3.3) - 55
 - The same as `\subsection` but without a number or an entry in the table of contents.
- `\substack{1st line}\dots\{last line} [m][a]` (12.2.2) - 261
 - With the `amsmath` package, produces centered multiline indices or limits; it must immediately follow `^` or `_` and be enclosed in `{ }`.

- `\subsubitem{sub_sub_entry}` (9.4.1) - 225
 In the `index` environment, a command to produce a third-level entry under a `\subitem` command.
- `\subsubsection[short form]{title}` (3.3.3) - 55
 The command in the sectioning hierarchy coming between `\subsection` and `\paragraph`. It formats *title* with the current subsection number and an automatic sequential sub-subsection number. If the optional *short title* is given, it appears in place of *title* in the table of contents.
- `\subsubsection*{title}` (3.3.3) - 55
 The same as `\subsubsection` but without a number or an entry in the table of contents.
- `\subset [m]` produces \subset (5.3.4) - 126
`\subseteq [m]` produces \subseteq (5.3.4) - 126
`\succ [m]` produces \succ (5.3.4) - 126
`\succeq [m]` produces \succeq (5.3.4) - 126
`\sum [m]` produces Σ (5.2.5) - 123
`\sup [m]` (5.3.8) - 128
 Command to produce the function name ‘sup’ in formulas. A lower limit may be set as a subscript.
- `\suppressfloats[loc]` (7.2) - 171
 Any floats given between this command and the end of the current page will be suspended at least until the next page. If the optional *loc* is given as one of `t` or `b` (not both), only floats with that placement parameter are suspended.
- `\supset [m]` produces \supset (5.3.4) - 126
`\supseteq [m]` produces \supseteq (5.3.4) - 126
`\surd [m]` produces \surd (5.3.6) - 127
`\swarrow [m]` produces \swarrow (5.3.5) - 127
`\symbol{n}` (4.1.6) - 66
 Produces the symbol in the current character font that is stored under the internal number *n*.
- `\t{xy}` (2.5.7) - 24
 Produces a ‘tie-after’ accent over two letters: `\t{oo}` = \widehat{oo} .
- `\tabbingsep` (4.6.4) - 83
 Determines the spacing between the text *ltext* and the current tabular stop when *ltext*’ is given in a `tabbing` environment. A new value may be assigned with the `\setlength` command.

- `\tabcolsep` (4.8.2) - 98
 Determines the half-column spacing in the `tabular` environment. A new value may be assigned with the `\setlength` command:
`\setlength{\tabcolsep}{3mm}`
- `\tableofcontents` (3.4.2) - 58
 Prints the table of contents from information in the sectioning commands and additional entries.
- `\tablename` (D.4.1) - 459
 Command containing the name for a table caption. In English, this is ‘Table’ but may be altered for adaptation to other languages.
- `\tabularnewline[len]` (4.8.1) - 98
 Terminates a row in the `tabular` or `array` environments, adding vertical spacing *len* if it is specified. This is equivalent to `\\[len]` except that there is no ambiguity as to whether it is terminating a row in the table or a line of text within a column entry. If something like `\raggedright` is given in the last column, then this command *must* be used in place of `\\`.
- `\tag{mark} [m][a]` (12.2.6) - 271
 Within one of the $\mathcal{A}\mathcal{M}\mathcal{S}$ -L^AT_EX alignment environments, prints *mark* in place of the equation number, in parentheses. The ***-form prints it without parentheses.
- `\tan [m]` (5.3.8) - 128
 Command to produce the function name ‘tan’ in formulas.
- `\tanh [m]` (5.3.8) - 128
 Command to produce the function name ‘tanh’ in formulas.
- `\tau [m]` produces τ (5.3.1) - 125
- `\tbinom{over}{under} [m][a]` (12.2.3) - 264
 With the `amsmath` package, produces a binomial as `\binom` does, but in `\textstyle` size.
- `\telephone{number}` (16.1), (16.2) - 352, 356
 In the `letter` document class, enters the sender’s telephone number. In the standard L^AT_EX `letter.sty`, *number* is only output if `\address` has not been called. It is intended to be used in company letter styles such as `mpletter`.
- `\TeX` produces T_EX (2.1) - 19
- `\text{short_text}` [m][a] (12.2.1) - 259
 When one of the packages `amsmath` or `amstext` has been loaded, this command prints *short_text* as normal text within a math formula. If used in subscripts or superscripts, automatic sizing takes place.

`\textsym_name` (D.6) - 462

An alternative means to produce certain special symbols that otherwise are only available in math mode or through ligature combinations:

`\textbullet` (●); `\textemdash` (—); `\textendash` (–);
`\textexclamdown` (¡); `\textperiodcentered` (·);
`\textquestiondown` (¿); `\textquotedblleft` (“);
`\textquotedblright` (”); `\textquoteleft` (‘); `\textquoteright` (’);
`\textvisiblespace` (␣)
`\textasciicircum` (^); `\textasciitilde` (~); `\textbackslash` (\);
`\textbar` (|); `\textgreater` (>); `\textless` (<)

`\textbf{text}` (4.1.4) - 65

This command sets its argument in a font in the current family and shape, but with the **bold** series attribute. It is equivalent to `{\bfseries text}`.

`\textcircled{char}` (D.6) - 462

Produces the specified character in a circle: `\textcircled{s}` = Ⓢ.

`\textcolor col_spec{text}` (6.2) - 167

A command made available with the `color` package. The *text* is set in the specified color. The *col_spec* is the same as for `\color`.

`\textcompwordmark` (D.6) - 462

Prints an invisible character that may be used to break ligatures:
`f\textcompwordmark i = fi`

`\textfloatsep` (7.3) - 172

The vertical spacing between floats at the top of the page and the following text or between text and floats at the bottom of the page. A new value is set with the `\setlength` command.

`\setlength{\textfloatsep}{20pt plus 2pt minus 4pt}`

`\textfraction` (7.3) - 172

The minimum fraction of a page containing text and floats that must be filled with text. A new value is set with

`\renewcommand{\textfraction}{decimal_frac}`

`\textheight` (3.2.5) - 48

The total height reserved for the text on each page, excluding head and footlines. A new value may be assigned with the `\setlength` command:

`\setlength{\textheight}{45\baselineskip}`

- `\textit{text}` (4.1.4) - 65
 This command sets its argument in a font in the current family and series, but with the *italic* shape attribute. It is equivalent to `{\itshape text}`.
- `\textmd{text}` (4.1.4) - 65
 This command sets its argument in a font in the current family and shape, **but with the medium series attribute**. It is equivalent to `{\mdseries text}`.
- `\textnormal{text}` (4.1.3) - 65
 This command sets its argument in the font with the default family, series, and shape attributes. It is equivalent to `{\normalfont text}`.
- `\textquotedbl` (G.4.5) - 503
 When T1 encoding is active, prints the symbol ".
- `\textregistered` produces ® (D.6) - 462
- `\textrm{text}` (4.1.4) - 65
 Sets *text* in a font in the current series and shape, but with the Roman family attribute. It is equivalent to `{\rmfamily text}`.
- `\textsc{text}` (4.1.4) - 65
 Sets *text* in a font in the current family and series, but with the CAPS AND SMALL CAPS shape attribute. It is equivalent to `{\scshape text}`.
- `\textsf{text}` (4.1.4) - 65
 Sets *text* in a font in the current series and shape, but with the sans serif family attribute. It is equivalent to `{\sffamily text}`.
- `\textsl{text}` (4.1.4) - 65
 Sets *text* in a font in the current family and series, but with the *slanted* shape attribute. It is equivalent to `{\slshape text}`.
- `\textstyle [m]` (5.5.2) - 146
 Switches to font size `\textstyle` inside a math formula.
- `char` (D.6) - 462
 Produces a superscript in the current text, rather than math, font: `12 = 12`.
- `\texttrademark` produces ™ (D.6) - 462
- `\texttt{text}` (4.1.4) - 65
 Sets *text* in a font in the current series and shape, but with the typewriter family attribute. It is equivalent to `{\ttfamily text}`.
- `\textup{text}` (4.1.4) - 65
 Sets *text* in a font in the current family and series, *but with the upright shape attribute*. It is equivalent to `{\upshape text}`.

