LaTeX2e: An unofficial reference manual

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puszcza.gnu.org.ua/software/latexrefman

This document is an unofficial reference manual for LaTeX, a document preparation system, version of July 2018.

This manual was originally translated from `LATEX.HLP` v1.0a in the VMS Help Library. The pre-translation version was written by George D. Greenwade of Sam Houston State University. The LaTeX 2.09 version was written by Stephen Gilmore. The LaTeX2e version was adapted from this by Torsten Martinsen. Karl Berry made further updates and additions, and gratefully acknowledges using *Hypertext Help with LaTeX*, by Sheldon Green, and *LaTeX Command Summary* (for LaTeX 2.09) by L. Botway and C. Biemesderfer (published by the TeX Users Group as *TeXniques* number 10), as reference material (no text was directly copied).

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1 About this document

This is an unofficial reference manual for the LaTeX2e document preparation system, which is a macro package for the TeX typesetting program (see Chapter 2 [Overview], page 3). This document's home page is `puszcza.gnu.org.ua/software/latexrefman`. That page has links to the current output in various formats, sources, mailing list archives and subscriptions, and other infrastructure.

In this document, we will mostly just use 'LaTeX' rather than 'LaTeX2e', since the previous version of LaTeX (2.09) was frozen decades ago.

LaTeX is currently maintained by a group of volunteers (`http://latex-project.org`). The official documentation written by the LaTeX project is available from their web site. This document is completely unofficial and has not been reviewed by the LaTeX maintainers. Do not send bug reports or anything else about this document to them. Instead, please send all comments to `latexrefman@tug.org`.

This document is a reference. There is a vast array of other sources of information about LaTeX, at all levels. Here are a few introductions.

`http://ctan.org/pkg/latex-doc-ptr`
: Two pages of recommended references to LaTeX documentation.

`http://ctan.org/pkg/first-latex-doc`
: Writing your first document, with a bit of both text and math.

`http://ctan.org/pkg/usrguide`
: The guide for document authors that is maintained as part of LaTeX. Many other guides by many other people are also available, independent of LaTeX itself; one such is the next item:

`http://ctan.org/pkg/lshort`
: A short introduction to LaTeX, translated to many languages.

`http://tug.org/begin.html`
: Introduction to the TeX system, including LaTeX, with further references.

2 Overview of LaTeX

LaTeX is a system for typesetting documents. It was originally created by Leslie Lamport and is now maintained by a group of volunteers (`http://latex-project.org`). It is widely used, particularly for complex and technical documents, such as those involving mathematics.

A LaTeX user writes an input file containing text along with interspersed commands, for instance commands describing how the text should be formatted. It is implemented as a set of related commands that interface with Donald E. Knuth's TeX typesetting program (the technical term is that LaTeX is a *macro package* for the TeX engine). The user produces the output document by giving that input file to the TeX engine.

The term LaTeX is also sometimes used to mean the language in which the document is marked up, that is, to mean the set of commands available to a LaTeX user.

The name LaTeX is short for "Lamport TeX". It is pronounced LAH-teck or LAY-teck, or sometimes LAY-tecks. Inside a document, produce the logo with `\LaTeX`. Where use of the logo is not sensible, such as in plain text, write it as '`LaTeX`'.

2.1 Starting and ending

LaTeX files have a simple global structure, with a standard beginning and ending. This is a small example.

```
\documentclass{article}
\begin{document}
Hello, \LaTeX\ world.
\end{document}
```

Every LaTeX document has a `\begin{document}` line and an `\end{document}` line.

Here, the '`article`' is the *document class*. It is implemented in a file `article.cls`. You can use any document class on your system. A few document classes are defined by LaTeX itself, and vast array of others are widely available. See Chapter 3 [Document classes], page 9.

You can include other LaTeX commands between the `\documentclass` and the `\begin{document}` commands. This area is called the *preamble*.

The `\begin{document}`, `\end{document}` pair defines an *environment*; the '`document`' environment (and no others) is required in all LaTeX documents (see Section 8.6 [document], page 51). LaTeX make available to you many environments that are documented here (see Chapter 8 [Environments], page 46). Many more are available to you from external packages, most importantly those available at CTAN (see Section 2.5 [CTAN], page 8).

The following sections discuss how to produce PDF or other output from a LaTeX input file.

2.2 Output files

LaTeX produces a main output file and at least two auxiliary files. The main output file's name ends in either `.dvi` or `.pdf`.

`.dvi` If LaTeX is invoked with the system command `latex` then it produces a DeVice Independent file, with extension `.dvi`. You can view this file with a command

such as `xdvi`, or convert it to a PostScript `.ps` file with `dvips` or to a Portable Document Format `.pdf` file with `dvipdfmx`. The contents of the file can be dumped in human-readable form with `dvitype`. A vast array of other DVI utility programs are available (`http://mirror.ctan.org/dviware`).

`.pdf` If LaTeX is invoked via the system command `pdflatex`, among other commands (see Section 2.3 [TeX engines], page 4), then the main output is a Portable Document Format (PDF) file. Typically this is a self-contained file, with all fonts and images included.

LaTeX also produces at least two additional files.

`.log` This transcript file contains summary information such as a list of loaded packages. It also includes diagnostic messages and perhaps additional information for any errors.

`.aux` Auxiliary information is used by LaTeX for things such as cross references. For example, the first time that LaTeX finds a forward reference—a cross reference to something that has not yet appeared in the source—it will appear in the output as a doubled question mark `??`. When the referred-to spot does eventually appear in the source then LaTeX writes its location information to this `.aux` file. On the next invocation, LaTeX reads the location information from this file and uses it to resolve the reference, replacing the double question mark with the remembered location.

LaTeX may produce yet more files, characterized by the filename ending. These include a `.lof` file that is used to make a list of figures, a `.lot` file used to make a list of tables, and a `.toc` file used to make a table of contents (see Section 25.1 [Table of contents etc.], page 200). A particular class may create others; the list is open-ended.

2.3 TeX engines

LaTeX is defined to be a set of commands that are run by a TeX implementation (see Chapter 2 [Overview], page 3). This section gives a terse overview of the main programs (see also Chapter 28 [Command line], page 218).

`latex`

`pdflatex` In TeX Live (`http://tug.org/texlive`), if LaTeX is invoked via either the system command `latex` or `pdflatex`, then the pdfTeX engine is run (`http://ctan.org/pkg/pdftex`). When invoked as `latex`, the main output is a `.dvi` file; as `pdflatex`, the main output is a `.pdf` file.

pdfTeX incorporates the e-TeX extensions to Knuth's original program (`http://ctan.org/pkg/etex`), including additional programming features and bi-directional typesetting, and has plenty of extensions of its own. e-TeX is available on its own as the system command `etex`, but this is plain TeX (and produces `.dvi`).

In other TeX distributions, `latex` may invoke e-TeX rather than pdfTeX. In any case, the e-TeX extensions can be assumed to be available in LaTeX.

`lualatex` If LaTeX is invoked via the system command `lualatex`, the LuaTeX engine is run (`http://ctan.org/pkg/luatex`). This program allows code written

in the scripting language Lua (`http://luatex.org`) to interact with TeX's typesetting. LuaTeX handles UTF-8 Unicode input natively, can handle OpenType and TrueType fonts, and produces a `.pdf` file by default. There is also `dvilualatex` to produce a `.dvi` file, but this is rarely used.

`xelatex` If LaTeX is invoked with the system command `xelatex`, the XeTeX engine is run (`http://tug.org/xetex`). Like LuaTeX, XeTeX natively supports UTF-8 Unicode and TrueType and OpenType fonts, though the implementation is completely different, mainly using external libraries instead of internal code. XeTeX produces a `.pdf` file as output; it does not support DVI output.

Internally, XeTeX creates an `.xdv` file, a variant of DVI, and translates that to PDF using the (`x`)`dvipdfmx` program, but this process is automatic. The `.xdv` file is only useful for debugging.

Other variants of LaTeX and TeX exist, e.g., to provide additional support for Japanese and other languages ([u]pTeX, `http://ctan.org/pkg/ptex`, `http://ctan.org/pkg/uptex`).

2.4 LaTeX command syntax

In the LaTeX input file, a command name starts with a backslash character, `\`. The name itself then consists of either (a) a string of letters or (b) a single non-letter.

LaTeX commands names are case sensitive so that `\pagebreak` differs from `\Pagebreak` (the latter is not a standard command). Most commands are lowercase, but in any event you must enter all commands in the same case as they are defined.

A command may be followed by zero, one, or more arguments. These arguments may be either required or optional. Required arguments are contained in curly braces, `{...}`. Optional arguments are contained in square brackets, `[...]`. Generally, but not universally, if the command accepts an optional argument, it comes first, before any required arguments.

Inside of an optional argument, to use the character close square bracket (`]`) hide it inside curly braces, as in `\item[closing bracket {]}]`. Similarly, if an optional argument comes last, with no required argument after it, then to make the first character of the following text be an open square bracket, hide it inside curly braces.

LaTeX has the convention that some commands have a `*` form that is related to the form without a `*`, such as `\chapter` and `\chapter*`. The exact difference in behavior varies from command to command.

This manual describes all accepted options and `*`-forms for the commands it covers (barring unintentional omissions, a.k.a. bugs).

2.4.1 Environments

Synopsis:

```
\begin{environment name}
  ...
\end{environment name}
```

An area of LaTeX source, inside of which there is a distinct behavior. For instance, for poetry in LaTeX put the lines between `\begin{verse}` and `\end{verse}`.

```
\begin{verse}
```

```
  There once was a man from Nantucket \\
  ...
\end{verse}
```

See Chapter 8 [Environments], page 46, for a list of environments.

The *environment name* at the beginning must exactly match that at the end. This includes the case where *environment name* ends in a star (`*`); both the `\begin` and `\end` texts must include the star.

Environments may have arguments, including optional arguments. This example produces a table. The first argument is optional (and causes the table to be aligned on its top row) while the second argument is required (it specifies the formatting of columns).

```
\begin{tabular}[t]{r|l}
  ... rows of table ...
\end{tabular}
```

2.4.2 Command declarations

A command that changes the value, or changes the meaning, of some other command or parameter. For instance, the `\mainmatter` command changes the setting of page numbers from roman numerals to arabic.

2.4.3 `\makeatletter` & `\makeatother`

Synopsis:

```
\makeatletter
  ... definition of commands with @ in their name ..
\makeatother
```

Used to redefine internal LaTeX commands. `\makeatletter` makes the at-sign character `@` have the category code of a letter, 11. `\makeatother` sets the category code of `@` to 12, its original value.

As each character is read by TeX for LaTeX, it is assigned a character category code, or *catcode* for short. For instance, the backslash `\` is assigned the catcode 0, for characters that start a command. These two commands alter the catcode assigned to `@`.

The alteration is needed because many of LaTeX's commands use `@` in their name, to prevent users from accidentally defining a command that replaces one of LaTeX's own. Command names consist of a category 0 character, ordinarily backslash, followed by letters, category 11 characters (except that a command name can also consist of a category 0 character followed by a single non-letter symbol). So under the default category codes, user-defined commands cannot contain an `@`. But `\makeatletter` and `\makeatother` allow users to define or redefine commands named with `@`.

Use these two commands inside a `.tex` file, in the preamble, when defining or redefining a command with `@` in its name. Don't use them inside `.sty` or `.cls` files since the `\usepackage` and `\documentclass` commands set the at sign to have the character code of a letter.

For a comprehensive list of macros with an at-sign in their names see `http://ctan.org/pkg/macros2e`. These macros are mainly intended to package or class authors.

In this example the class file has a command `\thesis@universityname` that the user wants to change. These three lines should go in the preamble, before the `\begin{document}`.

```
\makeatletter
```

```
\renewcommand{\thesis@universityname}{Saint Michael's College}
\makeatother
```

2.4.3.1 \@ifstar

Synopsis:

```
\newcommand{\mycmd}{\@ifstar{\mycmd@star}{\mycmd@nostar}}
\newcommand{\mycmd@nostar}[nostar-num-args]{nostar-body}
\newcommand{\mycmd@star}[star-num-args]{star-body}
```

Many standard LaTeX environments or commands have a variant with the same name but ending with a star character `*`, an asterisk. Examples are the `table` and `table*` environments and the `\section` and `\section*` commands.

When defining environments, following this pattern is straightforward because `\newenvironment` and `\renewenvironment` allow the environment name to contain a star. For commands the situation is more complex. As in the synopsis above, there will be a user-called command, given above as `\mycmd`, which peeks ahead to see if it is followed by a star. For instance, LaTeX does not really have a `\section*` command; instead, the `\section` command peeks ahead. This command does not accept arguments but instead expands to one of two commands that do accept arguments. In the synopsis these two are `\mycmd@nostar` and `\mycmd@star`. They could take the same number of arguments or a different number, or no arguments at all. As always, in a LaTeX document a command using at-sign `@` must be enclosed inside a `\makeatletter ... \makeatother` block (see Section 2.4.3 [\makeatletter & \makeatother], page 6).

This example of `\@ifstar` defines the command `\ciel` and a variant `\ciel*`. Both have one required argument. A call to `\ciel{night}` will return "starry night sky" while `\ciel*{blue}` will return "starry not blue sky".

```
\newcommand*{\ciel@unstarred}[1]{starry #1 sky}
\newcommand*{\ciel@starred}[1]{starry not #1 sky}
\newcommand*{\ciel}{\@ifstar{\ciel@starred}{\ciel@unstarred}}
```

In the next example, the starred variant takes a different number of arguments than the unstarred one. With this definition, Agent 007's ``My name is \agentsecret*{Bond}, \agentsecret{James}{Bond}.'' is equivalent to entering the commands ``My name is \textsc{Bond}, \textit{James} textsc{Bond}.''

```
\newcommand*{\agentsecret@unstarred}[2]{\textit{#1} \textsc{#2}}
\newcommand*{\agentsecret@starred}[1]{\textsc{#1}}
\newcommand*{\agentsecret}{%
  \@ifstar{\agentsecret@starred}{\agentsecret@unstarred}}
```

There are two sometimes more convenient ways to accomplish the work of `\@ifstar`. The `suffix` package allows the construct `\newcommand\mycommand{unstarred version}` followed by `\WithSuffix\newcommand\mycommand*{starred version}`. And LaTeX3 has the `xparse` package that allows this code.

```
\NewDocumentCommand\foo{s}{\IfBooleanTF#1
  {starred version}%
  {unstarred version}%
  }
```

2.5 CTAN: Comprehensive TeX Archive Network

The Comprehensive TeX Archive Network, CTAN, is the TeX and LaTeX community's repository of free material. It is a set of Internet sites around the world that offer material related to LaTeX for download. Visit CTAN on the web at `https://ctan.org`.

This material is organized into packages, discrete bundles that typically offer some coherent functionality and are maintained by one person or a small number of people. For instance, many publishers have a package that allows authors to format papers to that publisher's specifications.

In addition to the massive holdings, the web site offers features such as search by name or by functionality.

CTAN is not a single site, but instead is a set of sites. One of the sites is the core. This site actively manages the material, for instance, by accepting uploads of new or updated packages. It is hosted by the German TeX group DANTE e.V. Other sites around the world help out by mirroring, that is, automatically syncing their collections with the core site and then in turn making their copies publicly available. This gives users close to their location better access and relieves the load on the core site. The list of mirrors is at `https://ctan.org/mirrors`.

3 Document classes

The document's overall class is defined with this command, which is normally the first command in a LaTeX source file.

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

The following document *class* names are built into LaTeX. (Many other document classes are available as separate packages; see Chapter 2 [Overview], page 3.)

`article` For a journal article, a presentation, and miscellaneous general use.

`book` Full-length books, including chapters and possibly including front matter, such as a preface, and back matter, such as an appendix (see Chapter 25 [Front/back matter], page 200).

`letter` Mail, optionally including mailing labels (see Chapter 26 [Letters], page 211).

`report` For documents of length between an `article` and a `book`, such as technical reports or theses, which may contain several chapters.

`slides` For slide presentations—rarely used today. In its place the `beamer` package is perhaps the most prevalent (see Section A.1 [beamer template], page 222).

Standard *options* are described in the next section.

3.1 Document class options

You can specify *global options* or *class options* to the `\documentclass` command by enclosing them in square brackets. To specify more than one *option*, separate them with a comma.

```
\documentclass[option1,option2,...]{class}
```

Here is the list of the standard class options.

All of the standard classes except `slides` accept the following options for selecting the typeface size (default is `10pt`):

```
10pt  11pt  12pt
```

All of the standard classes accept these options for selecting the paper size (these show height by width):

`a4paper` 210 by 297 mm (about 8.25 by 11.75 inches)

`a5paper` 148 by 210 mm (about 5.8 by 8.3 inches)

`b5paper` 176 by 250 mm (about 6.9 by 9.8 inches)

`executivepaper`
: 7.25 by 10.5 inches

`legalpaper`
: 8.5 by 14 inches

`letterpaper`
: 8.5 by 11 inches (the default)

When using one of the engines pdfLaTeX, LuaLaTeX, or XeLaTeX (see Section 2.3 [TeX engines], page 4), options other than `letterpaper` set the print area but you must also set the physical paper size. One way to do that is to put `\pdfpagewidth=\paperwidth` and `\pdfpageheight=\paperheight` in your document's preamble. The `geometry` package provides flexible ways of setting the print area and physical page size.