- `\textwidth` (3.2.5) - 48
 The total width reserved for the text on a page. For two-column formatting, this is the width of both columns plus the gap between them. A new value may be assigned with the `\setlength` command.
- `\tfrac{numerator}{denominator} [m][a]` (12.2.3) - 264
 With the `amsmath` package, produces a fraction as `\frac` does, but in `\textstyle` size.
- `\TH` (G.4.5) - 503
 When T1 encoding is active, prints the character \mathcal{P} .
- `\th` (G.4.5) - 503
 When T1 encoding is active, prints the character \mathcal{p} .
- `\thanks{footnote_text}` (3.3.1) - 54
 Produces a footnote to an author's name on the title page when `\maketitle` is called.
- `\thecounter` (8.1.4) - 183
 Internal commands for formatting and printing counter values, making possible use of other counters. For example, `\thesubsection` might be defined to be `\thesection.\roman{subsection}`. A new definition may be made with `\renewcommand{\thecounter}{def}`.
- `\Theta [m]` produces Θ (5.3.1) - 125
- `\theta [m]` produces θ (5.3.1) - 125
- `\thicklines` (13.1.4) - 300
 In the `picture` environment, this command sets all the sloping lines and arrows, circles, and ovals to be drawn with thicker than normal lines.
- `\thickspace [m][a]` (12.2.5) - 269
 With the `amsmath` package, this is an alias for `\;`, a thick space in a math formula.
- `\thinlines` (13.1.4) - 300
 In the `picture` environment, resets the line thickness for sloping lines and arrows, circles, and ovals back to the standard value after `\thicklines` has been given.
- `\thinspace [m][a]` (12.2.5) - 269
 With the `amsmath` package, this is an alias for `\,`, a thin space in a math formula.
- `\thisfancy page{cmds1}{cmds2}` (4.7.9) - 95
 With the `fancybox` package, places a framed box around the contents of the current page only; `cmds1` exclude the head and footlines, `cmds2` includes them. The arguments set box parameters like `\fboxrule` but must end with a box command like `\shadowbox`. Usually one set of `cmds` is left blank.

`\thispagestyle{style}` (3.2) - 42

Changes the page style for the current page only. Possible values for *style* are: `plain`, `empty`, `headings`, and `myheadings`.

`\tilde{x}` [m] (5.3.9) - 129

Produces a tilde (squiggle) over the math variable *x*: `\tilde{a}` = \tilde{a} .

`\Tilde{x}` [m][a] (12.2.2) - 263

With the `amsmath` package, can be used like `\tilde`, but with multiple $\mathcal{A}\mathcal{M}\mathcal{S}$ -L^AT_EX math accents the positioning will be correct.

`\tiny` (4.1.2) - 62

Switches to the smallest font size available `\tiny`, smaller than `\scriptsize`.

`\times` [m] produces \times (5.3.3) - 125

`\title{text}` (3.3.1) - 52

Enters the *text* for the title page that is produced by `\maketitle`.

`\to` [m] produces \rightarrow (5.3.5) - 127

`\today` (2.5.11), (D.4.2) - 27, 461

Prints the current date in the American fashion. This form may be changed to British or to that of other languages by redefining the command with the help of the internal T_EX commands `\day`, `\month`, and `\year`.

`\top` [m] produces \top (5.3.6) - 127

`\topfigrule` (7.3) - 173

A command that is executed after a float at the top of a page. It is normally defined to do nothing, but may be redefined to add a rule between the float and the main text. It must not add any net vertical spacing.

```
\renewcommand{\topfigrule}{\vspace*{-.4pt}
\rule{\columnwidth}{.4pt}}
```

`\topfraction` (7.3) - 172

The maximum fraction of a page that may be occupied at the top by floats at the top of the page. A new value is assigned with

```
\renewcommand{\topfraction}{decimal_frac}
```

`\topmargin` (3.2.5) - 48

The size of the margin from the top of the page to the page head. A new value may be assigned by the `\setlength` command:

```
\setlength{\topmargin}{0.5in}
```

- `topnumber` (7.3) - 171
 The maximum number of floats that may appear at the top of a page.
 A new value is assigned with:
`\setcounter{topnumber}{num}`
- `\topsep` (4.4.2), (5.5.4) - 75, 149
 The extra vertical spacing, in addition to `\parskip`, inserted at the beginning and end of a listing environment. When document class option `fleqn` has been chosen, it is also inserted at the beginning and end of displayed math formulas. A new value may be assigned with the `\setlength` command:
`\setlength{\topsep}{4pt plus2pt minus2pt}`
- `\topskip` (3.2.5) - 48
 The vertical distance from the top of the page body to the baseline of the first line of text. A new value may be assigned with the `\setlength` command:
`\setlength{\topskip}{12pt}`
- `\totalheight` (4.7.1) - 86
 A length parameter equal to the total natural height of a box (height plus depth); it may only be used in the *width* specification of `\makebox`, `\framebox`, or `\savebox`, or in the *height* specification of a `\parbox` or a `minipage` environment.
`\framebox[6\totalheight]{text}`
- `totalnumber` (7.3) - 172
 The total number of floats that may appear on a page regardless of their positions. A new value is assigned with:
`\setcounter{totalnumber}{num}`
- `\triangle [m]` produces Δ (5.3.6) - 127
`\triangleleft [m]` produces \triangleleft (5.3.3) - 125
`\triangleright [m]` produces \triangleright (5.3.3) - 125
- `\ttdefault` (A.3.1) - 372
 This command defines the family attribute that is selected with the `\ttfamily` command. It may be redefined with `\renewcommand`:
`\renewcommand{\ttdefault}{pcr}`
- `\ttfamily` (4.1.3), A.2) - 64, 371
 This declaration switches to a font in the current series and shape, but with the `typewriter` family attribute.
- `\twocolumn[text]` (3.2.7) - 51
 Begins a new page and switches to two-column page format. The optional *text* is set in one column extending over the two columns.

`\typein[\cmd]{message}` (9.1.3) – 211

Prints the *message* to the monitor and stops the program, waiting for a reply from the user. The text of the response is assigned to the L^AT_EX command named `\@typein`, or to `\cmd` if the optional argument has been given. After the return key is pressed, the processing continues. The typed-in text is inserted in place of `\@typein` if the optional argument was not given, otherwise it may be inserted as one pleases with the `\cmd` command.

`\typeout{message}` (9.1.3) – 211

Prints the *message* to the monitor and continues the processing. The *message* is also written to the `.log` file.

`\u{x}` (2.5.7) – 24

Produces a breve accent: `\u{o}` = ö.

`\unboldmath` (5.4.9) – 143

Countermands the `\boldmath` command. It must be given outside of the math mode. Afterwards, formulas are set in standard ‘*math italics*’ once more.

`\underbrace{sub_form} [m]` (5.4.4) – 136

Produces a horizontal curly brace beneath the math formula *sub_form*. Any following subscript will be placed centered below the horizontal brace.

$$\underbrace{a+b}: \underbrace{a+b}$$

$$\underbrace{x+y+z}_{\xi\eta\zeta}: \underbrace{x+y+z}_{\xi\eta\zeta}$$

`\underleftarrow{expr} [m][a]` (12.2.2) – 262

With the `amsmath` package, places a long leftwards pointing arrow beneath the mathematical expression *expr*.

`\underleftrightharrow{expr} [m][a]` (12.2.2) – 262

With the `amsmath` package, places a long double arrow beneath the mathematical expression *expr*.

`\underline{text}` (5.4.4) – 136

Underlines the *text* in both math and normal text modes: `\underline{Text}` = Text.

`\underrightarrow{expr} [m][a]` (12.2.2) – 262

With the `amsmath` package, places a long rightwards pointing arrow beneath the mathematical expression *expr*.

`\underset{char}{\symbol}` [m][a] (12.2.2) - 262

With the `amsmath` package, places *char* below the math symbol `\symbol` in subscript size.

`\unitlength` (13.1.1) - 288

Defines the unit of length for the following `picture` environments. A value is assigned with the `\setlength` command:

`\setlength{\unitlength}{1.2cm}`

`\unlhd` [m] produces \triangleleft (5.3.3) - 125

`\unrhd` [m] produces \triangleright (5.3.3) - 125

`\Uparrow` [m] produces \Uparrow (5.3.5) - 127

`\uparrow` [m] produces \uparrow (5.3.5) - 127

`\updefault` (A.3.1) - 372

This command defines the shape attribute that is selected with the `\upshape` command. It may be redefined with `\renewcommand`:

`\renewcommand{\updefault}{n}`

`\Updownarrow` [m] produces \Updownarrow (5.3.5) - 127

`\updownarrow` [m] produces \updownarrow (5.3.5) - 127

`\uplus` [m] produces \uplus (5.3.3) - 125

`\upshape` (4.1.3), (A.2) - 64, 371

This declaration switches to a font in the current family and series, *but with the upright shape attribute*.

`\Upsilon` [m] produces Υ (5.3.1) - 125

`\upsilon` [m] produces υ (5.3.1) - 125

`\uproot{shift}` [m][a] (12.2.5) - 269

With the `amsmath` package, used in the index to a `\sqrt` command to shift it slightly upwards. The *shift* is a number specifying how many units to move it. Example:

`\sqrt[\leftroot{-1}]{\uproot{3}\beta}`{k}

`\url{address}` (4.9.2) - 112

With the `url` package, prints *address* literally, normally in typewriter font, with line breaks after non-letters, without hyphens. Intended for Internet and email addresses. With the `hyperref` package, *address* becomes an active link in a PDF file. The *address* argument may be delimited either by curly braces as usual, or by some other character, as is done with `\verb`. Examples:

`\url{w_smith@xyz.com}` or `\url|w_smith@xyz.com|`

`\urlstyle{style}` (4.9.2) - 112

With the `url` package, sets the typeface for subsequent `\url` commands, where *style* is one of `tt`, `rm`, `sf`, or `same`, for typewriter, Roman, sans serif, or unchanged font, respectively.

`\usebox{boxname}` (4.7.1) – 87

Inserts into the text the contents of the box that was saved with the `\sbox` or `\savebox` command under the name `\boxname`, which has been previously created with the `\newsavebox` command.

`\usecounter{counter}` (4.4.1) – 75

Command in the `list` environment that specifies which counter is to be employed in the standard labels with the `\item` commands. This counter is incremented by one with each `\item` call.

`\usefont{code}{fam}{ser}{shp}` (A.1) – 369

Activates the font with the given set of attributes in the current size. Is equivalent to selecting the given font attributes and then calling `\selectfont`.

`\usepackage[options]{packages}[version] [p]` (3.1.2) – 41

Loads one or more package files containing additional L^AT_EX or T_EX definitions. The files have the extension `.sty`. More than one package may be specified in `packages`, the names being separated by commas. Any `options` listed will be applied to all packages. Furthermore, any options listed in the `\documentclass` command will also be applied to the package files.

The optional `version` is a date, given in the form `yyyy/mm/dd`, as for example `1994/08/01`. If the date of the package file is earlier than this, a warning message is printed.

Example:

```
\usepackage{bezier,ifthen}[1994/06/01]
```

`\v{x}` (2.5.7) – 24

Produces háček accent: `\v{o}` = \check{o} .

`\value{counter}` (8.1.3) – 183

The current value of the number stored in `counter` for use with commands that require a number. It does *not* output this number. For example, `\setcounter{counter1}{\value{counter2}}` sets `counter1` to the same value as that of `counter2`.

`\varepsilon` [m] produces ε (5.3.1) – 125

`\varinjlim` [m][a] produces ‘ \lim ’ in formulas (12.2.5) – 268

`\varliminf` [m][a] produces ‘ \liminf ’ in formulas (12.2.5) – 268

`\varlimsup` [m][a] produces ‘ \limsup ’ in formulas (12.2.5) – 268

`\varphi` [m] produces φ (5.3.1) – 125

`\varpi` [m] produces ϖ (5.3.1) – 125

`\varprojlim` [m][a] produces ‘ \lim ’ in formulas (12.2.5) – 268

`\varrho` [m] produces ϱ (5.3.1) – 125

`\varsigma` [m] produces ς (5.3.1) – 125

- `\vartheta` [m] produces ϑ (5.3.1) - 125
- `\vdash` [m] produces \vdash (5.3.6) - 127
- `\vdots` [m] produces \vdots (5.2.6) - 123
- `\vec{x}` [m] (5.3.9) - 129
 A vector symbol over the variable x : `\vec{a}` = \vec{a} .
- `\Vec{x}` [m][a] (12.2.2) - 263
 With the `amsmath` package, can be used like `\vec`, but with multiple $\mathcal{A}\mathcal{M}\mathcal{S}\text{-}\mathcal{L}\mathcal{A}\mathcal{T}\mathcal{E}\mathcal{X}$ math accents the positioning will be correct.
- `\vector(\Delta x, \Delta y){length}` (13.1.4) - 295
 A picture element command within a `picture` environment for drawing horizontal and vertical arrows of any length as well as slanted arrows at a limited number of angles. For horizontal and vertical arrows, the *length* argument is the actual length in units of `\unitlength`. For slanted arrows, *length* is the length of the projection on to the x-axis (horizontal displacement). The slope is determined by the $(\Delta x, \Delta y)$ arguments, which take on integral values such that $-4 \leq \Delta x \leq 4$ and $-4 \leq \Delta y \leq 4$. This command is the argument of a `\put` or `\multiput` command.
- `\vee` [m] produces \vee (5.3.3) - 125
- `\verb|source_text|` (4.9) - 110
 Everything that comes between the `|...|` symbols is output in the typewriter font exactly as is with no interpretation of special symbols or commands. Any symbol other than `*` may be used as the switch character, illustrated here as `|`, as long as it does not appear in *source_text*.
- `\verb*|source_text|` (4.9) - 110
 The same as `\verb` except that blanks are made visible with the symbol `_`.
- `\vfill` (2.7.3) - 32
 A vertical rubber spacing with a natural length of zero that can be stretched to any value. Used to fill up parts of a page with blank spacing. This command is an abbreviation for `\vspace{\fill}`.
- `\visible` (15.1.2) - 326
 In `slides` class, a declaration that countermands a previous `\invisible` command, making text printed again. It remains in effect until the end of the environment, or end of the curly braces, in which it was issued, or until `\invisible` is given. It is used for making overlays.
- `\vline` (4.8.1) - 97
 Prints a vertical rule within the column entry of a table in the `tabular` environment.

`\voffset` 602, 603

Vertical offset of the output page from the printer border set by the printer driver. This printer border is normally 1 inch from the top edge of the paper. The standard value of `\voffset` is 0 pt so that the top reference margin of the page is identical with the printer margin. A new value is assigned with the `\setlength` command:

`\setlength{\voffset}{-1in}`

`\pageref[current][non-current]{key}` (9.2.4) - 215

With the `varioref` package, this is equivalent to `on page \pageref{key}`, unless `\label{key}` is on the current or adjacent page, in which case appropriate text is automatically substituted, e.g., ‘on the next page’. The first optional argument is inserted for the current page, the second for other pages.

`\vref{key}` (9.2.4) - 215

With the `varioref` package, this is equivalent to `\ref{key}` on page `\pageref{key}`, unless `\label{key}` is on the current or adjacent page, in which case appropriate text is automatically substituted for the page specification, e.g., ‘on the next page’.

`\vspace{height}` (2.7.3) - 32

Produces vertical spacing of length *height*. It is ignored if it occurs at the beginning or end of a page.

`\vspace*{height}` (2.7.3) - 32

Produces vertical spacing of length *height* even at the beginning or end of a page.