Miscellaneous other options:

`draft`
`final` Mark (`draft`) or do not mark (`final`) overfull boxes with a black box in the margin; default is `final`.

`fleqn` Put displayed formulas flush left; default is centered.

`landscape`
Selects landscape format; default is portrait.

`leqno` Put equation numbers on the left side of equations; default is the right side.

`openbib` Use "open" bibliography format.

`titlepage`
`notitlepage`
Specifies whether there is a separate page for the title information and for the abstract also, if there is one. The default for the `report` class is `titlepage`, for the other classes it is `notitlepage`.

The following options are not available with the `slides` class.

`onecolumn`
`twocolumn`
Typeset in one or two columns; default is `onecolumn`.

`oneside`
`twoside` Selects one- or two-sided layout; default is `oneside`, except that in the `book` class the default is `twoside`.

For one-sided printing, the text is centered on the page. For two-sided printing, the `\evensidemargin` (`\oddsidemargin`) parameter determines the distance on even (odd) numbered pages between the left side of the page and the text's left margin, with `\oddsidemargin` being 40% of the difference between `\paperwidth` and `\textwidth`, and `\evensidemargin` is the remainder.

`openright`
`openany` Determines if a chapter should start on a right-hand page; default is `openright` for `book`, and `openany` for `report`.

The `slides` class offers the option `clock` for printing the time at the bottom of each note.

3.2 Additional packages

Load a package *pkg*, with the package options given in the comma-separated list *options*, as here.

```
\usepackage[options]{pkg}.
```

To specify more than one package you can separate them with a comma, as in `\usepackage{pkg1,pkg2,...}`, or use multiple `\usepackage` commands.

Any options given in the `\documentclass` command that are unknown to the selected document class are passed on to the packages loaded with `\usepackage`.

3.3 Class and package construction

You can create new document classes and new packages. For instance, if your memos must satisfy some local requirements, such as a standard header for each page, then you could create a new class `smcmemo.cls` and begin your documents with `\documentclass{smcmemo}`.

What separates a package from a document class is that the commands in a package are useful across classes while those in a document class are specific to that class. Thus, a command to set page headers is for a package while a command to make the page headers say `Memo from the SMC Math Department` is for a class.

Inside of a class or package file you can use the at-sign `@` as a character in command names without having to surround the code containing that command with `\makeatletter` and `\makeatother`. See Section 2.4.3 [\makeatletter & \makeatother], page 6. This allow you to create commands that users will not accidentally redefine. Another technique is to preface class- or package-specific commands with some string to prevent your class or package from interfering with others. For instance, the class `smcmemo` might have commands `\smc@tolist`, `\smc@fromlist`, etc.

3.3.1 Class and package structure

A class file or package file typically has four parts.

In the *identification part*, the file says that it is a LaTeX package or class and describes itself, using the `\NeedsTeXFormat` and `\ProvidesClass` or `\ProvidesPackage` commands.

1. The *preliminary declarations part* declares some commands and can also load other files. Usually these commands will be those needed for the code used in the next part. For example, an `smcmemo` class might be called with an option to read in a file with a list of people for the to-head, as `\documentclass[mathto]{smcmemo}`, and therefore needs to define a command `\newcommand{\setto}[1]{\def\@tolist{#1}}` used in that file.
2. In the *handle options part* the class or package declares and processes its options. Class options allow a user to start their document as `\documentclass[option list]{class name}`, to modify the behavior of the class. An example is when you declare `\documentclass[11pt]{article}` to set the default document font size.
3. Finally, in the *more declarations part* the class or package usually does most of its work: declaring new variables, commands and fonts, and loading other files.

Here is a starting class file, which should be saved as `stub.cls` where LaTeX can find it, for example in the same directory as the `.tex` file.

```
\NeedsTeXFormat{LaTeX2e}
\ProvidesClass{stub}[2017/07/06 stub to start building classes from]
\DeclareOption*{\PassOptionsToClass{\CurrentOption}{article}}
\ProcessOptions\relax
\LoadClass{article}
```

It identifies itself, handles the class options via the default of passing them all to the `article` class, and then loads the `article` class to provide the basis for this class's code.

For more, see the official guide for class and package writers, the Class Guide, at `http://www.latex-project.org/help/documentation/clsguide.pdf` (much of the descriptions here derive from this document), or the tutorial `https://www.tug.org/TUGboat/tb26-3/tb84heff.pdf`.

3.3.2 Class and package commands

These are the commands designed to help writers of classes or packages.

`\AtBeginDvi{specials}`

Save in a box register things that are written to the `.dvi` file at the beginning of the shipout of the first page of the document.

`\AtEndOfClass{`*code*`}`
`\AtEndOfPackage{`*code*`}`

Hook to insert *code* to be executed when LaTeX finishes processing the current class or package. You can use these hooks multiple times; the `code` will be executed in the order that you called it. See also Section 8.6.1 [\AtBeginDocument], page 51.

`\CheckCommand{`*cmd*`}[`*num*`][`*default*`]{`*definition*`}`
`\CheckCommand*{`*cmd*`}[`*num*`][`*default*`]{`*definition*`}`

Like `\newcommand` (see Section 12.1 [\newcommand & \renewcommand], page 105) but does not define *cmd*; instead it checks that the current definition of *cmd* is exactly as given by *definition* and is or is not *long* as expected. A long command is a command that accepts `\par` within an argument. The *cmd* command is expected to be long with the unstarred version of `\CheckCommand`. Raises an error when the check fails. This allows you to check before you start redefining `cmd` yourself that no other package has already redefined this command.

`\ClassError{`*class name*`}{`*error text*`}{`*help text*`}`
`\PackageError{`*package name*`}{`*error text*`}{`*help text*`}`
`\ClassWarning{`*class name*`}{`*warning text*`}`
`\PackageWarning{`*package name*`}{`*warning text*`}`
`\ClassWarningNoLine{`*class name*`}{`*warning text*`}`
`\PackageWarningNoLine{`*package name*`}{`*warning text*`}`
`\ClassInfo{`*class name*`}{`*info text*`}`
`\PackageInfo{`*package name*`}{`*info text*`}`
`\ClassInfoNoLine{`*class name*`}{`*info text*`}`
`\PackageInfoNoLine{`*package name*`}{`*info text*`}`

Produce an error message, or warning or informational messages.

For `\ClassError` and `\PackageError` the message is *error text*, followed by TeX's `?` error prompt. If the user then asks for help by typing `h`, they see the *help text*.

The four warning commands are similar except that they write *warning text* on the screen with no error prompt. The four info commands write *info text*

only in the transcript file. The `NoLine` versions do not show the number of the line generating the message, while the other versions do show that number.

To format the messages, including the *help text*: use `\protect` to stop a command from expanding, get a line break with `\MessageBreak`, and get a space with `\space` when a space character does not allow it, like after a command. Note that LaTeX appends a period to the messages.

`\CurrentOption`

Expands to the name of the currently-being-processed option. Can only be used within the *code* argument of either `\DeclareOption` or `\DeclareOption*`.

`\DeclareOption{`*option*`}{`*code*`}`
`\DeclareOption*{`*code*`}`

Make an option available to a user to invoke in their `\documentclass` command. For example, the `smcmemo` class could have an option `\documentclass[logo]{smcmemo}` allowing users to put the institutional logo on the first page. The class file must contain `\DeclareOption{logo}{`*code*`}` (and later, `\ProcessOptions`).

If you request an option that has not been declared, by default this will produce a warning like `Unused global option(s): [badoption].` Change this behaviour with the starred version `\DeclareOption*{`*code*`}`. For example, many classes extend an existing class, using a declaration such as `\LoadClass{article}`, and for passing extra options to the underlying class use code such as this.

```
\DeclareOption*{%
\PassOptionsToClass{\CurrentOption}{article}%
}
```

Another example is that the class `smcmemo` may allow users to keep lists of memo recipients in external files. Then the user could invoke `\documentclass[math]{smcmemo}` and it will read the file `math.memo`. This code handles the file if it exists and otherwise passes the option to the `article` class.

```
\DeclareOption*{\InputIfFileExists{\CurrentOption.memo}{}{%
    \PassOptionsToClass{\CurrentOption}{article}}}
```

`\DeclareRobustCommand{`*cmd*`}[`*num*`][`*default*`]{`*definition*`}`
`\DeclareRobustCommand*{`*cmd*`}[`*num*`][`*default*`]{`*definition*`}`

Like `\newcommand` and `\newcommand*` (see Section 12.1 [\newcommand & \renewcommand], page 105) but these declare a robust command, even if some code within the *definition* is fragile. (For a discussion of robust and fragile commands see Section 12.9 [\protect], page 113.) Use this command to define new robust commands or to redefine existing commands and make them robust. Unlike `\newcommand` these do not give an error if macro *cmd* already exists; instead, a log message is put into the transcript file if a command is redefined.

Commands defined this way are a bit less efficient than those defined using `\newcommand` so unless the command's data is fragile and the command is used within a moving argument, use `\newcommand`.

The `etoolbox` package offers the commands `\newrobustcmd`, `\newrobustcmd*`, as well as the commands `\renewrobustcmd`, `\renewrobustcmd*`, and the commands `\providerobustcmd`, and `\providerobustcmd*`. These are similar to `\newcommand`, `\newcommand*`, `\renewcommand`, `\renewcommand*`, `\providecommand`, and `\providecommand*`, but define a robust *cmd* with two advantages as compared to `\DeclareRobustCommand`:

1. They use the low-level e-TEX protection mechanism rather than the higher level LATEX `\protect` mechanism, so they do not incur the slight loss of performance mentioned above, and
2. They make the same distinction between `\new...`, `\renew...`, and `\provide...`, as the standard commands, so they do not just make a log message when you redefine *cmd* that already exists, in that case you need to use either `\renew...` or `\provide...` or you get an error.

`\IfFileExists{`*file name*`}{`*true code*`}{`*false code*`}`
`\InputIfFileExists{`*file name*`}{`*true code*`}{`*false code*`}`

Execute *true code* if LATEX finds the file *file name* or *false code* otherwise. In the first case it executing *true code* and then inputs the file. Thus the command

```
\IfFileExists{img.pdf}{%
  \includegraphics{img.pdf}}{\typeout{!! img.pdf not found}
```

will include the graphic `img.pdf` if it is found and otherwise give a warning.

This command looks for the file in all search paths that LATEX uses, not only in the current directory. To look only in the current directory do something like `\IfFileExists{./filename}{`*true code*`}{`*false code*`}`. If you ask for a filename without a `.tex` extension then LATEX will first look for the file by appending the `.tex`; for more on how LATEX handles file extensions see Section 24.3 [\input], page 199.

`\LoadClass[`*options list*`]{`*class name*`}[`*release date*`]`
`\LoadClassWithOptions{`*class name*`}[`*release date*`]`

Load a class, as with `\documentclass[`*options list*`]{`*class name*`}[`*release info*`]`. An example is `\LoadClass[twoside]{article}`.

The *options list*, if present, is a comma-separated list. The *release date* is optional. If present it must have the form *YYYY/MM/DD*.

If you request a *release date* and the date of the package installed on your system is earlier, then you get a warning on the screen and in the log like this.

```
You have requested, on input line 4, version ‘2038/01/19’ of
document class article, but only version ‘2014/09/29 v1.4h
Standard LaTeX document class’ is available.
```

The command version `\LoadClassWithOptions` uses the list of options for the current class. This means it ignores any options passed to it via `\PassOptionsToClass`. This is a convenience command that lets you build classes on existing ones, such as the standard `article` class, without having to track which options were passed.

`\ExecuteOptions{`*options-list*`}`

For each option *option* in the *options-list*, in order, this command executes the command `\ds@`*option*. If this command is not defined then that option is silently ignored.

It can be used to provide a default option list before `\ProcessOptions`. For example, if in a class file you want the default to be 11pt fonts then you could specify `\ExecuteOptions{11pt}\ProcessOptions\relax`.

`\NeedsTeXFormat{`*format*`}[`*format date*`]`

Specifies the format that this class must be run under. Often issued as the first line of a class file, and most often used as: `\NeedsTeXFormat{LaTeX2e}`. When a document using that class is processed, the format name given here must match the format that is actually being run (including that the *format* string is case sensitive). If it does not match then execution stops with an error like '`This file needs format 'LaTeX2e' but this is 'xxx'.`'

To specify a version of the format that you know to have certain features, include the optional *format date* on which those features were implemented. If present it must be in the form `YYYY/MM/DD`. If the format version installed on your system is earlier than *format date* then you get a warning like this.

```
You have requested release '2038/01/20' of LaTeX, but only
release '2016/02/01' is available.
```

`\OptionNotUsed`

Adds the current option to the list of unused options. Can only be used within the *code* argument of either `\DeclareOption` or `\DeclareOption*`.

`\PassOptionsToClass{`*option list*`}{`*class name*`}`
`\PassOptionsToPackage{`*option list*`}{`*package name*`}`

Adds the options in the comma-separated list *option list* to the options used by any future `\RequirePackage` or `\usepackage` command for package *package name* or the class *class name*.

The reason for these commands is: you may load a package any number of times with no options but if you want options then you may only supply them when you first load the package. Loading a package with options more than once will get you an error like `Option clash for package foo.` (LaTeX throws an error even if there is no conflict between the options.)

If your own code is bringing in a package twice then you can collapse that to once, for example replacing the two `\RequirePackage[landscape]{geometry}` and `\RequirePackage[margins=1in]{geometry}` with the single command `\RequirePackage[landscape,margins=1in]{geometry}`.

However, imagine that you are loading `firstpkg` and inside that package it loads `secondpkg`, and you need the second package to be loaded with option `draft`. Then before doing the first package you must queue up the options for the second package, like this.

```
\PassOptionsToPackage{draft}{secondpkg}
\RequirePackage{firstpkg}
```

(If `firstpkg.sty` loads an option in conflict with what you want then you may have to alter its source.)

These commands are useful for general users as well as class and package writers. For instance, suppose a user wants to load the `graphicx` package with the option `draft` and also wants to use a class `foo` that loads the `graphicx` package, but without that option. The user could start their LaTeX file with `\PassOptionsToPackage{draft}{graphicx}\documentclass{foo}`.

`\ProcessOptions`
`\ProcessOptions*\@options`

Execute the code for each option that the user has invoked. Include it in the class file as `\ProcessOptions\relax` (because of the existence of the starred command).

Options come in two types. *Local options* have been specified for this particular package in the *options* argument of `\PassOptionsToPackage{options}`, `\usepackage[options]`, or `\RequirePackage[options]`. *Global options* are those given by the class user in `\documentclass[options]` (If an option is specified both locally and globally then it is local.)

When `\ProcessOptions` is called for a package `pkg.sty`, the following happens:

1. For each option *option* so far declared with `\DeclareOption`, it looks to see if that option is either a global or a local option for `pkg`. If so then it executes the declared code. This is done in the order in which these options were given in `pkg.sty`.
2. For each remaining local option, it executes the command `\ds@option` if it has been defined somewhere (other than by a `\DeclareOption`); otherwise, it executes the default option code given in `\DeclareOption*`. If no default option code has been declared then it gives an error message. This is done in the order in which these options were specified.

When `\ProcessOptions` is called for a class it works in the same way except that all options are local, and the default *code* for `\DeclareOption*` is `\OptionNotUsed` rather than an error.

The starred version `\ProcessOptions*` executes the options in the order specified in the calling commands, rather than in the order of declaration in the class or package. For a package this means that the global options are processed first.

`\ProvidesClass{class name}[release date brief additional information]`
`\ProvidesClass{class name}[release date]`
`\ProvidesPackage{package name}[release date brief additional information]`
`\ProvidesPackage{package name}[release date]`

Identifies the class or package, printing a message to the screen and the log file.

When you load a class or package, for example with `\documentclass{smcmemo}` or `\usepackage{test}`, LaTeX inputs a file. If the name of the file does not match the class or package name declared in it then you get a warning. Thus, if you invoke `\documentclass{smcmemo}`, and the file `smcmemo.cls` has the statement `\ProvidesClass{xxx}` then you get a warning like `You have requested document class ‘smcmemo’, but the document class provides ’xxx’.` This

warning does not prevent LaTeX from processing the rest of the class file normally.

If you include the optional argument then you must include a date, before any spaces, of the form `YYYY/MM/DD`. The rest of the optional argument is free-form, although it traditionally identifies the class, and is written to the screen during compilation and to the log file. Thus, if your file `smcmemo.cls` contains the line `\ProvidesClass{smcmemo}[2008/06/01 v1.0 SMC memo class]` and your document's first line is `\documentclass{smcmemo}` then you will see `Document Class: smcmemo 2008/06/01 v1.0 SMC memo class`.

The date in the optional argument allows class and package users to ask to be warned if the version of the class or package is earlier than *release date*. For instance, a user could enter `\documentclass{smcmemo}[2018/10/12]` or `\usepackage{foo}[[2017/07/07]]` to require a class or package with certain features by specifying that it must be released no earlier than the given date. (Although, in practice package users only rarely include a date, and class users almost never do.)

`\ProvidesFile{`*file name*`}[`*additional information*`]`

Declare a file other than the main class and package files, such as configuration files or font definition files. Put this command in that file and you get in the log a string like `File: test.config 2017/10/12 config file for test.cls` for *file name* equal to '`test.config`' and *additional information* equal to '`2017/10/12 config file for test.cls`'.