`\wedge [m]` produces \wedge (5.3.3) - 125

`\whiledo{test}{do_text}` (8.3.5) - 193

A conditional command available when the standard package `ifthen` has been loaded. The *do_text* is inserted repeatedly as long as the logical statement *test* evaluates to (*true*). The logical statement may be relational (two numbers with one of `<` `=` `>` between them), an even-odd test (`\isodd{number}`), a comparison of two texts (`\equal{text1}{text2}`), a comparison of two lengths (`\lengthtest{length1 op length2}`, *op* is one of `<` `=` `>`), or a test of a boolean switch (`\boolean{switch}`). Switches are created with `\newboolean{switch}` and set with `\setboolean{switch}{value}`, where *value* is `true` or `false`. Logical statements may be combined with logical operators `\and`, `\or`, and `\not`, and grouped with `\(` and `\)`.

`\widehat{xyz} [m]` (5.3.9) - 129

Produces a wide $\hat{\hspace}$ symbol over several characters: `\widehat{xyz} = \widehat{x}y\widehat{z}`.

- `\widetilde{xyz}` [m] (5.3.9) - 129
 Produces a wide `\tilde` symbol over several characters:
 $\widetilde{xyz} = \widetilde{xyz}$.
- `\width` (4.7.1) - 86
 A length parameter equal to the natural width of a box; it may only be used in the *width* specification of `\makebox`, `\framebox`, or `\savebox`, or in the *height* specification of a `\parbox` or a `minipage` environment.
`\framebox[2\width]{text}`
- `\wp` [m] produces \wp (5.3.6) - 127
- `\wr` [m] produces \wr (5.3.3) - 125
- `\Xi` [m] produces Ξ (5.3.1) - 125
- `\xi` [m] produces ξ (5.3.1) - 125
- `\xleftarrow[below]{above}` [m][a] (12.2.2) - 262
 With the `amsmath` package, draws leftward pointing arrow with *above* printed over it in superscript size, and optionally *below* beneath it in subscript size.
- `\xrightarrow[below]{above}` [m][a] (12.2.2) - 262
 With the `amsmath` package, draws rightward pointing arrow with *above* printed over it in superscript size, and optionally *below* beneath it in subscript size.
- `\zeta` [m] produces ζ (5.3.1) - 125

H.2 Summary tables and figures

Table H.1 Font attribute commands (4.1.3) – p. 64.

<code>\rmfamily</code>	<code>\textrm{<i>text</i>}</code>	Roman
<code>\sffamily</code>	<code>\textsf{<i>text</i>}</code>	sans serif
<code>\ttfamily</code>	<code>\texttt{<i>text</i>}</code>	typewriter
<code>\upshape</code>	<code>\textup{<i>text</i>}</code>	upright
<code>\itshape</code>	<code>\textit{<i>text</i>}</code>	<i>italic</i>
<code>\slshape</code>	<code>\textsl{<i>text</i>}</code>	<i>slanted</i>
<code>\scshape</code>	<code>\textsc{<i>text</i>}</code>	SMALL CAPS
<code>\mdseries</code>	<code>\textmd{<i>text</i>}</code>	medium
<code>\bfseries</code>	<code>\textbf{<i>text</i>}</code>	bold face

Table H.2 Math alphabet commands (5.4.2) – p. 133.

<code>\mathrm{<i>text</i>}</code>	Roman
<code>\mathsf{<i>text</i>}</code>	sansserif
<code>\mathnormal{<i>text</i>}</code>	<i>normal</i>
<code>\mathtt{<i>text</i>}</code>	typewriter
<code>\mathit{<i>text</i>}</code>	<i>italic</i>
<code>\mathbf{<i>text</i>}</code>	boldface
<code>\mathcal{<i>text</i>}</code>	<i>CAŁ</i>

Table H.3 Font sizes (4.1.2) – p. 62.

<code>\tiny</code>	smallest
<code>\scriptsize</code>	very small
<code>\footnotesize</code>	smaller
<code>\small</code>	small
<code>\normalsize</code>	normal
<code>\large</code>	large
<code>\Large</code>	larger
<code>\LARGE</code>	even larger
<code>\huge</code>	still larger
<code>\Huge</code>	largest

Table H.4 L^AT_EX 2.09 font declarations (F.2.1) – p. 485.

<code>\rm</code>	Roman	<code>\it</code>	<i>Italic</i>	<code>\sc</code>	SMALL CAPS
<code>\bf</code>	Bold Face	<code>\sl</code>	<i>Slanted</i>	<code>\sf</code>	Sans Serif
<code>\tt</code>	Typewriter	<code>\mit</code>	<i>ΓΠΦ</i>	<code>\cal</code>	<i>CAŁ</i>

Table H.5 Dimensions (2.4.1) - p. 21.

mm	millimeter	bp	big point (1 in = 72 bp)
cm	centimeter	dd	(1157 dd = 1238 pt)
in	inch (1 in = 2.54 cm)	cc	cicero (1 cc = 12 dd)
pt	point (1 in = 72.27 pt)	sp	(1 pt = 65536 sp)
pc	pica (1 pc = 12 pt)		
em	The current width of a capital M		
ex	The current height of the letter x		

Table H.6 Accents (2.5.7) - p. 24.

$\grave{o} = \backslash ' \{o\}$	$\acute{o} = \backslash \prime \{o\}$	$\hat{o} = \backslash ^ \{o\}$	$\ddot{o} = \backslash " \{o\}$	$\tilde{o} = \backslash \sim \{o\}$
$\bar{o} = \backslash = \{o\}$	$\dot{o} = \backslash . \{o\}$	$\ddot{o} = \backslash u \{o\}$	$\check{o} = \backslash v \{o\}$	$\hat{o} = \backslash H \{o\}$
$\tilde{o} = \backslash t \{oo\}$	$\grave{o} = \backslash c \{o\}$	$\grave{o} = \backslash d \{o\}$	$\grave{o} = \backslash b \{o\}$	$\grave{o} = \backslash r \{o\}$

Table H.7 Special letters from other languages (2.5.6) - p. 24.

$\alpha = \{ \backslash oe \}$	$\text{C} = \{ \backslash OE \}$	$\text{æ} = \{ \backslash ae \}$	$\text{Æ} = \{ \backslash AE \}$	$\text{å} = \{ \backslash aa \}$	$\text{Å} = \{ \backslash AA \}$	$\text{ı} = \{ \backslash i \}$
$\text{o} = \{ \backslash o \}$	$\text{Ø} = \{ \backslash O \}$	$\text{ı} = \{ \backslash I \}$	$\text{Ł} = \{ \backslash L \}$	$\text{ß} = \{ \backslash ss \}$	$\text{SS} = \{ \backslash SS \}$	$\text{¿} = \{ \backslash ? \}$

Table H.8 Special symbols (2.5.5) - 23.

$\dagger \backslash dag$	$\S \backslash S$	$\copyright \backslash copyright$	$\ddagger \backslash ddag$	$\P \backslash P$	$\pounds \backslash pounds$
--------------------------	-------------------	-----------------------------------	----------------------------	-------------------	-----------------------------

Table H.9 Command symbols (2.5.4) - 23.

$\$ \backslash \$$	$\% \backslash \%$	$\{ \backslash \{$	$- \backslash -$	$\& \backslash \&$	$\# \backslash \#$	$\} \backslash \}$
--------------------	--------------------	--------------------	------------------	--------------------	--------------------	--------------------

Table H.10 Greek letters (5.3.1) - p. 125.

Lower case letters

$\alpha \backslash alpha$	$\theta \backslash theta$	$\sigma \backslash sigma$	$\tau \backslash tau$
$\beta \backslash beta$	$\vartheta \backslash vartheta$	$\pi \backslash pi$	$\upsilon \backslash upsilon$
$\gamma \backslash gamma$	$\iota \backslash iota$	$\varpi \backslash varpi$	$\phi \backslash phi$
$\delta \backslash delta$	$\kappa \backslash kappa$	$\rho \backslash rho$	$\varphi \backslash varphi$
$\epsilon \backslash epsilon$	$\lambda \backslash lambda$	$\varrho \backslash varrho$	$\chi \backslash chi$
$\varepsilon \backslash varepsilon$	$\mu \backslash mu$	$\sigma \backslash sigma$	$\psi \backslash psi$
$\zeta \backslash zeta$	$\nu \backslash nu$	$\varsigma \backslash varsigma$	$\omega \backslash omega$
$\eta \backslash eta$	$\xi \backslash xi$		

Upper case letters

$\Gamma \backslash Gamma$	$\Lambda \backslash Lambda$	$\Sigma \backslash Sigma$	$\Psi \backslash Psi$
$\Delta \backslash Delta$	$\Xi \backslash Xi$	$\Upsilon \backslash Upsilon$	$\Omega \backslash Omega$
$\Theta \backslash Theta$	$\Pi \backslash Pi$	$\Phi \backslash Phi$	

Table H.11 Binary operation symbols (5.3.3) - p. 125.

\pm	<code>\pm</code>	\cap	<code>\cap</code>	\circ	<code>\circ</code>	\bigcirc	<code>\bigcirc</code>
\mp	<code>\mp</code>	\cup	<code>\cup</code>	\bullet	<code>\bullet</code>	\square	<code>\Box</code>
\times	<code>\times</code>	\uplus	<code>\uplus</code>	\diamond	<code>\diamond</code>	\diamond	<code>\Diamond</code>
\div	<code>\div</code>	\sqcap	<code>\sqcap</code>	\triangleleft	<code>\lhd</code>	\triangle	<code>\bigtriangleup</code>
\cdot	<code>\cdot</code>	\sqcup	<code>\sqcup</code>	\triangleright	<code>\rhd</code>	∇	<code>\bigtriangledown</code>
$*$	<code>\ast</code>	\vee	<code>\vee</code>	\triangleleft	<code>\unlhd</code>	\triangleleft	<code>\triangleleft</code>
\star	<code>\star</code>	\wedge	<code>\wedge</code>	\triangleright	<code>\unrhd</code>	\triangleright	<code>\triangleright</code>
\dagger	<code>\dagger</code>	\oplus	<code>\oplus</code>	\oslash	<code>\oslash</code>	\setminus	<code>\setminus</code>
\ddagger	<code>\ddagger</code>	\ominus	<code>\ominus</code>	\odot	<code>\odot</code>	\wr	<code>\wr</code>
\amalg	<code>\amalg</code>	\otimes	<code>\otimes</code>				

Table H.12 Relational symbols (5.3.4) - p. 126.

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

Table H.13 Negated relational symbols (5.3.4) - p. 127.

$\not<$	<code>\not<</code>	$\not>$	<code>\not></code>	\neq	<code>\neq</code>
$\not\leq$	<code>\not\le</code>	$\not\geq$	<code>\not\ge</code>	$\not\equiv$	<code>\not\equiv</code>
$\not\prec$	<code>\not\prec</code>	$\not\succ$	<code>\not\succ</code>	$\not\sim$	<code>\not\sim</code>
$\not\preceq$	<code>\not\preceq</code>	$\not\succeq$	<code>\not\succeq</code>	$\not\simeq$	<code>\not\simeq</code>
$\not\subset$	<code>\not\subset</code>	$\not\supset$	<code>\not\supset</code>	$\not\approx$	<code>\not\approx</code>
$\not\subseteq$	<code>\not\subseteq</code>	$\not\supseteq$	<code>\not\supseteq</code>	$\not\cong$	<code>\not\cong</code>
$\not\sqsubset$	<code>\not\sqsubset</code>	$\not\sqsupseteq$	<code>\not\sqsupseteq</code>	$\not\asymp$	<code>\not\asymp</code>
\notin	<code>\notin</code>	\notin	<code>\notin</code>		

Table H.14 Brackets (5.4.1) - p. 132.

$($	<code>(</code>	$)$	<code>)</code>	\lfloor	<code>\lfloor</code>	\rfloor	<code>\rfloor</code>
$[$	<code>[</code>	$]$	<code>]</code>	\lceil	<code>\lceil</code>	\rceil	<code>\rceil</code>
$\{$	<code>\{</code>	$\}$	<code>\}</code>	\langle	<code>\langle</code>	\rangle	<code>\rangle</code>
$ $	<code> </code>	$\ $	<code>\ </code>	\uparrow	<code>\uparrow</code>	\Uparrow	<code>\Uparrow</code>
$/$	<code>/</code>	\backslash	<code>\backslash</code>	\downarrow	<code>\downarrow</code>	\Downarrow	<code>\Downarrow</code>
				\updownarrow	<code>\updownarrow</code>	\Updownarrow	<code>\Updownarrow</code>

Table H.15 Arrows (5.3.5) - p. 127.

\leftarrow	<code>\leftarrow</code>	<code>\gets</code>	\longleftarrow	<code>\longleftarrow</code>	\uparrow	<code>\uparrow</code>
\Leftarrow	<code>\Leftarrow</code>		\Lleftarrow	<code>\Lleftarrow</code>	\Uparrow	<code>\Uparrow</code>
\rightarrow	<code>\rightarrow</code>	<code>\to</code>	\longrightarrow	<code>\longrightarrow</code>	\downarrow	<code>\downarrow</code>
\Rightarrow	<code>\Rightarrow</code>		\Rrightarrow	<code>\Rrightarrow</code>	\Downarrow	<code>\Downarrow</code>
\leftrightarrow	<code>\leftrightarrow</code>		\longleftrightarrow	<code>\longleftrightarrow</code>	\Updownarrow	<code>\Updownarrow</code>
\Leftrightarrow	<code>\Leftrightarrow</code>		\Llongleftrightarrow	<code>\Llongleftrightarrow</code>	\Updownarrow	<code>\Updownarrow</code>
\mapsto	<code>\mapsto</code>		\longmapsto	<code>\longmapsto</code>	\nearrow	<code>\nearrow</code>
\hookrightarrow	<code>\hookrightarrow</code>		\hookrightarrow	<code>\hookrightarrow</code>	\searrow	<code>\searrow</code>
\leftharpoonup	<code>\leftharpoonup</code>		\rightharpoonup	<code>\rightharpoonup</code>	\swarrow	<code>\swarrow</code>
\leftharpoondown	<code>\leftharpoondown</code>		\rightharpoondown	<code>\rightharpoondown</code>	\nwarrow	<code>\nwarrow</code>
\rightleftharpoons	<code>\rightleftharpoons</code>		\leadsto	<code>\leadsto</code>		

Table H.16 Miscellaneous symbols (5.3.6) - p. 127.

\aleph	<code>\aleph</code>	\prime	<code>\prime</code>	\forall	<code>\forall</code>	\Box	<code>\Box</code>
\hbar	<code>\hbar</code>	\emptyset	<code>\emptyset</code>	\exists	<code>\exists</code>	\Diamond	<code>\Diamond</code>
\imath	<code>\imath</code>	∇	<code>\nabla</code>	\neg	<code>\neg</code>	\triangle	<code>\triangle</code>
\jmath	<code>\jmath</code>	\surd	<code>\surd</code>	\flat	<code>\flat</code>	\clubsuit	<code>\clubsuit</code>
ℓ	<code>\ell</code>	∂	<code>\partial</code>	\natural	<code>\natural</code>	\diamondsuit	<code>\diamondsuit</code>
\wp	<code>\wp</code>	\top	<code>\top</code>	\sharp	<code>\sharp</code>	\heartsuit	<code>\heartsuit</code>
\Re	<code>\Re</code>	\perp	<code>\perp</code>	\parallel	<code>\parallel</code>	\spadesuit	<code>\spadesuit</code>
\Im	<code>\Im</code>	\vdash	<code>\vdash</code>	\angle	<code>\angle</code>	\Join	<code>\Join</code>
\mho	<code>\mho</code>	\dashv	<code>\dashv</code>	\backslash	<code>\backslash</code>	∞	<code>\infty</code>

The underlined commands in Tables H.11, H.12, H.15, and H.16 can only be used in $\text{\LaTeX} 2_{\epsilon}$ if one of the packages `latexsym` or `amsfonts` has been loaded.