`\RequirePackage[`*option list*`]{`*package name*`}[`*release date*`]`
`\RequirePackageWithOptions{`*package name*`}[`*release date*`]`

Load a package, like the command `\usepackage` (see Section 3.2 [Additional packages], page 10). The LaTeX development team strongly recommends use of these commands over Plain TeX's `\input`; see the Class Guide. An example is `\RequirePackage[landscape,margin=1in]{geometry}`.

The *option list*, if present, is a comma-separated list. The *release date*, if present, must have the form *YYYY/MM/DD*. If the release date of the package as installed on your system is earlier than *release date* then you get a warning like `You have requested, on input line 9, version '2017/07/03' of package jhtest, but only version '2000/01/01' is available`.

The `\RequirePackageWithOptions` version uses the list of options for the current class. This means it ignores any options passed to it via `\PassOptionsToClass`. This is a convenience command to allow easily building classes on existing ones without having to track which options were passed.

The difference between `\usepackage` and `\RequirePackage` is small. The `\usepackage` command is intended for the document file while `\RequirePackage` is intended for package and class files. Thus, using `\usepackage` before the `\documentclass` command causes LaTeX to give error like `\usepackage before \documentclass`, but you can use `\RequirePackage` there.

4 Fonts

Two important aspects of selecting a *font* are specifying a size and a style. The LaTeX commands for doing this are described here.

4.1 Font styles

The following type style commands are supported by LaTeX.

In the table below the listed commands, the `\text...` commands, is used with an argument, as in `\textit{`*text*`}`. This is the preferred form. But shown after it, in parenthesis, is the corresponding declaration form, which is sometimes useful. This form takes no arguments, as in `{\itshape` *text*`}`. The scope of the declaration form lasts until the next type style command or the end of the current group. In addition, each has an environment form such as `\begin{itshape}...\end{itshape}`.

These commands, in both the argument form and the declaration form, are cumulative; for instance you can get bold sans serif by saying either of `\sffamily\bfseries` or `\bfseries\sffamily`.

One advantage of these commands is that they automatically insert italic corrections if needed (see Section 19.9 [\/], page 160). Specifically, they insert the italic correction unless the following character is in the list `\nocorrlist`, which by default consists of a period and a comma. To suppress the automatic insertion of italic correction, use `\nocorr` at the start or end of the command argument, such as `\textit{\nocorr text}` or `\textsc{text \nocorr}`.

`\textrm (\rmfamily)`
: Roman.

`\textit (\itshape)`
: Italics.

`\textmd (\mdseries)`
: Medium weight (default).

`\textbf (\bfseries)`
: Boldface.

`\textup (\upshape)`
: Upright (default).

`\textsl (\slshape)`
: Slanted.

`\textsf (\sffamily)`
: Sans serif.

`\textsc (\scshape)`
: Small caps.

`\texttt (\ttfamily)`
: Typewriter.

`\textnormal (\normalfont)`
: Main document font.

Although it also changes fonts, the `\emph{`*`text`*`}` command is semantic, for text to be emphasized, and should not be used as a substitute for `\textit`. For example, `\emph{`*`start text `*`\emph{`*`middle text`*`} `*`end text`*`}` will result in the *start text* and *end text* in italics, but *middle text* will be in roman.

LaTeX also provides the following commands, which unconditionally switch to the given style, that is, are *not* cumulative. They are used as declarations: `{\`*`cmd`*`...}` instead of `\`*`cmd`*`{...}`.

(The unconditional commands below are an older version of font switching. The earlier commands are an improvement in most circumstances. But sometimes an unconditional font switch is precisely what you want.)

`\bf` Switch to bold face.

`\cal` Switch to calligraphic letters for math.

`\it` Italics.

`\rm` Roman.

`\sc` Small caps.

`\sf` Sans serif.

`\sl` Slanted (oblique).

`\tt` Typewriter (monospace, fixed-width).

The `\em` command is the unconditional version of `\emph`.

The following commands are for use in math mode. They are not cumulative, so `\mathbf{\mathit{`*`symbol`*`}}` does not create a boldface and italic *symbol*; instead, it will just be in italics. This is because typically math symbols need consistent typographic treatment, regardless of the surrounding environment.

`\mathrm` Roman, for use in math mode.

`\mathbf` Boldface, for use in math mode.

`\mathsf` Sans serif, for use in math mode.

`\mathtt` Typewriter, for use in math mode.

`\mathit`
`(\mit)` Italics, for use in math mode.

`\mathnormal`
For use in math mode, e.g., inside another type style declaration.

`\mathcal` Calligraphic letters, for use in math mode.

In addition, the command `\mathversion{bold}` can be used for switching to bold letters and symbols in formulas. `\mathversion{normal}` restores the default.

Finally, the command `\oldstylenums{`*`numerals`*`}` will typeset so-called "old-style" numerals, which have differing heights and depths (and sometimes widths) from the standard "lining" numerals, which all have the same height as uppercase letters. LaTeX's default fonts support this, and will respect `\textbf` (but not other styles; there are no italic old-style numerals in Computer Modern). Many other fonts have old-style numerals also; sometimes the `textcomp` package must be loaded, and sometimes package options are provided to make them the default. FAQ entry: `http://www.tex.ac.uk/cgi-bin/texfaq2html?label=osf`.

4.2 Font sizes

The following standard type size commands are supported by LaTeX. The table shows the command name and the corresponding actual font size used (in points) with the '`10pt`', '`11pt`', and '`12pt`' document size options, respectively (see Section 3.1 [Document class options], page 9).

Command	`10pt`	`11pt`	`12pt`
`\tiny`	5	6	6
`\scriptsize`	7	8	8
`\footnotesize`	8	9	10
`\small`	9	10	10.95
`\normalsize` (default)	10	10.95	12
`\large`	12	12	14.4
`\Large`	14.4	14.4	17.28
`\LARGE`	17.28	17.28	20.74
`\huge`	20.74	20.74	24.88
`\Huge`	24.88	24.88	24.88

The commands are listed here in declaration forms. You use them by declaring them, as with this example.

```
\begin{quotation} \small
  The Tao that can be named is not the eternal Tao.
\end{quotation}
```

The scope of the `\small` lasts until the end of the `quotation` environment. It would also end at the next type style command or the end of the current group, so you could enclose it in extra curly braces `{\small We are here, we are here, we are here!}`. You can instead use the environment form of these commands; for instance, `\begin{tiny}...\end{tiny}`.

4.3 Low-level font commands

These commands are primarily intended for writers of macros and packages. The commands listed here are only a subset of the available ones.

`\fontencoding{`*encoding*`}`

Select the font encoding, the encoding of the output font. There are a large number of valid encodings. The most common are `OT1`, Knuth's original encoding for Computer Modern (the default), and `T1`, also known as the Cork encoding, which has support for the accented characters used by the most widespread European languages (German, French, Italian, Polish and others), which allows TeX to hyphenate words containing accented letters. For more, see `https://ctan.org/pkg/encguide`.

`\fontfamily{`*family*`}`

Select the font family. The web page `http://www.tug.dk/FontCatalogue/` provides one way to browse through many of the fonts easily used with LaTeX. Here are examples of some common families.

`pag` Avant Garde
`fvs` Bitstream Vera Sans

`pbk` Bookman
`bch` Charter
`ccr` Computer Concrete
`cmr` Computer Modern
`cmss` Computer Modern Sans Serif
`cmtt` Computer Modern Typewriter
`pcr` Courier
`phv` Helvetica
`fi4` Inconsolata
`lmr` Latin Modern
`lmss` Latin Modern Sans
`lmtt` Latin Modern Typewriter
`pnc` New Century Schoolbook
`ppl` Palatino
`ptm` Times
`uncl` Uncial
`put` Utopia
`pzc` Zapf Chancery

`\fontseries{`*`series`*`}`

Select the font series. A *series* combines a *weight* and a *width*. Typically, a font supports only a few of the possible combinations. Some common combined series values include:

`m` Medium (normal)
`b` Bold
`c` Condensed
`bc` Bold condensed
`bx` Bold extended

The possible values for weight, individually, are:

`ul` Ultra light
`el` Extra light
`l` Light
`sl` Semi light
`m` Medium (normal)
`sb` Semi bold
`b` Bold
`eb` Extra bold
`ub` Ultra bold

The possible values for width, individually, are (the meaning and relationship of these terms varies with individual typefaces):

`uc` Ultra condensed
`ec` Extra condensed
`c` Condensed
`sc` Semi condensed
`m` Medium
`sx` Semi expanded

`x` Expanded
`ex` Extra expanded
`ux` Ultra expanded

When forming the *series* string from the weight and width, drop the `m` that stands for medium weight or medium width, unless both weight and width are `m`, in which case use just one ('`m`').

`\fontshape{`*`shape`*`}`

Select font shape. Valid shapes are:

`n` Upright (normal)
`it` Italic
`sl` Slanted (oblique)
`sc` Small caps
`ui` Upright italics
`ol` Outline

The two last shapes are not available for most font families, and small caps are often missing as well.

`\fontsize{`*`size`*`}{`*`skip`*`}`

Set the font size and the line spacing. The unit of both parameters defaults to points (`pt`). The line spacing is the nominal vertical space between lines, baseline to baseline. It is stored in the parameter `\baselineskip`. The default `\baselineskip` for the Computer Modern typeface is 1.2 times the `\fontsize`. Changing `\baselineskip` directly is inadvisable since its value is reset every time a size change happens; see `\baselinestretch`, next.

`\baselinestretch`

LaTeX multiplies the line spacing by the value of the `\baselinestretch` parameter; the default factor is 1. A change takes effect when `\selectfont` (see below) is called. You can make a line skip change happen for the entire document, for instance doubling it, by doing `\renewcommand{\baselinestretch}{2.0}` in the preamble.

However, the best way to double-space a document is to use the `setspace` package. In addition to offering a number of spacing options, this package keeps the line spacing single-spaced in places where that is typically desirable, such as footnotes and figure captions. See the package documentation.

`\linespread{`*`factor`*`}`

Equivalent to `\renewcommand{\baselinestretch}{`*`factor`*`}`, and therefore must be followed by `\selectfont` to have any effect. Best specified in the preamble, or use the `setspace` package, as just described.

`\selectfont`

The effects of the font commands described above do not happen until `\selectfont` is called, as in `\fontfamily{`*`familyname`*`}\selectfont`. It is often useful to put this in a macro:
`\newcommand*{\myfont}{\fontfamily{`*`familyname`*`}\selectfont}`
(see Section 12.1 [\newcommand & \renewcommand], page 105).

`\usefont{`*`enc`*`}{`*`family`*`}{`*`series`*`}{`*`shape`*`}`

The same as invoking `\fontencoding`, `\fontfamily`, `\fontseries` and `\fontshape` with the given parameters, followed by `\selectfont`. For example:

```
\usefont{ot1}{cmr}{m}{n}
```

5 Layout

Commands for controlling the general page layout.

5.1 \onecolumn

Synopsis:

```
\onecolumn
```

Start a new page and produce single-column output. If the document is given the class option `onecolumn` then this is the default behavior (see Section 3.1 [Document class options], page 9). This command is fragile (see Section 12.9 [\protect], page 113).

5.2 \twocolumn

Synopses:

```
\twocolumn
\twocolumn[prelim one column text]
```

Start a new page and produce two-column output. If the document is given the class option `twocolumn` then this is the default (see Section 3.1 [Document class options], page 9). This command is fragile (see Section 12.9 [\protect], page 113).

If the optional *prelim one column text* argument is present, it is typeset in one-column mode before the two-column typesetting starts.

These parameters control typesetting in two-column output:

`\columnsep`
: The distance between columns. The default is 35pt. Change it with a command such as `\setlength{\columnsep}{40pt}` You must change it before the two column environment starts; in the preamble is a good place.

`\columnseprule`
: The width of the rule between columns. The rule appears halfway between the two columns. The default is 0pt, meaning that there is no rule. Change it with a command such as `\setlength{\columnseprule}{0.4pt}`, before the two-column environment starts.

`\columnwidth`
: The width of a single column. In one-column mode this is equal to `\textwidth`. In two-column mode by default LaTeX sets the width of each of the two columns to be half of `\textwidth` minus `\columnsep`.

In a two-column document, the starred environments `table*` and `figure*` are two columns wide, whereas the unstarred environments `table` and `figure` take up only one column (see Section 8.10 [figure], page 54, and see Section 8.22 [table], page 78). LaTeX places starred floats at the top of a page. The following parameters control float behavior of two-column output.

`\dbltopfraction`
: The maximum fraction at the top of a two-column page that may be occupied by two-column wide floats. The default is 0.7, meaning that the height of a

`table*` or `figure*` environment must not exceed `0.7\textheight` . If the height of your starred float environment exceeds this then you can take one of the following actions to prevent it from floating all the way to the back of the document:

- Use the `[tp]` location specifier to tell LaTeX to try to put the bulky float on a page by itself, as well as at the top of a page.
- Use the `[t!]` location specifier to override the effect of `\dbltopfraction` for this particular float.
- Increase the value of `\dbltopfraction` to a suitably large number, to avoid going to float pages so soon.

You can redefine it, as with `\renewcommand{\dbltopfraction}{0.9}`.

`\dblfloatpagefraction`
: For a float page of two-column wide floats, this is the minimum fraction that must be occupied by floats, limiting the amount of blank space. LaTeX's default is `0.5`. Change it with `\renewcommand`.

`\dblfloatsep`
: On a float page of two-column wide floats, this length is the distance between floats, at both the top and bottom of the page. The default is `12pt plus2pt minus2pt` for a document set at `10pt` or `11pt`, and `14pt plus2pt minus4pt` for a document set at `12pt`.

`\dbltextfloatsep`
: This length is the distance between a multi-column float at the top or bottom of a page and the main text. The default is `20pt plus2pt minus4pt`.

`\dbltopnumber`
: On a float page of two-column wide floats, this counter gives the maximum number of floats allowed at the top of the page. The LaTeX default is `2`.

This example uses `\twocolumn`'s optional argument of to create a title that spans the two-column article:

```
\documentclass[twocolumn]{article}
\newcommand{\authormark}[1]{\textsuperscript{#1}}
\begin{document}
\twocolumn[{% inside this optional argument goes one-column text
  \centering
  \LARGE The Title \\[1.5em]
  \large Author One\authormark{1},
         Author Two\authormark{2},
         Author Three\authormark{1} \\[1em]
  \normalsize
  \begin{tabular}{p{.2\textwidth}@{\hspace{2em}}p{.2\textwidth}}
    \authormark{1}Department one  &\authormark{2}Department two \\
     School one                   &School two
  \end{tabular}\\[3em] % space below title part
  }]
```

```
Two column text here.
```

5.3 \flushbottom

Make all pages in the documents after this declaration have the same height, by stretching the vertical space where necessary to fill out the page. This is most often used when making two-sided documents since the differences in facing pages can be glaring.

If TEX cannot satisfactorily stretch the vertical space in a page then you get a message like '`Underfull \vbox (badness 10000) has occurred while \output is active`'. If you get that, one option is to change to `\raggedbottom` (see Section 5.4 [\raggedbottom], page 26). Alternatively, you can adjust the `textheight` to make compatible pages, or you can add some vertical stretch glue between lines or between paragraphs, as in `\setlength{\parskip}{0ex plus0.1ex}`. Your last option is to, in a final editing stage, adjust the height of individual pages (see Section 10.3 [\enlargethispage], page 98).

The `\flushbottom` state is the default only if you select the `twoside` document class option (see Section 3.1 [Document class options], page 9).

5.4 \raggedbottom

Make all later pages the natural height of the material on that page; no rubber vertical lengths will be stretched. Thus, in a two-sided document the facing pages may be different heights. This command can go at any point in the document body. See Section 5.3 [\flushbottom], page 26.

This is the default unless you select the `twoside` document class option (see Section 3.1 [Document class options], page 9).

5.5 Page layout parameters

`\columnsep`
`\columnseprule`
`\columnwidth`
: The distance between the two columns, the width of a rule between the columns, and the width of the columns, when the document class option `twocolumn` is in effect (see Section 3.1 [Document class options], page 9). See Section 5.2 [\twocolumn], page 24.

`\headheight`
: Height of the box that contains the running head. The default in the `article`, `report`, and `book` classes is '`12pt`', at all type sizes.

`\headsep`
: Vertical distance between the bottom of the header line and the top of the main text. The default in the `article` and `report` classes is '`25pt`'. In the `book` class the default is: if the document is set at 10pt then it is '`0.25in`', and at 11pt and 12pt it is '`0.275in`'.

`\footskip`
: Distance from the baseline of the last line of text to the baseline of the page footer. The default in the `article` and `report` classes is '`30pt`'. In the `book`

class the default is: when the type size is 10pt the default is '`0.35in`', while at 11pt it is '`0.38in`', and at 12pt it is '`30pt`'.

`\linewidth`
: Width of the current line, decreased for each nested `list` (see Section 8.16 [list], page 59). That is, the nominal value for `\linewidth` is to equal `\textwidth` but for each nested list the `\linewidth` is decreased by the sum of that list's `\leftmargin` and `\rightmargin` (see Section 8.14 [itemize], page 57).

`\marginparpush`
`\marginsep`
`\marginparwidth`
: The minimum vertical space between two marginal notes, the horizontal space between the text body and the marginal notes, and the horizontal width of the notes.

  Normally marginal notes appear on the outside of the page, but the declaration `\reversemarginpar` changes that (and `\normalmarginpar` changes it back).

  The defaults for `\marginparpush` in both `book` and `article` classes are: '`7pt`' if the document is set at 12pt, and '`5pt`' if the document is set at 11pt or 10pt.

  For `\marginsep`, in `article` class the default is '`10pt`' except if the document is set at 10pt and in two-column mode where the default is '`11pt`'.

  For `\marginsep` in `book` class the default is '`10pt`' in two-column mode and '`7pt`' in one-column mode.

  For `\marginparwidth` in both `book` and `article` classes, in two-column mode the default is 60% of `\paperwidth` − `\textwidth`, while in one-column mode it is 50% of that distance.

`\oddsidemargin`
`\evensidemargin`
: The `\oddsidemargin` is the extra distance between the left side of the page and the text's left margin, on odd-numbered pages when the document class option `twoside` is chosen and on all pages when `oneside` is in effect. When `twoside` is in effect, on even-numbered pages the extra distance on the left is `evensidemargin`.

  LaTeX's default is that `\oddsidemargin` is 40% of the difference between `\paperwidth` and `\textwidth`, and `\evensidemargin` is the remainder.

`\paperheight`
: The height of the paper, as distinct from the height of the print area. Normally set with a document class option, as in `\documentclass[a4paper]{article}` (see Section 3.1 [Document class options], page 9).

`\paperwidth`
: The width of the paper, as distinct from the width of the print area. Normally set with a document class option, as in `\documentclass[a4paper]{article}` (see Section 3.1 [Document class options], page 9).

`\textheight`
: The normal vertical height of the page body. If the document is set at a nominal type size of 10pt then for an `article` or `report` the default is

'43\baselineskip', while for a book it is '41\baselineskip'. At a type size of 11pt the default is '38\baselineskip' for all document classes. At 12pt it is '36\baselineskip' for all classes.

\textwidth
: The full horizontal width of the entire page body. For an article or report document, the default is '345pt' when the chosen type size is 10pt, the default is '360pt' at 11pt, and it is '390pt' at 12pt. For a book document, the default is '4.5in' at a type size of 10pt, and '5in' at 11pt or 12pt.

  In multi-column output, \textwidth remains the width of the entire page body, while \columnwidth is the width of one column (see Section 5.2 [\twocolumn], page 24).

  In lists (see Section 8.16 [list], page 59), \textwidth remains the width of the entire page body (and \columnwidth the width of the entire column), while \linewidth may decrease for nested lists.

  Inside a minipage (see Section 8.18 [minipage], page 65) or \parbox (see Section 20.3 [\parbox], page 169), all the width-related parameters are set to the specified width, and revert to their normal values at the end of the minipage or \parbox.

\hsize
: This entry is included for completeness: \hsize is the TEX primitive parameter used when text is broken into lines. It should not be used in normal LATEX documents.

\topmargin
: Space between the top of the TEX page (one inch from the top of the paper, by default) and the top of the header. The value is computed based on many other parameters: \paperheight − 2in − \headheight − \headsep − \textheight − \footskip, and then divided by two.

\topskip
: Minimum distance between the top of the page body and the baseline of the first line of text. For the standard classes, the default is the same as the font size, e.g., '10pt' at a type size of 10pt.

5.6 Floats

Some typographic elements, such as figures and tables, cannot be broken across pages. They must be typeset outside of the normal flow of text, for instance floating to the top of a later page.

LATEX can have a number of different classes of floating material. The default is the two classes, figure (see Section 8.10 [figure], page 54) and table (see Section 8.22 [table], page 78), but you can create a new class with the package float.

Within any one float class LATEX always respects the order, so that the first figure in a document source must be typeset before the second figure. However, LATEX may mix the classes, so it can happen that while the first table appears in the source before the first figure, it appears in the output after it.

The placement of floats is subject to parameters, given below, that limit the number of floats that can appear at the top of a page, and the bottom, etc. If so many floats are

queued that the limits prevent them all from fitting on a page then LaTeX places what it can and defers the rest to the next page. In this way, floats may end up being typeset far from their place in the source. In particular, a float that is big may migrate to the end of the document. In which event, because all floats in a class must appear in sequential order, every following float in that class also appears at the end.

In addition to changing the parameters, for each float you can tweak where the float placement algorithm tries to place it by using its *placement* argument. The possible values are a sequence of the letters below. The default for both `figure` and `table`, in both `article` and `book` classes, is `tbp`.

`t` (Top)—at the top of a text page.

`b` (Bottom)—at the bottom of a text page. (However, `b` is not allowed for full-width floats (`figure*`) with double-column output. To ameliorate this, use the `stfloats` or `dblfloatfix` package, but see the discussion at caveats in the FAQ: `http://www.tex.ac.uk/cgi-bin/texfaq2html?label=2colfloat`.

`h` (Here)—at the position in the text where the `figure` environment appears. However, `h` is not allowed by itself; `t` is automatically added.

To absolutely force a float to appear "here", you can `\usepackage{float}` and use the `H` specifier which it defines. For further discussion, see the FAQ entry at `http://www.tex.ac.uk/cgi-bin/texfaq2html?label=figurehere`.

`p` (Page of floats)—on a separate *float page*, which is a page containing no text, only floats.

`!` Used in addition to one of the above; for this float only, LaTeX ignores the restrictions on both the number of floats that can appear and the relative amounts of float and non-float text on the page. The `!` specifier does *not* mean "put the float here"; see above.

Note: the order in which letters appear in the *placement* argument does not change the order in which LaTeX tries to place the float; for instance, `btp` has the same effect as `tbp`. All that *placement* does is that if a letter is not present then the algorithm does not try that location. Thus, LaTeX's default of `tbp` is to try every location except placing the float where it occurs in the source.

To prevent LaTeX from moving floats to the end of the document or a chapter you can use a `\clearpage` command to start a new page and insert all pending floats. If a pagebreak is undesirable then you can use the `afterpage` package and issue `\afterpage{\clearpage}`. This will wait until the current page is finished and then flush all outstanding floats.

LaTeX can typeset a float before where it appears in the source (although on the same output page) if there is a `t` specifier in the *placement* parameter. If this is not desired, and deleting the `t` is not acceptable as it keeps the float from being placed at the top of the next page, then you can prevent it by either using the `flafter` package or using the command `\suppressfloats[t]`, which causes floats for the top position on this page to moved to the next page.

Parameters relating to fractions of pages occupied by float and non-float text (change them with `\renewcommand{`*`parameter`*`}{`*`decimal between 0 and 1`*`}`):

`\bottomfraction`
: The maximum fraction of the page allowed to be occupied by floats at the bottom; default '`.3`'.

`\floatpagefraction`
: The minimum fraction of a float page that must be occupied by floats; default '`.5`'.

`\textfraction`
: Minimum fraction of a page that must be text; if floats take up too much space to preserve this much text, floats will be moved to a different page. The default is '`.2`'.

`\topfraction`
: Maximum fraction at the top of a page that may be occupied before floats; default '`.7`'.

Parameters relating to vertical space around floats (change them with a command of the form `\setlength{`*`parameter`*`}{`*`length expression`*`}`):

`\floatsep`
: Space between floats at the top or bottom of a page; default '`12pt plus2pt minus2pt`'.

`\intextsep`
: Space above and below a float in the middle of the main text; default '`12pt plus2pt minus2pt`' for 10 point and 11 point documents, and '`14pt plus4pt minus4pt`' for 12 point documents.

`\textfloatsep`
: Space between the last (first) float at the top (bottom) of a page; default '`20pt plus2pt minus4pt`'.

Counters relating to the number of floats on a page (change them with a command of the form `\setcounter{`*`ctrname`*`}{`*`natural number`*`}`):

`bottomnumber`
: Maximum number of floats that can appear at the bottom of a text page; default 1.

`dbltopnumber`
: Maximum number of full-sized floats that can appear at the top of a two-column page; default 2.

`topnumber`
: Maximum number of floats that can appear at the top of a text page; default 2.

`totalnumber`
: Maximum number of floats that can appear on a text page; default 3.

The principal TEX FAQ entry relating to floats `http://www.tex.ac.uk/cgi-bin/texfaq2html?label=floats` contains suggestions for relaxing LATEX's default parameters to reduce the problem of floats being pushed to the end. A full explanation of the float

placement algorithm is in Frank Mittelbach's article "How to influence the position of float environments like figure and table in LaTeX?" (`http://latex-project.org/papers/tb111mitt-float.pdf`).

6 Sectioning

Structure your text into divisions: parts, chapters, sections, etc. All sectioning commands have the same form, one of:

```
sectioning-command{title}
sectioning-command*{title}
sectioning-command[toc-title]{title}
```

For instance, declare the start of a subsection as with `\subsection{Motivation}`.

The table has each *sectioning-command* in LaTeX. All are available in all of LaTeX's standard document classes `book`, `report`, and `article`, except that `\chapter` is not available in `article`.

Sectioning unit	**Command**	**Level**
Part	`\part`	-1 (`book`, `report`), 0 (`article`)
Chapter	`\chapter`	0
Section	`\section`	1
Subsection	`\subsection`	2
Subsubsection	`\subsubsection`	3
Paragraph	`\paragraph`	4
Subparagraph	`\subparagraph`	5

All these commands have a `*`-form that prints *title* as usual but is not numbered and does not make an entry in the table of contents. An example of using this is for an appendix in an `article` . The input `\appendix\section{Appendix}` gives the output '`A Appendix`' (see Section 6.6 [\appendix], page 38). You can lose the numbering '`A`' by instead entering `\section*{Appendix}` (articles often omit a table of contents and have simple page headers so the other differences from the `\section` command may not matter).

The section title *title* provides the heading in the main text, but it may also appear in the table of contents and in the running head or foot (see Chapter 18 [Page styles], page 151). You may not want the same text in these places as in the main text. All of these commands have an optional argument *toc-title* for these other places.

The level number in the table above determines which sectional units are numbered, and which appear in the table of contents. If the sectioning command's *level* is less than or equal to the value of the counter `secnumdepth` then the titles for this sectioning command will be numbered (see [Sectioning/secnumdepth], page 32). And, if *level* is less than or equal to the value of the counter `tocdepth` then the table of contents will have an entry for this sectioning unit (see [Sectioning/tocdepth], page 33).

LaTeX expects that before you have a `\subsection` you will have a `\section` and, in a book, that before a `\section` you will have a `\chapter`. Otherwise you can get a something like a subsection numbered '`3.0.1`'.

Two counters relate to the appearance of sectioning commands.

`secnumdepth`
: Controls which sectioning commands are numbered. Suppress numbering of sectioning at any depth greater than *level* `\setcounter{secnumdepth}{`*level*`}` (see Section 13.4 [\setcounter], page 118). See the above table for the

level numbers. For instance, if the `secnumdepth` is 1 in an `article` then a `\section{Introduction}` command will produce output like '`1 Introduction`' while `\subsection{Discussion}` will produce output like '`Discussion`', without the number. LaTeX's default `secnumdepth` is 3 in `article` class and 2 in the `book` and `report` classes.

`tocdepth` Controls which sectioning units are listed in the table of contents. The setting `\setcounter{tocdepth}{`*level*`}` makes the sectioning units at *level* be the smallest ones listed (see Section 13.4 [\setcounter], page 118). See the above table for the level numbers. For instance, if `tocdepth` is 1 then the table of contents will list sections but not subsections. LaTeX's default `secnumdepth` is 3 in `article` class and 2 in the `book` and `report` classes.

6.1 \part

Synopsis, one of:

```
\part{title}
\part*{title}
\part[toc-title]{title}
```

Start a document part. The standard LaTeX classes `book`, `report`, and `article`, all have this command.

This produces a document part, in a book.

```
\part{VOLUME I \\
      PERSONAL MEMOIRS OF  U.\ S.\ GRANT}
\chapter{ANCESTRY--BIRTH--BOYHOOD.}
My family is American, and has been for generations,
in all its branches, direct and collateral.
```

In each standard class the `\part` command outputs a part number such as '`Part I`', alone on its line, in boldface, and in large type. Then LaTeX outputs *title*, also alone on its line, in bold and in even larger type. In class `book`, the LaTeX default puts each part alone on its own page. If the book is two-sided then LaTeX will skip a page if needed to have the new part on an odd-numbered page. In `report` it is again alone on a page, but LaTeX won't force it onto an odd-numbered page. In an `article` LaTeX does not put it on a fresh page, but instead outputs the part number and part title onto the main document page.

The `*` form shows *title* but it does not show the part number, does not increment the `part` counter, and produces no table of contents entry.

The optional argument *toc-title* will appear as the part title in the table of contents (see Section 25.1 [Table of contents etc.], page 200) and in running headers (see Chapter 18 [Page styles], page 151). If it is not present then *title* will be there. This example puts a line break in *title* but leaves out the break in the table of contents.

```
\part[Up from the bottom; my life]{Up from the bottom\\ my life}
```

For determining which sectional units are numbered and which appear in the table of contents, the level number of a part is -1 (see [Sectioning/secnumdepth], page 32, and see [Sectioning/tocdepth], page 33).

In the class `article`, if a paragraph immediately follows the part title then it is not indented. To get an indent you can use the package `indentfirst`.

One package to change the behavior of `\part` is `titlesec`. See its documentation on CTAN.

6.2 \chapter

Synopsis, one of:

```
\chapter{title}
\chapter*{title}
\chapter[toc-title]{title}
```

Start a chapter. The standard LaTeX classes `book` and `report` have this command but `article` does not.

This produces a chapter.

```
\chapter{Loomings}
Call me Ishmael.
Some years ago---never mind how long precisely---having little or no
money in my purse, and nothing particular to interest me on shore, I
thought I would sail about a little and see the watery part of
the world.
```

The LaTeX default starts each chapter on a fresh page, an odd-numbered page if the document is two-sided. It produces a chapter number such as '`Chapter 1`' in large boldface type (the size is `\huge`). It then puts *title* on a fresh line, in boldface type that is still larger (size `\Huge`). It also increments the `chapter` counter, adds an entry to the table of contents (see Section 25.1 [Table of contents etc.], page 200), and sets the running header information (see Chapter 18 [Page styles], page 151).

The `*` form shows *title* on a fresh line, in boldface. But it does not show the chapter number, does not increment the `chapter` counter, produces no table of contents entry, and does not affect the running header. (If you use the page style `headings` in a two-sided document then the header will be from the prior chapter.) This example illustrates.

```
\chapter*{Preamble}
```

The optional argument *toc-title* will appear as the chapter title in the table of contents (see Section 25.1 [Table of contents etc.], page 200) and in running headers (see Chapter 18 [Page styles], page 151). If it is not present then *title* will be there. This shows the full name in the chapter title,

```
\chapter[Weyl]{Hermann Klaus Hugo (Peter) Weyl (1885--1955)}
```

but only '`Weyl`' on the contents page. This puts a line break in the title but that doesn't work well with running headers so it omits the break in the contents

```
\chapter[Given it all\\ my story]{Given it all\\ my story}
```

For determining which sectional units are numbered and which appear in the table of contents, the level number of a chapter is 0 (see [Sectioning/secnumdepth], page 32, and see [Sectioning/tocdepth], page 33).

The paragraph that follows the chapter title is not indented, as is a standard typographical practice. To get an indent use the package `indentfirst`.

You can change what is shown for the chapter number. To change it to something like '`Lecture 1`', put in the preamble either `\renewcommand{\chaptername}{Lecture}` or this (see Section 2.4.3 [\makeatletter & \makeatother], page 6).

```
\makeatletter
\renewcommand{\@chapapp}{Lecture}
\makeatother
```

To make this change because of the primary language for the document, see the package `babel`.

In a two-sided document LaTeX puts a chapter on odd-numbered page, if necessary leaving an even-numbered page that is blank except for any running headers. To make that page completely blank, see Section 10.1 [\clearpage & \cleardoublepage], page 97.

To change the behavior of the `\chapter` command, you can copy its definition from the LaTeX format file and make adjustments. But there are also many packages on CTAN that address this. One is `titlesec`. See its documentation, but the example below gives a sense of what it can do.

```
\usepackage{titlesec}   % in preamble
\titleformat{\chapter}
  {\Huge\bfseries}  % format of title
  {}                % label, such as 1.2 for a subsection
  {0pt}             % length of separation between label and title
  {}                % before-code hook
```

This omits the chapter number '`Chapter 1`' from the page but unlike `\chapter*` it keeps the chapter in the table of contents and the running headers.

6.3 \section

Synopsis, one of:

```
\section{title}
\section*{title}
\section[toc-title]{title}
```

Start a section. The standard LaTeX classes `article`, `book`, and `report` all have this command.

This produces a section.

```
In this Part we tend to be more interested in the function,
in the input-output behavior,
than in the details of implementing that behavior.

\section{Turing machines}
Despite this desire to downplay implementation,
we follow the approach of A~Turing that the
first step toward defining the set of computable functions
is to reflect on the details of what mechanisms can do.
```

For the standard LaTeX classes `book` and `report` the default output is like '`1.2 title`' (for chapter 1, section 2), alone on its line and flush left, in boldface and a larger type (the

type size is `\Large`). The same holds in `article` except that there are no chapters in that class so it looks like '2 *title*'.