Table H.17 Mathematical symbols in two sizes (5.3.7) - p. 128.

Σ	\sum	<code>\sum</code>	\cap	\bigcap	<code>\bigcap</code>	\odot	\bigodot	<code>\bigodot</code>
\int	\int	<code>\int</code>	\cup	\bigcup	<code>\bigcup</code>	\otimes	\bigotimes	<code>\bigotimes</code>
\oint	\oint	<code>\oint</code>	\sqcup	\bigsqcup	<code>\bigsqcup</code>	\oplus	\bigoplus	<code>\bigoplus</code>
\prod	\prod	<code>\prod</code>	\vee	\bigvee	<code>\bigvee</code>	\uplus	\biguplus	<code>\biguplus</code>
\coprod	\coprod	<code>\coprod</code>	\wedge	\bigwedge	<code>\bigwedge</code>			

Table H.18 Function names (5.3.8) - p. 128.

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

Table H.19 Math accents (5.3.9) – p. 129.

\hat{a} <code>\hat{a}</code>	\breve{a} <code>\breve{a}</code>	\grave{a} <code>\grave{a}</code>	\bar{a} <code>\bar{a}</code>
\check{a} <code>\check{a}</code>	\acute{a} <code>\acute{a}</code>	\tilde{a} <code>\tilde{a}</code>	\vec{a} <code>\vec{a}</code>
\dot{a} <code>\dot{a}</code>	\ddot{a} <code>\ddot{a}</code>	\mathring{a} <code>\mathring{a}</code>	

The following symbols are made available with the package `amssymb`.

Table H.20 \mathcal{AMS} arrows

\dashrightarrow <code>\dashrightarrow</code>	\dashleftarrow <code>\dashleftarrow</code>
\Lleftarrow <code>\leftleftarrows</code>	\Rrightarrow <code>\leftrightarrows</code>
\Lleftarrow <code>\Lleftarrow</code>	\twoheadleftarrow <code>\twoheadleftarrow</code>
\leftarrowtail <code>\leftarrowtail</code>	\looparrowleft <code>\looparrowleft</code>
\leftrightharpoons <code>\leftrightharpoons</code>	\curvearrowleft <code>\curvearrowleft</code>
\circlearrowleft <code>\circlearrowleft</code>	\Lsh <code>\Lsh</code>
\upuparrows <code>\upuparrows</code>	\upharpoonleft <code>\upharpoonleft</code>
\downharpoonleft <code>\downharpoonleft</code>	\multimap <code>\multimap</code>
\leftrightsquigarrow <code>\leftrightsquigarrow</code>	\rightrightarrows <code>\rightrightarrows</code>
\rightleftarrows <code>\rightleftarrows</code>	\rightrightarrows <code>\rightrightarrows</code>
\rightleftarrows <code>\rightleftarrows</code>	\twoheadrightarrow <code>\twoheadrightarrow</code>
\rightarrowtail <code>\rightarrowtail</code>	\looparrowright <code>\looparrowright</code>
\rightleftharpoons <code>\rightleftharpoons</code>	\curvearrowright <code>\curvearrowright</code>
\circlearrowright <code>\circlearrowright</code>	\Rsh <code>\Rsh</code>
\downdownarrows <code>\downdownarrows</code>	\upharpoonright <code>\upharpoonright</code>
\downharpoonright <code>\downharpoonright</code>	\rightsquigarrow <code>\rightsquigarrow</code>

Negated arrows

\nleftarrow <code>\nleftarrow</code>	\nrightarrow <code>\nrightarrow</code>
\nLeftarrow <code>\nLeftarrow</code>	\nRightarrow <code>\nRightarrow</code>
\nleftrightarrow <code>\nleftrightarrow</code>	\nLeftrightarrow <code>\nLeftrightarrow</code>

Table H.21 \mathcal{AMS} binary operation symbols

$\dot{+}$ <code>\dotplus</code>	\smallsetminus <code>\smallsetminus</code>
\Cap <code>\Cap</code>	\Cup <code>\Cup</code>
$\bar{\wedge}$ <code>\barwedge</code>	\veebar <code>\veebar</code>
$\overline{\bar{\wedge}}$ <code>\doublebarwedge</code>	\boxminus <code>\boxminus</code>
\boxtimes <code>\boxtimes</code>	\boxdot <code>\boxdot</code>
\boxplus <code>\boxplus</code>	\divertimes <code>\divertimes</code>
\ltimes <code>\ltimes</code>	\rtimes <code>\rtimes</code>
\leftthreetimes <code>\leftthreetimes</code>	\rightthreetimes <code>\rightthreetimes</code>
\curlywedge <code>\curlywedge</code>	\curlyvee <code>\curlyvee</code>
\circleddash <code>\circleddash</code>	\circledast <code>\circledast</code>
\circledcirc <code>\circledcirc</code>	\centerdot <code>\centerdot</code>
\intercal <code>\intercal</code>	

Table H.22 $\mathcal{A}_M\mathcal{S}$ Greek and Hebrew letters

F	<code>\digamma</code>	\varkappa	<code>\varkappa</code>
\beth	<code>\beth</code>	\daleth	<code>\daleth</code>
		λ	<code>\lambd</code>

Table H.23 $\mathcal{A}_M\mathcal{S}$ delimiters

\ulcorner	<code>\ulcorner</code>	\urcorner	<code>\urcorner</code>	\llcorner	<code>\llcorner</code>	\lrcorner	<code>\lrcorner</code>
-------------	------------------------	-------------	------------------------	-------------	------------------------	-------------	------------------------

Table H.24 $\mathcal{A}_M\mathcal{S}$ relational symbols

\leqq	<code>\leqq</code>	\leqslant	<code>\leqslant</code>
\leqslantless	<code>\leqslantless</code>	\lesssim	<code>\lesssim</code>
\lessapprox	<code>\lessapprox</code>	\approxeq	<code>\approxeq</code>
\lessdot	<code>\lessdot</code>	\lll	<code>\lll</code>
\lessgtr	<code>\lessgtr</code>	\lesseqgtr	<code>\lesseqgtr</code>
\lesseqqgtr	<code>\lesseqqgtr</code>	\doteqdot	<code>\doteqdot</code>
\risingdotseq	<code>\risingdotseq</code>	\fallingdotseq	<code>\fallingdotseq</code>
\backsim	<code>\backsim</code>	\backsimeq	<code>\backsimeq</code>
\subseteq	<code>\subseteq</code>	\Subset	<code>\Subset</code>
\sqsubset	<code>\sqsubset</code>	\preccurlyeq	<code>\preccurlyeq</code>
\curlyeqprec	<code>\curlyeqprec</code>	$\prec\sim$	<code>\prec\sim</code>
\precapprox	<code>\precapprox</code>	\vartriangleleft	<code>\vartriangleleft</code>
\trianglelefteq	<code>\trianglelefteq</code>	\Vdash	<code>\Vdash</code>
\Vvdash	<code>\Vvdash</code>	\smile	<code>\smile</code>
\smallfrown	<code>\smallfrown</code>	\bumpeq	<code>\bumpeq</code>
\Bumpeq	<code>\Bumpeq</code>	\geqq	<code>\geqq</code>
\geqslant	<code>\geqslant</code>	\geqslantgtr	<code>\geqslantgtr</code>
\gtrsim	<code>\gtrsim</code>	\gtrapprox	<code>\gtrapprox</code>
\gtrdot	<code>\gtrdot</code>	\ggg	<code>\ggg</code>
\gtrless	<code>\gtrless</code>	\gtreqless	<code>\gtreqless</code>
\gtreqqless	<code>\gtreqqless</code>	\eqcirc	<code>\eqcirc</code>
\circeq	<code>\circeq</code>	\triangleq	<code>\triangleq</code>
\thicksim	<code>\thicksim</code>	\thickapprox	<code>\thickapprox</code>
\supseteq	<code>\supseteq</code>	\Supset	<code>\Supset</code>
\sqsupset	<code>\sqsupset</code>	\succcurlyeq	<code>\succcurlyeq</code>
\curlyeqsucc	<code>\curlyeqsucc</code>	\succsim	<code>\succsim</code>
\succapprox	<code>\succapprox</code>	\vartriangleright	<code>\vartriangleright</code>
\trianglerighteq	<code>\trianglerighteq</code>	\Vdash	<code>\Vdash</code>
\shortmid	<code>\shortmid</code>	\shortparallel	<code>\shortparallel</code>
\between	<code>\between</code>	\pitchfork	<code>\pitchfork</code>
\varpropto	<code>\varpropto</code>	\blacktriangleleft	<code>\blacktriangleleft</code>
\therefore	<code>\therefore</code>	\backepsilon	<code>\backepsilon</code>
\blacktriangleright	<code>\blacktriangleright</code>	\because	<code>\because</code>