The `*` form shows *title*. But it does not show the section number, does not increment the `section` counter, produces no table of contents entry, and does not affect the running header. (If you use the page style `headings` in a two-sided document then the header will be from the prior section.)

The optional argument *toc-title* will appear as the section title in the table of contents (see Section 25.1 [Table of contents etc.], page 200) and in running headers (see Chapter 18 [Page styles], page 151). If it is not present then *title* will be there. This shows the full name in the title of the section,

```
\section[Elizabeth~II]{Elizabeth the Second,
  by the Grace of God of the United Kingdom,
  Canada and Her other Realms and Territories Queen,
  Head of the Commonwealth, Defender of the Faith.}
```

but only '`Elizabeth II`' on the contents page and in the headers. This has a line break in *title* but that does not work with headers so it is omitted from the contents and headers.

```
\section[Truth is, I cheated; my life story]{Truth is,
  I cheated\\my life story}
```

For determining which sectional units are numbered and which appear in the table of contents, the level number of a section is 1 (see [Sectioning/secnumdepth], page 32, and see [Sectioning/tocdepth], page 33).

The paragraph that follows the section title is not indented, as is a standard typographical practice. One way to get an indent is to use the package `indentfirst`.

In general, to change the behavior of the `\section` command, there are a number of options. One is the `\@startsection` command (see Section 6.8 [\@startsection], page 39). There are also many packages on CTAN that address this, including `titlesec`. See the documentation but the example below gives a sense of what they can do.

```
\usepackage{titlesec}   % in preamble
\titleformat{\section}
  {\normalfont\Large\bfseries}  % format of title
  {\makebox[1pc][r]{\thesection\hspace{1pc}}} % label
  {0pt}                   % length of separation between label and title
  {}                      % before-code hook
\titlespacing*{\section}
  {-1pc}{18pt}{10pt}[10pc]
```

That puts the section number in the margin.

6.4 \subsection

Synopsis, one of:

```
\subsection{title}
\subsection*{title}
\subsection[toc-title]{title}
```

Start a subsection. The standard LaTeX classes `article`, `book`, and `report` all have this command.

This produces a subsection.

```
We will show that there are more functions than Turing machines and that
therefore some functions have no associated machine.

\subsection{Cardinality} We will begin with two paradoxes that
dramatize the challenge to our intuition posed by comparing the sizes of
infinite sets.
```

For the standard LaTeX classes `book` and `report` the default output is like '`1.2.3` *`title`*' (for chapter 1, section 2, subsection 3), alone on its line and flush left, in boldface and a larger type (the type size is `\large`). The same holds in `article` except that there are no chapters in that class so it looks like '`2.3` *`title`*'.

The `*` form shows *title*. But it does not show the section number, does not increment the `section` counter, and produces no table of contents entry.

The optional argument *toc-title* will appear as the section title in the table of contents (see Section 25.1 [Table of contents etc.], page 200). If it is not present then *title* will be there. This shows the full name in the title of the section,

```
\subsection[$\alpha,\beta,\gamma$ paper]{\textit{The Origin of
  Chemical Elements} by R.A.~Alpher, H.~Bethe, and G.~Gamow}
```

but only 'α,β,γ `paper`' on the contents page.

For determining which sectional units are numbered and which appear in the table of contents, the level number of a subsection is 2 (see [Sectioning/secnumdepth], page 32, and see [Sectioning/tocdepth], page 33).

The paragraph that follows the subsection title is not indented, as is a standard typographical practice. One way to get an indent is to use the package `indentfirst`.

There are a number of ways to change the behavior of the `\subsection` command. One is the `\@startsection` command (see Section 6.8 [\@startsection], page 39). There are also many packages on CTAN that address this, including `titlesec`. See the documentation but the example below gives a sense of what they can do.

```
\usepackage{titlesec}   % in preamble
\titleformat{\subsection}[runin]
  {\normalfont\normalsize\bfseries}  % format of the title
  {\thesubsection}                   % label
  {0.6em}                            % space between label and title
  {}                                 % before-code hook
```

That puts the subsection number and *title* in the first line of text.

6.5 \subsubsection, \paragraph, \subparagraph

Synopsis, one of:

```
\subsubsection{title}
\subsubsection*{title}
\subsubsection[toc-title]{title}
```

or one of:

```
\paragraph{title}
```

```
\paragraph*{title}
\paragraph[toc-title]{title}
```

or one of:

```
\subparagraph{title}
\subparagraph*{title}
\subparagraph[toc-title]{title}
```

Start a subsubsection, paragraph, or subparagraph. The standard LaTeX classes `article`, `book`, and `report` all have these commands, although they are not commonly used.

This produces a subsubsection.

```
\subsubsection{Piston ring compressors: structural performance}
Provide exterior/interior wall cladding assemblies
capable of withstanding the effects of load and stresses from
consumer-grade gasoline engine piston rings.
```

The default output of each of the three does not change over the standard LaTeX classes `article`, `book`, and `report`. For `\subsubsection` the *title* is alone on its line, in boldface and normal size type. For `\paragraph` the *title* is inline with the text, not indented, in boldface and normal size type. For `\subparagraph` the *title* is inline with the text, with a paragraph indent, in boldface and normal size type (Because an `article` has no chapters its subsubsections are numbered and so it looks like '`1.2.3` *title*', for section 1, subsection 2, and subsubsection 3. The other two divisions are not numbered.)

The `*` form shows *title*. But it does not increment the associated counter and produces no table of contents entry (and does not show the number for `\subsubsection`).

The optional argument *toc-title* will appear as the division title in the table of contents (see Section 25.1 [Table of contents etc.], page 200). If it is not present then *title* will be there.

For determining which sectional units are numbered and which appear in the table of contents, the level number of a subsubsection is 3, of a paragraph is 4, and of a subparagraph is 5 (see [Sectioning/secnumdepth], page 32, and see [Sectioning/tocdepth], page 33).

The paragraph that follows the subsubsection title is not indented, as is a standard typographical practice. One way to get an indent is to use the package `indentfirst`.

There are a number of ways to change the behavior of the these commands. One is the `\@startsection` command (see Section 6.8 [\@startsection], page 39). There are also many packages on CTAN that address this, including `titlesec`. See the documentation on CTAN.

6.6 \appendix

Synopsis:

```
\appendix
```

This does not directly produce any output. But in a book or report it declares that subsequent `\chapter` commands start an appendix. In an article it does the same, for `\section` commands. It also resets the `chapter` and `section` counters to 0 in a book or report, and in an article resets the `section` and `subsection` counters.

In this book

```
\chapter{One}  ...
\chapter{Two}  ...
 ...
\appendix
\chapter{Three}  ...
\chapter{Four}  ...
```

the first two will generate output numbered '`Chapter 1`' and '`Chapter 2`'. After the `\appendix` the numbering will be '`Appendix A`' and '`Appendix B`'. See Section A.4 [Larger book template], page 223, for another example.

The `appendix` package adds the command `\appendixpage` to put a separate '`Appendices`' in the document body before the first appendix, and the command `\addappheadtotoc` to do the same in the table of contents. You can reset the name '`Appendix`' with a command like `\renewcommand{\appendixname}{Specification}`, as well as a number of other features. See the documentation on CTAN.

6.7 \frontmatter, \mainmatter, \backmatter

Synopsis, one of:

```
\frontmatter
\mainmatter
\backmatter
```

Format a `book` class document differently according to which part of the document is being produced. All three commands are optional.

Traditionally, a book's front matter contains such things as the title page, an abstract, a table of contents, a preface, a list of notations, a list of figures, and a list of tables. (Some of these front matter pages, such as the title page, are traditionally not numbered.) The back matter may contain such things as a glossary, notes, a bibliography, and an index.

The `\frontmatter` declaration makes the pages numbered in lowercase roman, and makes chapters not numbered, although each chapter's title appears in the table of contents; if you use other sectioning commands here, use the `*`-version (see Chapter 6 [Sectioning], page 32). The `\mainmatter` changes the behavior back to the expected version, and resets the page number. The `\backmatter` leaves the page numbering alone but switches the chapters back to being not numbered. See Section A.4 [Larger book template], page 223, for an example using the three.

6.8 \@startsection

Synopsis:

```
\@startsection{name}{level}{indent}{beforeskip}{afterskip}{style}
```

Used to help redefine the behavior of commands that start sectioning divisions such as `\section` or `\subsection`.

Note that the `titlesec` package makes manipulation of sectioning easier. Further, while most requirements for sectioning commands can be satisfied with `\@startsection`, some cannot. For instance, in the standard LaTeX `book` and `report` classes the commands

`\chapter` and `\report` are not constructed in this way. To make such a command you may want to use the `\secdef` command.

Technically, `\@startsection` has the form

```
\@startsection{name}
  {level}
  {indent}
  {beforeskip}
  {afterskip}
  {style}*[toctitle]{title}
```

so that issuing

```
\renewcommand{\section}{\@startsection{name}
  {level}
  {indent}
  {beforeskip}
  {afterskip}
  {style}}
```

redefines `\section` to have the form `\section*[toctitle]{title}` (here too, the star `*` is optional). See Chapter 6 [Sectioning], page 32. This implies that when you write a command like `\renewcommand{section}{...}`, the `\@startsection{...}` must come last in the definition. See the examples below.

name Name of the counter used to number the sectioning header. This counter must be defined separately. Most commonly this is either `section`, `subsection`, or `paragraph`. Although in those cases the counter name is the same as the sectioning command itself, you don't have to use the same name.

Then `\the`*name* displays the title number and `\`*name*`mark` is for the page headers. See the third example below.

level An integer giving the depth of the sectioning command. See Chapter 6 [Sectioning], page 32, for the list of standard level numbers.

If *level* is less than or equal to the value of the counter `secnumdepth` then titles for this sectioning command will be numbered (see [Sectioning/secnumdepth], page 32). For instance, if `secnumdepth` is 1 in an `article` then the command `\section{Introduction}` will produce output like "1 Introduction" while `\subsection{Discussion}` will produce output like "Discussion", without the number prefix.

If *level* is less than or equal to the value of the counter *tocdepth* then the table of contents will have an entry for this sectioning unit (see [Sectioning/tocdepth], page 33). For instance, in an `article`, if *tocdepth* is 1 then the table of contents will list sections but not subsections.

indent A length giving the indentation of all of the title lines with respect to the left margin. To have the title flush with the margin use `0pt`. A negative indentation such as `-\parindent` will move the title into the left margin.

beforeskip The absolute value of this length is the amount of vertical space that is inserted before this sectioning unit's title. This space will be discarded if the sectioning

unit happens to start at the top of a fresh page. If this number is negative then the first paragraph following the header is not indented, if it is non-negative then the first paragraph is indented. (Note that the negative of `1pt plus 2pt minus 3pt` is `-1pt plus -2pt minus -3pt`.)

For example, if *beforeskip* is `-3.5ex plus -1ex minus -0.2ex` then to start the new sectioning unit, LaTeX will add about 3.5 times the height of a letter x in vertical space, and the first paragraph in the section will not be indented. Using a rubber length, with `plus` and `minus`, is good practice here since it gives LaTeX more flexibility in making up the page (see Chapter 14 [Lengths], page 120).

The full accounting of the vertical space between the baseline of the line prior to this sectioning unit's header and the baseline of the header is that it is the sum of the `\parskip` of the text font, the `\baselineskip` of the title font, and the absolute value of the *beforeskip*. This space is typically rubber so it may stretch or shrink. (If the sectioning unit starts on a fresh page so that the vertical space is discarded then the baseline of the header text will be where LaTeX would put the baseline of the first text line on that page.)

afterskip This is a length. If *afterskip* is non-negative then this is the vertical space inserted after the sectioning unit's title header. If it is negative then the title header becomes a run-in header, so that it becomes part of the next paragraph. In this case the absolute value of the length gives the horizontal space between the end of the title and the beginning of the following paragraph. (Note that the negative of `1pt plus 2pt minus 3pt` is `-1pt plus -2pt minus -3pt`.)

As with *beforeskip*, using a rubber length, with `plus` and `minus` components, is good practice here since it gives LaTeX more flexibility in putting together the page.

If `afterskip` is non-negative then the full accounting of the vertical space between the baseline of the sectioning unit's header and the baseline of the first line of the following paragraph is that it is the sum of the `\parskip` of the title font, the `\baselineskip` of the text font, and the value of *after*. That space is typically rubber so it may stretch or shrink. (Note that because the sign of `afterskip` changes the sectioning unit header's from standalone to run-in, you cannot use a negative `afterskip` to cancel part of the `\parskip`.)

style Controls the styling of the title. See the examples below. Typical commands to use here are `\centering`, `\raggedright`, `\normalfont`, `\hrule`, or `\newpage`. The last command in *style* may be one that takes one argument, such as `\MakeUppercase` or `\fbox` that takes one argument. The section title will be supplied as the argument to this command. For instance, setting *style* to `\bfseries\MakeUppercase` would produce titles that are bold and uppercase.

These are LaTeX's defaults for the first three sectioning units that are defined with `\@startsection`, for the `article`, `book`, and `report` classes. For section, the *level* is 1, the *indent* is 0 pt, the *beforeskip* is `-3.5ex plus -1ex minus -0.2ex`, the *afterskip* is `2.3ex plus 0.2ex`, and the *style* is `\normalfont\Large\bfseries`. For subsection, the *level* is 2, the *indent* is 0 pt, the *beforeskip* is `-3.25ex plus -1ex minus -0.2ex`, the *afterskip* is `1.5ex plus 0.2ex`, and the *style* is `\normalfont\large\bfseries`. For subsubsection, the *level*

is 3, the *indent* is 0 pt, the *beforeskip* is `-3.25ex plus -1ex minus -0.2ex`, the *afterskip* is `1.5ex plus 0.2ex`, and the *style* is `\normalfont\normalsize\bfseries`.

Here are examples. They go either in a package or class file or in the preamble of a LaTeX document. If you put them in the preamble they must go between a `\makeatletter` command and a `\makeatother`. (Probably the error message `You can't use ‘\spacefactor’ in vertical mode.` means that you forgot this.) See Section 2.4.3 [\makeatletter & \makeatother], page 6.

This will put section titles in large boldface type, centered. It says `\renewcommand` because LaTeX's standard classes have already defined a `\section`. For the same reason it does not define a `section` counter, or the commands `\thesection` and `\l@section`.

```
\renewcommand\section{%
  \@startsection{section}% [name], page 40
    {1}% [level], page 40
    {0pt}% [indent], page 40
    {-3.5ex plus -1ex minus -.2ex}% [beforeskip], page 40
    {2.3ex plus.2ex}% [afterskip], page 41
    {\centering\normalfont\Large\bfseries}% [style], page 41
  }
```

This will put `subsection` titles in small caps type, inline with the paragraph.

```
\renewcommand\subsection{%
  \@startsection{subsection}%  [name], page 40
    {2}% [level], page 40
    {0em}% [indent], page 40
    {-1ex plus 0.1ex minus -0.05ex}% [beforeskip], page 40
    {-1em plus 0.2em}% [afterskip], page 41
    {\scshape}% [style], page 41
  }
```

The prior examples redefined existing sectional unit title commands. This defines a new one, illustrating the needed counter and macros to display that counter.

```
\setcounter{secnumdepth}{6}% show counters this far down
\newcounter{subsubparagraph}[subparagraph]% counter for numbering
\renewcommand{\thesubsubparagraph}%               how to display
  {\thesubparagraph.\@arabic\c@subsubparagraph}%  numbering
\newcommand{\subsubparagraph}{\@startsection
                        {subsubparagraph}%
                        {6}%
                        {0em}%
                        {\baselineskip}%
                        {0.5\baselineskip}%
                        {\normalfont\normalsize}}
\newcommand*\l@subsubparagraph{\@dottedtocline{6}{10em}{5em}}% for toc
\newcommand{\subsubparagraphmark}[1]{}% for page headers
```

7 Cross references

We often want something like '`See Theorem~31`'. But by-hand typing the 31 is poor practice. Instead you should write a *label* such as `\label{eq:GreensThm}` and then *reference* it, as with `See equation~\ref{eq:GreensThm}`. LaTeX will automatically work out the number, put it into the output, and will change that number later if needed.

```
We will see this with Theorem~\ref{th:GreensThm}. % forward reference
...
\begin{theorem} \label{th:GreensThm}
  ...
\end{theorem}
...
See Theorem~\ref{th:GreensThm} on page~\pageref{th:GreensThm}.
```

LaTeX tracks cross reference information in a file having the extension `.aux` and with the same base name as the file containing the `\label`. So if `\label` is in `calculus.tex` then the information is in `calculus.aux`. LaTeX puts the information in that file every time it runs across a `\label`.

The behavior described in the prior paragraph results in a quirk that happens when your document has a *forward reference*, a `\ref` that appears before the associated `\label`. If this is the first time that you are compiling the document then you will get '`LaTeX Warning: Label(s) may have changed. Rerun to get cross references right`' and in the output the forward reference will appear as two question marks '`??`', in boldface. A similar thing happens if you change some things so the references changes; you get the same warning and the output contains the old reference information. In both cases, resolve this by compiling the document a second time.

The `cleveref` package enhances LaTeX's cross referencing features. You can arrange that if you enter `\begin{thm}\label{th:Nerode}...\end{thm}` then `\cref{th:Nerode}` will output '`Theorem 3.21`', without you having to enter the "Theorem."

7.1 \label

Synopsis:

```
\label{key}
```

Assign a reference number to *key*. In ordinary text `\label{key}` assigns to *key* the number of the current sectional unit. Inside an environment with numbering, such as a `table` or `theorem` environment, `\label{key}` assigns to *key* the number of that environment. Retrieve the assigned number with the `\ref{key}` command (see Section 7.3 [\ref], page 44).

A key name can consist of any sequence of letters, digits, or common punctuation characters. Upper and lowercase letters are distinguished, as usual.

A common convention is to use labels consisting of a prefix and a suffix separated by a colon or period. Thus, `\label{fig:Post}` is a label for a figure with a portrait of Emil Post. This helps to avoid accidentally creating two labels with the same name, and makes your source more readable. Some commonly-used prefixes:

`ch` for chapters

`sec`
`subsec` for lower-level sectioning commands

`fig` for figures

`tab` for tables

`eq` for equations

In the auxiliary file the reference information is kept as the text of a command of the form `\newlabel{`*label*`}{{`*currentlabel*`}{`*pagenumber*`}}`. Here *currentlabel* is the current value of the macro `\@currentlabel` that is usually updated whenever you call `\refstepcounter{`*counter*`}`.

Below, the key `sec:test` will get the number of the current section and the key `fig:test` will get the number of the figure. (Incidentally, put labels after captions in figures and tables.)

```
\section{section name}
\label{sec:test}
This is Section~\ref{sec:test}.
\begin{figure}
  ...
  \caption{caption text}
  \label{fig:test}
\end{figure}
See Figure~\ref{fig:test}.
```

7.2 \pageref

Synopsis:

```
\pageref{key}
```

Produce the page number of the place in the text where the corresponding `\label{`*key*`}` command appears.

If there is no `\label{`*key*`}` then you get something like '`LaTeX Warning: Reference 'th:GrensThm' on page 1 undefined on input line 11.`'

Below, the `\label{eq:main}` is used both for the formula number and for the page number. (Note that the two references are forward references so this document would need to be compiled twice to resolve those.)

```
The main result is formula~\ref{eq:main} on page~\pageref{eq:main}.
  ...
\begin{equation} \label{eq:main}
   \mathbf{P}=\mathbf{NP}
\end{equation}
```

7.3 \ref

Synopsis:

```
\ref{key}
```

Produces the number of the sectional unit, equation, footnote, figure, ..., of the corresponding `\label` command (see Section 7.1 [\label], page 43). It does not produce any text, such as the word 'Section' or 'Figure', just the bare number itself.

If there is no `\label{`*key*`}` then you get something like '`LaTeX Warning: Reference 'th:GrensThm' on page 1 undefined on input line 11.`'

In this example the `\ref{popular}` produces '`2`'. Note that it is a forward reference since it comes before `\label{popular}` so this document would have to be compiled twice.

```
The most widely-used format is item number~\ref{popular}.
\begin{enumerate}
\item Plain \TeX
\item \label{popular} \LaTeX
\item Con\TeX t
\end{enumerate}
```

The `cleveref` package includes text such as '`Theorem`' in the reference. See the documentation on CTAN.

8 Environments

LaTeX provides many environments for delimiting certain behavior. An environment begins with `\begin` and ends with `\end`, like this:

```
\begin{environment-name}
  ...
\end{environment-name}
```

The *environment-name* at the beginning must exactly match that at the end. For instance, the input `\begin{table*}...\end{table}` will cause an error like: '`! LaTeX Error: \begin{table*} on input line 5 ended by \end{table}.`'

Environments are executed within a group.

8.1 abstract

Synopsis:

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

Produce an abstract, possibly of multiple paragraphs. This environment is only defined in the `article` and `report` document classes (see Chapter 3 [Document classes], page 9).

Using the example below in the `article` class produces a displayed paragraph. Document class option `titlepage` causes the abstract to be on a separate page (see Section 3.1 [Document class options], page 9); this is the default only in the `report` class.

```
\begin{abstract}
  We compare all known accounts of the proposal made by Porter Alexander
  to Robert E Lee at the Appomattox Court House that the army continue
  in a guerrilla war, which Lee refused.
\end{abstract}
```

The next example produces a one column abstract in a two column document (for a more flexible solution, use the package `abstract`).

```
\documentclass[twocolumn]{article}
  ...
\begin{document}
\title{Babe Ruth as Cultural Progenitor: a Atavistic Approach}
\author{Smith \\ Jones \\ Robinson\thanks{Railroad tracking grant.}}
\twocolumn[
  \begin{@twocolumnfalse}
     \maketitle
     \begin{abstract}
       Ruth was not just the Sultan of Swat, he was the entire swat
       team.
     \end{abstract}
   \end{@twocolumnfalse}
   ]
{   % by-hand insert a footnote at page bottom
```

```
 \renewcommand{\thefootnote}{\fnsymbol{footnote}}
 \footnotetext[1]{Thanks for all the fish.}
}
```

8.2 array

Synopsis:

```
\begin{array}{cols}
  column 1 entry &column 2 entry ... &column n entry \\
  ...
\end{array}
```

or:

```
\begin{array}[pos]{cols}
  column 1 entry &column 2 entry ... &column n entry \\
  ...
\end{array}
```

Produce a mathematical array. This environment can only be used in math mode, and normally appears within a displayed mathematics environment such as `equation` (see Section 8.9 [equation], page 53). Inside of each row the column entries are separated by an ampersand, (`&`). Rows are terminated with double-backslashes (see Section 9.1 [\\], page 92).

This example shows a three by three array.

```
\begin{equation*}
  \chi(x) =
  \left|              % vertical bar fence
    \begin{array}{ccc}
      x-a  &-b  &-c  \\
      -d   &x-e &-f  \\
      -g   &-h  &x-i
    \end{array}
 \right|
\end{equation*}
```

The required argument *cols* describes the number of columns, their alignment, and the formatting of the intercolumn regions. For instance, `\begin{array}{rcl}...\end{array}` gives three columns: the first flush right, the second centered, and the third flush left. See Section 8.23 [tabular], page 79, for the complete description of *cols* and of the other common features of the two environments, including the optional *pos* argument.

There are two ways that `array` diverges from `tabular`. The first is that `array` entries are typeset in math mode, in textstyle (see Chapter 17 [Modes], page 149) except if the *cols* definition specifies the column with `p{...}`, which causes the entry to be typeset in text mode. The second is that, instead of `tabular`'s parameter `\tabcolsep`, LaTeX's intercolumn space in an `array` is governed by `\arraycolsep`, which gives half the width between columns. The default for this is '`5pt`' so that between two columns comes 10 pt of space.

To obtain arrays with braces the standard is to use the `amsmath` package. It comes with environments `pmatrix` for an array surrounded by parentheses `(...)`, `bmatrix` for

an array surrounded by square brackets `[...]`, `Bmatrix` for an array surrounded by curly braces `{...}`, `vmatrix` for an array surrounded by vertical bars `|...|`, and `Vmatrix` for an array surrounded by double vertical bars `||...||`, along with a number of other array constructs.

The next example uses the `amsmath` package.

```
\usepackage{amsmath}  % in preamble

\begin{equation}
  \begin{vmatrix}{cc}  % array with vert lines
    a  &b \\
    c  &d
  \end{vmatrix}=ad-bc
\end{equation}
```

There are many packages concerning arrays. The `array` package has many useful extensions, including more column types. The `dcolumn` package adds a column type to center on a decimal point. For both see the documentation on CTAN.

8.3 center

Synopsis:

```
\begin{center}
  line1 \\
  line2 \\
  ...
\end{center}
```

Create a new paragraph consisting of a sequence of lines that are centered within the left and right margins. Use double-backslash, `\\`, to get a line break (see Section 9.1 [\\], page 92). If some text is too long to fit on a line then LaTeX will insert line breaks that avoid hyphenation and avoid stretching or shrinking any interword space.

This environment inserts space above and below the text body. See Section 8.3.1 [\centering], page 49, to avoid such space, for example inside a `figure` environment.

This example produces three centered lines. There is extra vertical space between the last two lines.

```
\begin{center}
  A Thesis Submitted in Partial Fufillment \\
  of the Requirements of \\[0.5ex]
  the School of Environmental Engineering
\end{center}
```

In this example, depending on the page's line width, LaTeX may choose a line break for the part before the double backslash. If so, it will center each of the two lines and if not it will center the single line. Then LaTeX will break at the double backslash, and will center the ending.

```
\begin{center}
  My father considered that anyone who went to chapel and didn't drink
  alcohol was not to be tolerated.\\
```

```
  I grew up in that belief.  --Richard Burton
\end{center}
```

A double backslash after the final line is optional. If present it doesn't add any vertical space.

In a two-column document the text is centered in a column, not in the entire page.

8.3.1 \centering

Synopsis:

```
{\centering ... }
```

or

```
\begin{group}
  \centering ...
\end{group}
```

Center the material in its scope. It is most often used inside an environment such as `figure`, or in a `parbox`.

This example's `\centering` declaration causes the graphic to be horizontally centered.

```
\begin{figure}
  \centering
  \includegraphics[width=0.6\textwidth]{ctan_lion.png}
  \caption{CTAN Lion}  \label{fig:CTANLion}
\end{figure}
```

The scope of this `\centering` ends with the `\end{figure}`.

Unlike the `center` environment, the `\centering` command does not add vertical space above and below the text. That's its advantage in the above example; there is not an excess of space.

It also does not start a new paragraph; it simply changes how LaTeX formats paragraph units. If `ww {\centering xx \\ yy} zz` is surrounded by blank lines then LaTeX will create a paragraph whose first line '`ww xx`' is centered and whose second line, not centered, contains '`yy zz`'. Usually what is desired is for the scope of the declaration to contain a blank line or the `\end` command of an environment such as `figure` or `table` that ends the paragraph unit. Thus, if `{\centering xx \\ yy\par} zz` is surrounded by blank lines then it makes a new paragraph with two centered lines '`xx`' and '`yy`', followed by a new paragraph with '`zz`' that is formatted as usual.

8.4 description

Synopsis:

```
\begin{description}
  \item[label of first item] text of first item
  \item[label of second item] text of second item
   ...
\end{description}
```

Environment to make a list of labeled items. Each item's *label* is typeset in bold and is flush left, so that long labels continue into the first line of the item text. There must

be at least one item; having none causes the LaTeX error '`Something's wrong--perhaps a missing \item`'.

This example shows the environment used for a sequence of definitions.

```
\begin{definition}
  \item[lama] A priest.
  \item[llama] A beast.
\end{definition}
```

The labels '`lama`' and '`llama`' are output in boldface, with the left edge on the left margin.

Start list items with the `\item` command (see Section 8.16.1 [\item], page 63). Use the optional labels, as in `\item[Main point]`, because there is no sensible default. Following the `\item` is optional text, which may contain multiple paragraphs.

Since the labels are in bold style, if the label text calls for a font change given in argument style (see Section 4.1 [Font styles], page 18) then it will come out bold. For instance, if the label text calls for typewriter with `\item[\texttt{label text}]` then it will appear in bold typewriter, if that is available. The simplest way around this, in this example to get non-bold typewriter, is to use declarative style: `\item[{\tt label text}]`. Similarly, get the standard roman font with `\item[{\rm label text}]`.

For other major LaTeX labelled list environments, see Section 8.14 [itemize], page 57, and Section 8.7 [enumerate], page 51. Unlike those environments, nesting `description` environments does not change the default label; it is boldface and flush left at all levels.

For information about list layout parameters, including the default values, and for information about customizing list layout, see Section 8.16 [list], page 59. The package `enumitem` is useful for customizing lists.

This example changes the description labels to small caps.

```
\renewcommand{\descriptionlabel}[1]{%
  {\hspace{\labelsep}\textsc{#1}}}
```

8.5 displaymath

Synopsis:

```
\begin{displaymath}
  mathematical text
\end{displaymath}
```

Environment to typeset the math text on its own line, in display style and centered. To make the text be flush-left use the global option `fleqn`; see Section 3.1 [Document class options], page 9.

In the `displaymath` environment no equation number is added to the math text. One way to get an equation number is to use the `equation` environment (see Section 8.9 [equation], page 53).

LaTeX will not break the *math text* across lines.

Note that the `amsmath` package has significantly more extensive displayed equation facilities. For example, there are a number of ways in that package for having math text broken across lines.

The construct `\[`*math text*`\]` is essentially a synonym for `\begin{displaymath}`*math text*`\end{displaymath}` but the latter is easier to work with in the source file; for instance, searching for a square bracket may get false positives but the word `displaymath` will likely be unique. (The construct `$$`*math text*`$$` from Plain TEX is sometimes mistakenly used as a synonym for `displaymath`. It is not a synonym, because the `displaymath` environment checks that it isn't started in math mode and that it ends in math mode begun by the matching environment start, because the `displaymath` environment has different vertical spacing, and because the `displaymath` environment honors the `fleqn` option.)

The output from this example is centered and alone on its line.

```
\begin{displaymath}
  \int_1^2 x^2\,dx=7/3
\end{displaymath}
```

Also, the integral sign is larger than the inline version `\( \int_1^2 x^2\,dx=7/3 \)` produces.

8.6 document

The `document` environment encloses the entire body of a document. It is required in every LATEX document. See Section 2.1 [Starting and ending], page 3.

8.6.1 \AtBeginDocument

Synopsis:

```
\AtBeginDocument{code}
```

Save *code* and execute it when `\begin{document}` is executed, at the very end of the preamble. The code is executed after the font selection tables have been set up, so the normal font for the document is the current font. However, the code is executed as part of the preamble so you cannot do any typesetting with it.

You can issue this command more than once; the successive code lines will be executed in the order that you gave them.

8.6.2 \AtEndDocument

Synopsis:

```
\AtEndDocument{code}
```

Save *code* and execute it near the end of the document. Specifically, it is executed when `\end{document}` is executed, before the final page is finished and before any leftover floating environments are processed. If you want some of the code to be executed after these two processes then include a `\clearpage` at the appropriate point in *code*.

You can issue this command more than once; the successive code lines will be executed in the order that you gave them.

8.7 enumerate

Synopsis:

```
\begin{enumerate}
  \item[optional label of first item] text of first item
```

```
  \item[optional label of second item] text of second item
  ...
\end{enumerate}
```

Environment to produce a numbered list of items. The format of the label numbering depends on the nesting level of this environment; see below. The default top-level numbering is '`1.`', '`2.`', etc. Each `enumerate` list environment must have at least one item; having none causes the LaTeX error '`Something's wrong--perhaps a missing \item`'.

This example gives the first two finishers in the 1908 Olympic marathon. As a top-level list the labels would come out as '`1.`' and '`2.`'.

```
\begin{enumerate}
 \item Johnny Hayes (USA)
 \item Charles Hefferon (RSA)
\end{enumerate}
```

Start list items with the `\item` command (see Section 8.16.1 [\item], page 63). If you give `\item` an optional argument by following it with square brackets, as in `\item[Interstitial label]`, then the next item will continue the interrupted sequence (see Section 8.16.1 [\item], page 63). That is, you will get labels like '`1.`', then '`Interstitial label`', then '`2.`'. Following the `\item` is optional text, which may contain multiple paragraphs.

Enumerations may be nested within other `enumerate` environments, or within any paragraph-making environment such as `itemize` (see Section 8.14 [itemize], page 57), up to four levels deep. This gives LaTeX's default for the format at each nesting level, where 1 is the top level, the outermost level.

1. arabic number followed by a period: '`1.`', '`2.`', ...
2. lowercase letter inside parentheses: '`(a)`', '`(b)`' ...
3. lowercase roman numeral followed by a period: '`i.`', '`ii.`', ...
4. uppercase letter followed by a period: '`A.`', '`B.`', ...

The `enumerate` environment uses the counters `\enumi` through `\enumiv` (see Chapter 13 [Counters], page 116).

For other major LaTeX labeled list environments, see Section 8.4 [description], page 49, and Section 8.14 [itemize], page 57. For information about list layout parameters, including the default values, and for information about customizing list layout, see Section 8.16 [list], page 59. The package `enumitem` is useful for customizing lists.

To change the format of the label use `\renewcommand` (see Section 12.1 [\newcommand & \renewcommand], page 105) on the commands `\labelenumi` through `\labelenumiv`. For instance, this first level list will be labelled with uppercase letters, in boldface, and without a trailing period.

```
\renewcommand{\labelenumi}{\textbf{\Alph{enumi}}}
\begin{enumerate}
  \item Shows as boldface A
  \item Shows as boldface B
\end{enumerate}
```

For a list of counter-labeling commands see Section 13.1 [\alph \Alph \arabic \roman \Roman \fnsymbol], page 116.

8.8 eqnarray

The `eqnarray` environment is obsolete. It has infelicities, including spacing that is inconsistent with other mathematics elements. (See "Avoid eqnarray!" by Lars Madsen `http://tug.org/TUGboat/tb33-1/tb103madsen.pdf`). New documents should include the `amsmath` package and use the displayed mathematics environments provided there, such as the `align` environment. We include a description only for completeness and for working with old documents.