Table H.25 $\mathcal{A}\mathcal{M}\mathcal{S}$ negated relational symbols

\nless	<code>\nless</code>	\nleq	<code>\nleq</code>
\nleqslant	<code>\nleqslant</code>	\nleqq	<code>\nleqq</code>
\lneq	<code>\lneq</code>	\lneqq	<code>\lneqq</code>
\lvertneqq	<code>\lvertneqq</code>	\lnsim	<code>\lnsim</code>
\lnapprox	<code>\lnapprox</code>	\nprec	<code>\nprec</code>
\npreceq	<code>\npreceq</code>	\nprecnsim	<code>\nprecnsim</code>
\precnapprox	<code>\precnapprox</code>	\nsim	<code>\nsim</code>
\nshortmid	<code>\nshortmid</code>	\nmid	<code>\nmid</code>
\nvDash	<code>\nvDash</code>	\nVDash	<code>\nVDash</code>
\ntriangleleft	<code>\ntriangleleft</code>	\ntriangleleftteq	<code>\ntriangleleftteq</code>
\nsubseteq	<code>\nsubseteq</code>	\subsetneq	<code>\subsetneq</code>
\varsubsetneq	<code>\varsubsetneq</code>	\subsetneqq	<code>\subsetneqq</code>
\varsubsetneqq	<code>\varsubsetneqq</code>	\ngtr	<code>\ngtr</code>
\ngeq	<code>\ngeq</code>	\ngeqslant	<code>\ngeqslant</code>
\ngeqq	<code>\ngeqq</code>	\gneq	<code>\gneq</code>
\gneqq	<code>\gneqq</code>	\gvertneqq	<code>\gvertneqq</code>
\gnsim	<code>\gnsim</code>	\gnapprox	<code>\gnapprox</code>
\nsucc	<code>\nsucc</code>	\nsucceq	<code>\nsucceq</code>
\nsucceq	<code>\nsucceq</code>	\succnsim	<code>\succnsim</code>
\succnapprox	<code>\succnapprox</code>	\ncong	<code>\ncong</code>
\nshortparallel	<code>\nshortparallel</code>	\nparallel	<code>\nparallel</code>
\nvDash	<code>\nvDash</code>	\nVDash	<code>\nVDash</code>
\ntriangleright	<code>\ntriangleright</code>	\ntrianglerightteq	<code>\ntrianglerightteq</code>
\nsupseteq	<code>\nsupseteq</code>	\nsupseteqq	<code>\nsupseteqq</code>
\supseteq	<code>\supseteq</code>	\varsupseteq	<code>\varsupseteq</code>
\supseteqq	<code>\supseteqq</code>	\varsupseteqq	<code>\varsupseteqq</code>

Table H.26 Miscellaneous $\mathcal{A}\mathcal{M}\mathcal{S}$ symbols

\hbar	<code>\hbar</code>	\hslash	<code>\hslash</code>
\triangle	<code>\vartriangle</code>	∇	<code>\triangledown</code>
\square	<code>\square</code>	\lozenge	<code>\lozenge</code>
\textcircled{S}	<code>\circledS</code>	\sphericalangle	<code>\angle</code>
\sphericalangle	<code>\measuredangle</code>	\nexists	<code>\nexists</code>
\mho	<code>\mho</code>	\Finv	<code>\Finv</code>
\Game	<code>\Game</code>	\Bbbk	<code>\Bbbk</code>
\backprime	<code>\backprime</code>	\varnothing	<code>\varnothing</code>
\blacktriangle	<code>\blacktriangle</code>	\blacktriangledown	<code>\blacktriangledown</code>
\blacksquare	<code>\blacksquare</code>	\blacklozenge	<code>\blacklozenge</code>
\bigstar	<code>\bigstar</code>	\sphericalangle	<code>\sphericalangle</code>
\complement	<code>\complement</code>	\eth	<code>\eth</code>
\diagup	<code>\diagup</code>	\diagdown	<code>\diagdown</code>

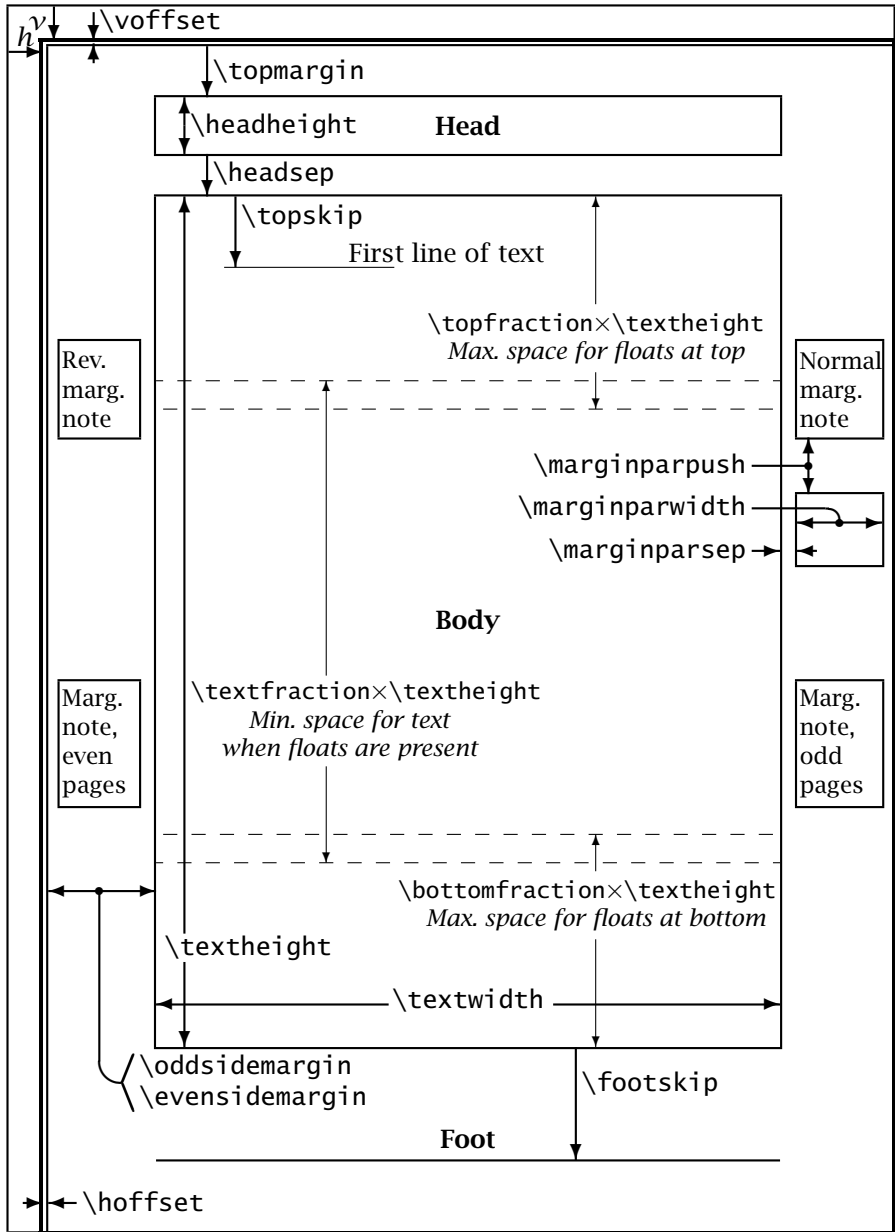


Figure H.1 Single column page format
 (3.2.5), p. 48 - (4.10.6), p. 118 - (7.3), p. 172.