Synopsis:

```
\begin{eqnarray}
  first formula left  &first formula middle  &first formula right \\
  ...
\end{eqnarray}
```

or

```
\begin{eqnarray*}
  first formula left  &first formula middle  &first formula right \\
  ...
\end{eqnarray*}
```

Display a sequence of equations or inequalities. The left and right sides are typeset in display mode, while the middle is typeset in text mode.

It is similar to a three-column `array` environment, with items within a row separated by an ampersand (`&`), and with rows separated by double backslash `\\`). The starred form of line break (`\\*`) can also be used to separate equations, and will disallow a page break there (see Section 9.1 [\\], page 92).

The unstarred form `eqnarray` places an equation number on every line (using the `equation` counter), unless that line contains a `\nonumber` command. The starred form `eqnarray*` omits equation numbering, while otherwise being the same.

The command `\lefteqn` is used for splitting long formulas across lines. It typesets its argument in display style flush left in a box of zero width.

This example shows three lines. The first two lines make an inequality, while the third line has not entry on the left side.

```
\begin{eqnarray*}
  \lefteqn{x_1+x_2+\cdots+x_n}     \\
    &\leq &y_1+y_2+\cdots+y_n      \\
    &=    &z+y_3+\cdots+y_n
\end{eqnarray*}
```

8.9 equation

Synopsis:

```
\begin{equation}
  mathematical text
\end{equation}
```

The same as a `displaymath` environment (see Section 8.5 [displaymath], page 50) except that LaTeX puts an equation number flush to the right margin. The equation number is generated using the `equation` counter.

You should have no blank lines between `\begin{equation}` and `\begin{equation}`, or LaTeX will tell you that there is a missing dollar sign.

The package `amsmath` package has extensive displayed equation facilities. New documents should include this package.

8.10 figure

Synopsis:

```
\begin{figure}[placement]
  figure body
  \caption[loftitle]{title}  % optional
  \label{label}              % optional
\end{figure}
```

or:

```
\begin{figure*}[placement]
  figure body
  \caption[loftitle]{title}  % optional
  \label{label}              % optional
\end{figure*}
```

Figures are for material that is not part of the normal text. An example is material that you cannot have split between two pages, such as a graphic. Because of this, LaTeX does not typeset figures in sequence with normal text but instead "floats" them to a convenient place, such as the top of a following page (see Section 5.6 [Floats], page 28).

The *figure body* can consist of imported graphics (see Chapter 22 [Graphics], page 177), or text, LaTeX commands, etc. It is typeset in a `parbox` of width `\textwidth`.

The possible values of *placement* are `h` for '`here`', `t` for '`top`', `b` for '`bottom`', and `p` for '`on a separate page of floats`'. For the effect of these options on the float placement algorithm, see Section 5.6 [Floats], page 28.

The starred form `figure*` is used when a document is in double-column mode (see Section 5.2 [\twocolumn], page 24). It produces a figure that spans both columns, at the top of the page. To add the possibility of placing at a page bottom see the discussion of *placement* `b` in Section 5.6 [Floats], page 28.

The label is optional; it is used for cross references (see Chapter 7 [Cross references], page 43). The optional `\caption` command specifies caption text for the figure. By default it is numbered. If *loftitle* is present, it is used in the list of figures instead of *title* (see Section 25.1 [Table of contents etc.], page 200).

This example makes a figure out of a graphic. LaTeX will place that graphic and its caption at the top of a page or, if it is pushed to the end of the document, on a page of floats.

```
\usepackage{graphicx}  % in preamble
  ...
\begin{figure}[t]
  \centering
  \includegraphics[width=0.5\textwidth]{CTANlion.png}
  \caption{The CTAN lion, by Duane Bibby}
```

```
\end{figure}
```

8.11 filecontents: Write an external file

Synopsis:

```
\begin{filecontents}{filename}
  text
\end{filecontents}
```

or

```
\begin{filecontents*}{filename}
  text
\end{filecontents*}
```

Create a file named *filename* and fill it with *text*. The unstarred version of the environment `filecontents` prefixes the content of the created file with a header; see the example below. The starred version `filecontents*` does not include the header.

This environment can be used anywhere in the preamble, although it often appears before the `\documentclass` command. It is typically used when a source file requires a nonstandard style or class file. The environment will write that file to the directory containing the source and thus make the source file self-contained. Another use is to include `bib` references in the file, again to make it self-contained.

The environment checks whether a file of that name already exists and if so, does not do anything. There is a `filecontents` package that redefines the `filecontents` environment so that instead of doing nothing in that case, it will overwrite the existing file.

For example, this document

```
\documentclass{article}
\begin{filecontents}{JH.sty}
\newcommand{\myname}{Jim Hef{}feron}
\end{filecontents}
\usepackage{JH}
\begin{document}
Article by \myname.
\end{document}
```

produces this file `JH.sty`.

```
%% LaTeX2e file `JH.sty'
%% generated by the `filecontents' environment
%% from source `test' on 2015/10/12.
%%
\newcommand{\myname}{Jim Hef{}feron}
```

8.12 flushleft

Synopsis:

```
\begin{flushleft}
  line1 \\
  line2 \\
```

```
  ...
\end{flushleft}
```

An environment that creates a paragraph whose lines are flush to the left-hand margin, and ragged right. If you have lines that are too long then LaTeX will linebreak them in a way that avoids hyphenation and stretching or shrinking spaces. To force a new line use a double backslash, `\\`. For the declaration form see Section 8.12.1 [\raggedright], page 56.

This creates a box of text that is at most 3 inches wide, with the text flush left and ragged right.

```
\noindent\begin{minipage}{3in}
\begin{flushleft}
  A long sentence that will be broken by \LaTeX{}
    at a convenient spot. \\
  And, a fresh line forced by the double backslash.
\end{flushleft}
\end{minipage}
```

8.12.1 \raggedright

Synopses:

```
{\raggedright  ... }
```

or

```
\begin{environment} \raggedright
  ...
\end{environment}
```

A declaration which causes lines to be flush to the left margin and ragged right. It can be used inside an environment such as `quote` or in a `parbox`. For the environment form see Section 8.12 [flushleft], page 55.

Unlike the `flushleft` environment, the `\raggedright` command does not start a new paragraph; it only changes how LaTeX formats paragraph units. To affect a paragraph unit's format, the scope of the declaration must contain the blank line or `\end` command that ends the paragraph unit.

Here `\raggedright` in each second column keeps LaTeX from doing very awkward typesetting to fit the text into the narrow column. Note that `\raggedright` is inside the curly braces `{...}` to delimit its effect.

```
\begin{tabular}{rp{2in}}
  Team alpha  &{\raggedright This team does all the real work.} \\
  Team beta   &{\raggedright This team ensures that the water
                cooler is never empty.}                         \\
\end{tabular}
```

8.13 flushright

```
\begin{flushright}
  line1 \\
  line2 \\
  ...
```

```
\end{flushright}
```

An environment that creates a paragraph whose lines are flush to the right-hand margin and ragged left. If you have lines that are too long to fit the margins then LaTeX will linebreak them in a way that avoids hyphenation and stretching or shrinking spaces. To force a new line use a double backslash, `\\`. For the declaration form see Section 8.13.1 [\raggedleft], page 57.

For an example related to this environment, see Section 8.12 [flushleft], page 55.

8.13.1 `\raggedleft`

Synopses:

```
{\raggedleft  ... }
```

or

```
\begin{environment} \raggedleft
  ...
\end{environment}
```

A declaration which causes lines to be flush to the right margin and ragged left. It can be used inside an environment such as `quote` or in a `parbox`. For the environment form see Section 8.13 [flushright], page 56.

Unlike the `flushright` environment, the `\raggedleft` command does not start a new paragraph; it only changes how LaTeX formats paragraph units. To affect a paragraph unit's format, the scope of the declaration must contain the blank line or `\end` command that ends the paragraph unit.

For an example related to this environment, see Section 8.12.1 [\raggedright], page 56.

8.14 `itemize`

Synopsis:

```
\begin{itemize}
  \item[optional label of first item] text of first item
  \item[optional label of second item] text of second item
  ...
\end{itemize}
```

Produce a list that is unordered, sometimes called a bullet list. The environment must have at least one `\item`; having none causes the LaTeX error '`Something's wrong--perhaps a missing \item`'.

This gives a two-item list.

```
\begin{itemize}
 \item Pencil and watercolor sketch by Cassandra
 \item Rice portrait
\end{itemize}
```

As a top-level list each label would come out as a bullet, •. The format of the labeling depends on the nesting level; see below.

Start list items with the `\item` command (see Section 8.16.1 [\item], page 63). If you give `\item` an optional argument by following it with square brackets, as in `\item[Optional`

`label]`, then by default it will appear in bold and be flush right, so it could extend into the left margin. For labels that are flush left see the Section 8.4 [description], page 49, environment. Following the `\item` is optional text, which may contain multiple paragraphs.

Itemized lists can be nested within one another, up to four levels deep. They can also be nested within other paragraph-making environments, such as `enumerate` (see Section 8.7 [enumerate], page 51). The `itemize` environment uses the commands `\labelitemi` through `\labelitemiv` to produce the default label (this also uses the convention of lowercase roman numerals at the end of the command names that signify the nesting level). These are the default marks at each level.

1. • (bullet, from `\textbullet`)
2. -- (bold en-dash, from `\normalfont\bfseries\textendash`)
3. * (asterisk, from `\textasteriskcentered`)
4. · (centered dot, from `\textperiodcentered`)

Change the labels with `\renewcommand`. For instance, this makes the first level use diamonds.

```
\renewcommand{\labelitemi}{$\diamond$}
```

The distance between the left margin of the enclosing environment and the left margin of the `itemize` list is determined by the parameters `\leftmargini` through `\leftmarginvi`. (Note the convention of using lowercase roman numerals a the end of the command name to denote the nesting level.) The defaults are: `2.5em` in level 1 (`2em` in two-column mode), `2.2em` in level 2, `1.87em` in level 3, and `1.7em` in level 4, with smaller values for more deeply nested levels.

For other major LaTeX labeled list environments, see Section 8.4 [description], page 49, and Section 8.7 [enumerate], page 51. For information about list layout parameters, including the default values, and for information about customizing list layout, see Section 8.16 [list], page 59. The package `enumitem` is useful for customizing lists.

This example greatly reduces the margin space for outermost itemized lists.

```
\setlength{\leftmargini}{1.25em} % default 2.5em
```

Especially for lists with short items, it may be desirable to elide space between items. Here is an example defining an `itemize*` environment with no extra spacing between items, or between paragraphs within a single item (`\parskip` is not list-specific, see Section 15.3 [\parindent & \parskip], page 126):

```
\newenvironment{itemize*}%
  {\begin{itemize}%
    \setlength{\itemsep}{0pt}%
    \setlength{\parsep}{0pt}}%
  {\end{itemize}}
```

8.15 `letter` environment: writing letters

This environment is used for creating letters. See Chapter 26 [Letters], page 211.

8.16 `list`

Synopsis:

```
\begin{list}{labeling}{spacing}
  \item[optional label of first item] text of first item
  \item[optional label of second item] text of second item
  ...
\end{list}
```

An environment for constructing lists.

Note that this environment does not typically appear in the document body. Most lists created by LaTeX authors are the ones that come standard: the `description`, `enumerate`, and `itemize` environments (see Section 8.4 [description], page 49, Section 8.7 [enumerate], page 51, and Section 8.14 [itemize], page 57).

Instead, the `list` environment is most often used in macros. For example, many standard LaTeX environments that do not immediately appear to be lists are in fact constructed using `list`, including `quotation`, `quote`, and `center` (see Section 8.20 [quotation & quote], page 75, see Section 8.3 [center], page 48).

This uses the `list` environment to define a new custom environment.

```
\newcounter{namedlistcounter}  % number the items
\newenvironment{named}
  {\begin{list}
     {Item~\Roman{namedlistcounter}.} % labeling
     {\usecounter{namedlistcounter}   % set counter
      \setlength{\leftmargin}{3.5em}} % set spacing
  }
  {\end{list}}

\begin{named}
  \item Shows as ``Item~I.''
  \item[Special label.] Shows as ``Special label.''
  \item Shows as ``Item~II.''
\end{named}
```

The mandatory first argument *labeling* specifies the default labeling of list items. It can contain text and LaTeX commands, as above where it contains both '`Item`' and '`\Roman{...}`'. LaTeX forms the label by putting the *labeling* argument in a box of width `\labelwidth`. If the label is wider than that, the additional material extends to the right. When making an instance of a list you can override the default labeling by giving `\item` an optional argument by including square braces and the text, as in the above `\item[Special label.]`; see Section 8.16.1 [\item], page 63.

The mandatory second argument *spacing* has a list of commands. This list can be empty. A command that can go in here is `\usecounter{`*countername*`}` (see Section 13.2 [\usecounter], page 117). Use this to tell LaTeX to number the items using the given counter. The counter will be reset to zero each time LaTeX enters the environment, and the counter is incremented by one each time LaTeX encounters an `\item` that does not have an optional argument.

Another command that can go in *spacing* is `\makelabel`, which constructs the label box. By default it puts the contents flush right. Its only argument is the label, which it typesets in LR mode (see Chapter 17 [Modes], page 149). One example of changing its definition is that to the above `named` example, before the definition of the environment add `\newcommand{\namedmakelabel}[1]{\textsc{#1}}`, and between the `\setlength` command and the parenthesis that closes the *spacing* argument also add `\let\makelabel\namedmakelabel`. Then the items will be typeset in small caps. Similarly, changing the second code line to `\let\makelabel\fbox` puts the labels inside a framed box. Another example of the `\makelabel` command is below, in the definition of the `redlabel` environment.

Also often in *spacing* are commands to redefine the spacing for the list. Below are the spacing parameters with their default values. (Default values for derived environments such as `itemize` can be different than the values shown here.) See also the figure that follows the list. Each is a length (see Chapter 14 [Lengths], page 120). The vertical spaces are normally rubber lengths, with `plus` and `minus` components, to give TEX flexibility in setting the page. Change each with a command such as `\setlength{itemsep}{2pt plus1pt minus1pt}`. For some effects these lengths should be zero or negative.

`\itemindent`
: Extra horizontal space indentation, beyond `leftmargin`, of the first line each item. Its default value is `0pt`.

`\itemsep`
: Vertical space between items, beyond the `\parsep`. The defaults for the first three levels in LATEX's '`article`', '`book`', and '`report`' classes at 10 point size are: `4pt plus2pt minus1pt`, `\parsep` (that is, `2pt plus1pt minus1pt`), and `\topsep` (that is, `2pt plus1pt minus1pt`). The defaults at 11 point are: `4.5pt plus2pt minus1pt`, `\parsep` (that is, `2pt plus1pt minus1pt`), and `topsep` (that is, `2pt plus1pt minus1pt`). The defaults at 12 point are: `5pt plus2.5pt minus1pt`, `\parsep` (that is, `2.5pt plus1pt minus1pt`), and `\topsep` (that is, `2.5pt plus1pt minus1pt`).

`\labelsep`
: Horizontal space between the label and text of an item. The default for LATEX's '`article`', '`book`', and '`report`' classes is `0.5em`.

`\labelwidth`
: Horizontal width. The box containing the label is nominally this wide. If `\makelabel` returns text that is wider than this then the first line of the item will be indented to make room for this extra material. If `\makelabel` returns text of width less than or equal to `\labelwidth` then LATEX's default is that the label is typeset flush right in a box of this width.

  The left edge of the label box is `\leftmargin+\itemindent-\labelsep-\labelwidth` from the left margin of the enclosing environment.

  The default for LATEX's '`article`', '`book`', and '`report`' classes at the top level is `\leftmargini-\labelsep`, (which is `2em` in one column mode and `1.5em` in two column mode). At the second level it is `\leftmarginii-\labelsep`, and at the third level it is `\leftmarginiii-\labelsep`. These definitions make the label's left edge coincide with the left margin of the enclosing environment.

`\leftmargin`
: Horizontal space between the left margin of the enclosing environment (or the left margin of the page if this is a top-level list), and the left margin of this list. It must be non-negative.

  In the standard LaTeX document classes, a top-level list has this set to the value of `\leftmargini`, while a list that is nested inside a top-level list has this margin set to `\leftmarginii`. More deeply nested lists get the values of `\leftmarginiii` through `\leftmarginvi`. (Nesting greater than level five generates the error message '`Too deeply nested`'.)

  The defaults for the first three levels in LaTeX's '`article`', '`book`', and '`report`' classes are: `\leftmargini` is `2.5em` (in two column mode, `2em`), `\leftmarginii` is `2.2em`, and `\leftmarginiii` is `1.87em`.

`\listparindent`
: Horizontal space of additional line indentation, beyond `\leftmargin`, for second and subsequent paragraphs within a list item. A negative value makes this an "outdent". Its default value is `0pt`.

`\parsep`
: Vertical space between paragraphs within an item. In the '`book`' and '`article`' classes The defaults for the first three levels in LaTeX's '`article`', '`book`', and '`report`' classes at 10 point size are: `4pt plus2pt minus1pt`, `2pt plus1pt minus1pt`, and `0pt`. The defaults at 11 point size are: `4.5pt plus2pt minus1pt`, `2pt plus1pt minus1pt`, and `0pt`. The defaults at 12 point size are: `5pt plus2.5pt minus1pt`, `2.5pt plus1pt minus1pt`, and `0pt`.