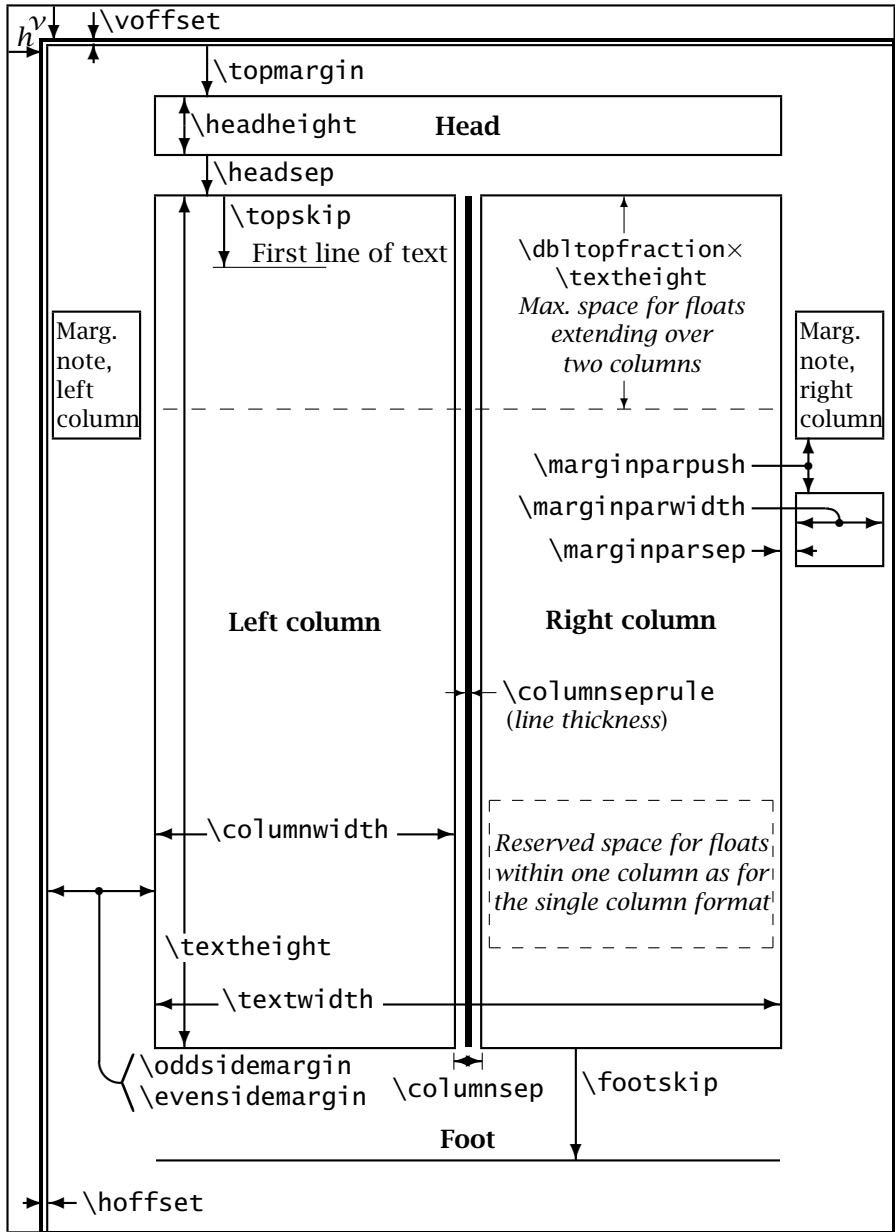


Figure H.2 Double column page format
 (3.2.5), p. 48 - (3.1.1), p. 40 - (4.10.6), p. 118 - (7.3), p. 172.

Remarks on the page format figures

The reference margins in the \LaTeX processing are shifted from the *logical* margins by the amounts \hoffset and \voffset . These in turn are displaced from the *physical* margins by h and v in the DVI driver. The default values for \hoffset and \voffset are 0 pt, so that the reference margins are equal to the *logical* ones. The usual values for h and v are 1 inch. Thus the logical page margins on the left and at the top are shifted 1 inch from the physical edge of the paper. The user may alter this by changing the values of \hoffset and \voffset .

$\text{\LaTeX} 2_{\epsilon}$ recognizes the parameters \paperwidth and \paperheight which contain the full dimensions of the paper, including the 1 inch margins. These are set by the paper size option to the class specification.

The parameter \footeight was specified but never used in $\text{\LaTeX} 2.09$; it has been dropped from $\text{\LaTeX} 2_{\epsilon}$.

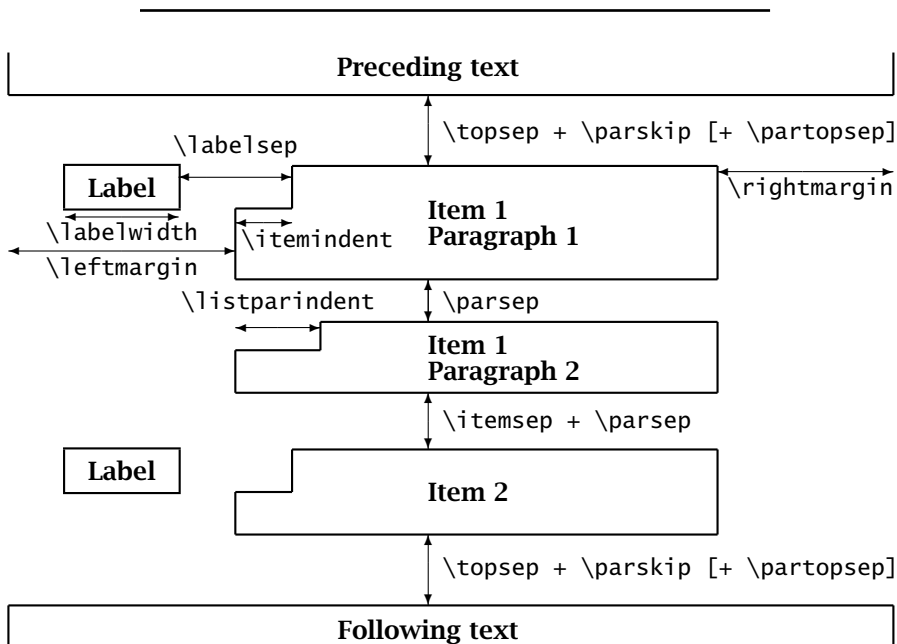


Figure H.3 Format of the list environment (4.4.2) – p. 75.

Note 1: The default values for the three parameters \itemindent , \listparindent , \rightmargin are 0 pt.

Note 2: The default values in the `trivlist` environment are 0 pt for \itemindent , \leftmargin , \rightmargin , and \labelwidth ; on the other hand, \parsep and \listparindent are assigned the respective values of \parskip and \parindent .

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Index

For purposes of alphabetization, the backslash character `\` is ignored at the start of an entry. Otherwise, the ordering is by the ASCII sequence.

Bold page numbers indicate the place where the command or concept is introduced, explained, or defined. Slanted page numbers refer to the Command Summary, Appendix H.

The keyword index is set up with main and two sub-entries. If a keyword cannot be found as a main entry, one should try to find it as a sub-entry to some more general term. Such major topics are

AMS-L^AT_EX, bibliographic database, bibliography, box, command, command (user-defined), cross-reference, error messages, exercises, file types, float, fonts, footnote, formula, hyphenation, L^AT_EX, L^AT_EX counters, letter, line breaking, lists, package, page breaking, page formatting, page numbering, page style, picture, PostScript, programming, sectioning, seminar, slides, spacing, style parameter, symbols, tabbing, table, table examples, T_EX, text.

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