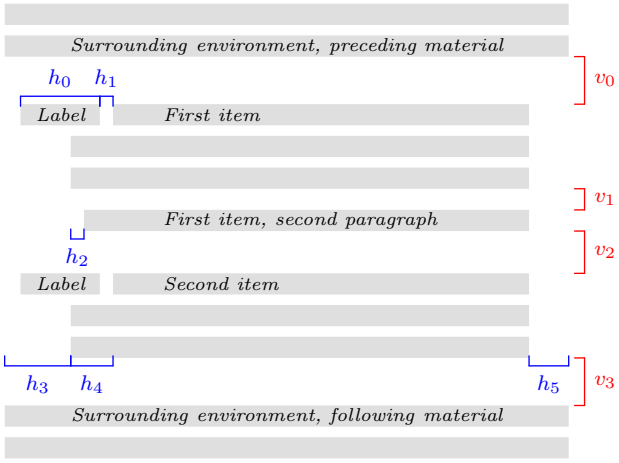
`\partopsep`
: Vertical space added, beyond `\topsep+\parskip`, to the top and bottom of the entire environment if the list instance is preceded by a blank line. (A blank line in the LaTeX source before the list changes spacing at both the top and bottom of the list; whether the line following the list is blank does not matter.)

  The defaults for the first three levels in LaTeX's '`article`', '`book`', and '`report`' classes at 10 point size are: `2pt plus1 minus1pt`, `2pt plus1pt minus1pt`, and `1pt plus0pt minus1pt`. The defaults at 11 point are: `3pt plus1pt minus1pt`, `3pt plus1pt minus1pt`, and `1pt plus0pt minus1pt`). The defaults at 12 point are: `3pt plus2pt minus3pt`, `3pt plus2pt minus2pt`, and `1pt plus0pt minus1pt`.

`\rightmargin`
: Horizontal space between the right margin of the list and the right margin of the enclosing environment. Its default value is `0pt`. It must be non-negative.

`\topsep`
: Vertical space added to both the top and bottom of the list, in addition to `\parskip` (see Section 15.3 [\parindent & \parskip], page 126). The defaults for the first three levels in LaTeX's '`article`', '`book`', and '`report`' classes at 10 point size are: `8pt plus2pt minus4pt`, `4pt plus2pt minus1pt`, and `2pt plus1pt minus1pt`. The defaults at 11 point are: `9pt plus3pt minus5pt`, `4.5pt plus2pt minus1pt`, and `2pt plus1pt minus1pt`. The defaults at 12 point are: `10pt plus4pt minus6pt`, `5pt plus2.5pt minus1pt`, and `2.5pt plus1pt minus1pt`.

This shows the horizontal and vertical distances.



The lengths shown are listed below. The key relationship is that the right edge of the bracket for *h1* equals the right edge of the bracket for *h4*, so that the left edge of the label box is at *h3*+*h4*-(*h0*+*h1*).

v0 `\topsep` + `\parskip` if the list environment does not start a new paragraph, and `\topsep+\parskip+\partopsep` if it does

v1 `\parsep`

v2 `\itemsep+\parsep`

v3 Same as *v0*. (This space is affected by whether a blank line appears in the source above the environment; whether a blank line appears in the source below the environment does not matter.)

h0 `\labelwidth`

h1 `\labelsep`

h2 `\listparindent`

h3 `\leftmargin`

h4 `\itemindent`

h5 `\rightmargin`

The list's left and right margins, shown above as *h3* and *h5*, are with respect to the ones provided by the surrounding environment, or with respect to the page margins for a top-level list. The line width used for typesetting the list items is `\linewidth` (see Section 5.5 [Page layout parameters], page 26). For instance, set the list's left margin to be one quarter of the distance between the left and right margins of the enclosing environment with `\setlength{\leftmargin}{0.25\linewidth}`.

Page breaking in a list structure is controlled by the three parameters below. For each, the LaTeX default is `-\@lowpenalty`, that is, `-51`. Because it is negative, it somewhat

encourages a page break at each spot. Change it with, e.g., `\@beginparpenalty=9999`; a value of 10000 prohibits a page break.

`\@beginparpenalty`
: The page breaking penalty for breaking before the list (default `-51`).

`\@itempenalty`
: The page breaking penalty for breaking before a list item (default `-51`).

`\@endparpenalty`
: The page breaking penalty for breaking after a list (default `-51`).

The package `enumitem` is useful for customizing lists.

This example has the labels in red. They are numbered, and the left edge of the label lines up with the left edge of the item text. See Section 13.2 [\usecounter], page 117.

```
\usepackage{color}
\newcounter{cnt}
\newcommand{\makeredlabel}[1]{\textcolor{red}{#1.}}
\newenvironment{redlabel}
  {\begin{list}
    {\arabic{cnt}}
    {\usecounter{cnt}
     \setlength{\labelwidth}{0em}
     \setlength{\labelsep}{0.5em}
     \setlength{\leftmargin}{1.5em}
     \setlength{\itemindent}{0.5em} % equals \labelwidth+\labelsep
     \let\makelabel=\makeredlabel
    }
  }
{\end{list} }
```

8.16.1 `\item`: An entry in a list

Synopsis:

```
\item text of item
```

or

```
\item[optional-label] text of item
```

An entry in a list. The entries are prefixed by a label, whose default depends on the list type.

Because the optional label is surrounded by square brackets '`[...]`', if you have an item whose text starts with '`[`', you have to to hide the bracket inside curly braces, as in: `\item {[} is an open square bracket`; otherwise, LaTeX will think it marks the start of an optional label.

Similarly, if the item does have the optional label and you need a close square bracket inside that label, you must hide it in the same way: `\item[Close square bracket, {]}]`. See Section 2.4 [LaTeX command syntax], page 5.

In this example the enumerate list has two items that use the default label and one that uses the optional label.

```
\begin{enumerate}
```

```
  \item Moe
  \item[sometimes] Shemp
  \item Larry
\end{enumerate}
```

The first item is labelled '`1.`', the second item is labelled '`sometimes`', and the third item is labelled '`2.`'. Because of the optional label in the second item, the third item is not labelled '`3.`'.

8.16.2 `trivlist`: A restricted form of `list`

Synopsis:

```
\begin{trivlist}
  ...
\end{trivlist}
```

A restricted version of the list environment, in which margins are not indented and an `\item` without an optional argument produces no text. It is most often used in macros, to define an environment where the `\item` command as part of the environment's definition. For instance, the `center` environment is defined essentially like this:

```
\newenvironment{center}
  {\begin{trivlist}\centering\item\relax}
  {\end{trivlist}}
```

Using `trivlist` in this way allows the macro to inherit some common code: combining vertical space of two adjacent environments; detecting whether the text following the environment should be considered a new paragraph or a continuation of the previous one; adjusting the left and right margins for possible nested list environments.

Specifically, `trivlist` uses the current values of the list parameters (see Section 8.16 [list], page 59), except that `\parsep` is set to the value of `\parskip`, and `\leftmargin`, `\labelwidth`, and `\itemindent` are set to zero.

This example outputs the items as two paragraphs, except that (by default) they have no paragraph indent and are vertically separated.

```
\begin{trivlist}
\item The \textit{Surprise} is not old; no one would call her old.
\item She has a bluff bow, lovely lines.
\end{trivlist}
```

8.17 `math`

Synopsis:

```
\begin{math}
math
\end{math}
```

The `math` environment inserts given *math* material within the running text. `\(...\)` and `$...$` are synonyms. See Chapter 16 [Math formulas], page 128.

8.18 minipage

Synopses:

```
\begin{minipage}{width}
  contents
\end{minipage}
```

or

```
\begin{minipage}[position][height][inner-pos]{width}
  contents
\end{minipage}
```

Put *contents* into a box that is *width* wide. This is like a small version of a page; it can contain its own footnotes, itemized lists, etc. (There are some restrictions, including that it cannot have floats.) This box will not be broken across pages. So `minipage` is similar to `\parbox` (see Section 20.3 [\parbox], page 169) but here you can have paragraphs.

This example will be 3 inches wide, and has two paragraphs.

```
\begin{minipage}{3in}
  Stephen Kleene was a founder of the Theory of Computation.

  He was a student of Church, wrote three influential texts,
  was President of the Association for Symbolic Logic,
  and won the National Medal of Science.
\end{minipage}
```

See below for a discussion of the paragraph indent inside a `minipage`.

The required argument *width* is a rigid length (see Chapter 14 [Lengths], page 120). It gives the width of the box into which *contents* are typeset.

There are three optional arguments, *position*, *height*, and *inner-pos*. You need not include all three. For example, get the default *position* and set the *height* with `\begin{minipage}[c][2.54cm]` *contents* `\end{minipage}`. (Get the natural height with an empty argument, `[]`.)

The optional argument *position* governs how the `minipage` vertically aligns with the surrounding material.

`c` (synonym `m`) Default. Positions the `minipage` so its vertical center lines up with the center of the adjacent text line (what Plain TEX calls `\vcenter`).

`t` Match the top line in the `minipage` with the baseline of the surrounding text (Plain TEX's `\vtop`.

`b` Match the bottom line in the `minipage` with the baseline of the surrounding text (Plain TEX's `\vbox`.

To see the effects of these, contrast running this

```
---\begin{minipage}[c]{0.25in}
  first\\ second\\ third
\end{minipage}
```

with the results of changing `c` to `b` or `t`.

The optional argument *height* is a rigid length (see Chapter 14 [Lengths], page 120). It sets the height of the `minipage`. You can enter any value larger than, or equal to, or smaller than the `minipage`'s natural height and LaTeX will not give an error or warning. You can also set it to a height of zero or a negative value.

The final optional argument *inner-pos* controls the placement of *content* inside the box. These are the possible values are (the default is the value of *position*).

`t` Place *content* at the top of the box.

`c` Place it in the vertical center.

`b` Place it at the box bottom.

`s` Stretch *contents* out vertically; it must contain vertically stretchable space.

The *inner-pos* argument makes sense when the *height* options is set to a value larger than the `minipage`'s natural height. To see the effect of the options, run this example with the various choices in place of `b`.

```
Text before
\begin{center}
  ---\begin{minipage}[c][3in][b]{0.25\textwidth}
       first\\ second\\ third
  \end{minipage}
\end{center}
Text after
```

By default paragraphs are not indented in a `minipage`. Change that with a command such as `\setlength{\parindent}{1pc}` at the start of *contents*.

Footnotes in a `minipage` environment are handled in a way that is particularly useful for putting footnotes in figures or tables. A `\footnote` or `\footnotetext` command puts the footnote at the bottom of the minipage instead of at the bottom of the page, and it uses the `\mpfootnote` counter instead of the ordinary `footnote` counter (see Chapter 13 [Counters], page 116).

This puts the footnote at the bottom of the table, not the bottom of the page.

```
\begin{center}           % center the minipage on the line
\begin{minipage}{2.5in}
  \begin{center}         % center the table inside the minipage
    \begin{tabular}{ll}
      \textsc{Monarch}  &\textsc{Reign}             \\ \hline
      Elizabeth II      &63 years\footnote{to date} \\
      Victoria          &63 years                   \\
      George III        &59 years
    \end{tabular}
  \end{center}
\end{minipage}
\end{center}
```

If you nest minipages then there is an oddness when using footnotes. Footnotes appear at the bottom of the text ended by the next `\end{minipage}` which may not be their logical place.

This puts a table containing data side by side with a map graphic. They are vertically centered.

```
\newcommand*{\vcenteredhbox}[1]{\begin{tabular}{@{}c@{}}#1\end{tabular}}
  ...
\begin{center}
  \vcenteredhbox{\includegraphics[width=0.3\textwidth]{nyc.png}}
  \hspace{0.1\textwidth}
  \begin{minipage}{0.5\textwidth}
    \begin{tabular}{r|l}
      \multicolumn{1}{r}{Borough} &Pop (million)  \\ \hline
      The Bronx      &$1.5$  \\
      Brooklyn       &$2.6$  \\
      Manhattan      &$1.6$  \\
      Queens         &$2.3$  \\
      Staten Island  &$0.5$
    \end{tabular}
  \end{minipage}
\end{center}
```

8.19 picture

Synopses:

```
\begin{picture}(width,height)
   picture commands
\end{picture}
```

or

```
\begin{picture}(width,height)(xoffset,yoffset)
  picture commands
\end{picture}
```

An environment to create simple pictures containing lines, arrows, boxes, circles, and text. Note that while this environment is not obsolete, new documents typically use much more powerful graphics creation systems, such as `TikZ`, `PSTricks`, `MetaPost`, or `Asymptote`. These are not covered in this document; see CTAN.

This shows the parallelogram law for adding vectors.

```
\setlength{\unitlength}{1cm}
\begin{picture}(6,6)      % picture box will be 6cm wide by 6cm tall
  \put(0,0){\vector(2,1){4}}  % for every 2 over this vector goes 1 up
    \put(2,1){\makebox(0,0)[l]{\ first leg}}
  \put(4,2){\vector(1,2){2}}
    \put(5,4){\makebox(0,0)[l]{\ second leg}}
  \put(0,0){\line(1,1){6}}
    \put(3,3){\makebox(0,0)[r]{sum\ }}
\end{picture}
```

You can also use this environment to place arbitrary material at an exact location.

```
\usepackage{color,graphicx}  % in preamble
```

```
  ...
\begin{center}
\setlength{\unitlength}{\textwidth}
\begin{picture}(1,1)      % leave space, \textwidth wide and tall
  \put(0,0){\includegraphics[width=\textwidth]{desertedisland.jpg}}
  \put(0.25,0.35){\textcolor{red}{X Treasure here}}
\end{picture}
\end{center}
```

The red X will be precisely a quarter of the `\linewidth` from the left margin, and `0.35\linewidth` up from the bottom. Another example of this usage is to put similar code in the page header to get repeat material on each of a document's pages.

The `picture` environment has one required argument, a pair of numbers (*width*,*height*). Multiply these by the value `\unitlength` to get the nominal size of the output, the space that LaTeX reserves on the output page. This nominal size need not be how large the picture really is; LaTeX will draw things from the picture outside the picture's box.

This environment also has an optional argument (*xoffset*,*yoffset*). It is used to shift the origin. Unlike most optional arguments, this one is not contained in square brackets. As with the required argument, it consists of two real numbers. Multiply these by `\unitlength` to get the point at the lower-left corner of the picture.

For example, if `\unitlength` has been set to `1mm`, the command

```
\begin{picture}(100,200)(10,20)
```

produces a box of width 100 millimeters and height 200 millimeters. The picture's origin is the point (10mm,20mm) and so the lower-left corner is there, and the upper-right corner is at (110mm,220mm). When you first draw a picture you typically omit the optional argument, leaving the origin at the lower-left corner. If you then want to modify your picture by shifting everything, you can just add the appropriate optional argument.

Each *picture command* tells LaTeX where to put something by naming its position. A *position* is a pair such as `(2.4,-5)` giving the x- and y-coordinates. A *coordinate* is a not a length, it is a real number (it may have a decimal point or a minus sign). It specifies a length in multiples of the unit length `\unitlength`, so if `\unitlength` has been set to `1cm`, then the coordinate 2.54 specifies a length of 2.54 centimeters.

LaTeX's default for `\unitlength` is `1pt`. it is a rigid length (see Chapter 14 [Lengths], page 120). Change it with the `\setlength` command (see Section 14.2 [\setlength], page 122). Make this change only outside of a `picture` environment.

Coordinates are given with respect to an origin, which is normally at the lower-left corner of the picture. Note that when a position appears as an argument, as with `\put(1,2){...}`, it is not enclosed in braces since the parentheses serve to delimit the argument. Also, unlike in some computer graphics systems, larger y-coordinates are further up the page.

There are four ways to put things in a picture: `\put`, `\multiput`, `\qbezier`, and `\graphpaper`. The most often used is `\put`. This

```
\put(11.3,-0.3){...}
```

places the object with its reference point at coordinates $(11.3, -0.3)$. The reference points for various objects will be described below. The `\put` command creates an *LR box* (see Chapter 17 [Modes], page 149). Anything that can go in an `\mbox` (see Section 20.1 [\mbox

& \makebox], page 167) can go in the text argument of the `\put` command. The reference point will be the lower left corner of the box. In this picture

```
\setlength{\unitlength}{1cm}
...\begin{picture}(1,1)
  \put(0,0){\line(1,0){1}}
  \put(0,0){\line(1,1){1}}
\end{picture}
```

the three dots are just slightly left of the point of the angle formed by the two lines. (Also, `\line(1,1){1}` does not call for a line of length one; rather the line has a change in the x coordinate of 1.)

The `\multiput`, `qbezier`, and `graphpaper` commands are described below.

This draws a rectangle with a wavy top, using `\qbezier` for that curve.

```
\begin{picture}(3,1.5)
  \put(0,0){\vector(1,0){8}}  % x axis
  \put(0,0){\vector(0,1){4}}  % y axis
  \put(2,0){\line(0,1){3}}       % left side rectangle
  \put(4,0){\line(0,1){3.5}}     % right side
  \qbezier(2,3)(2.5,2.9)(3,3.25)
    \qbezier(3,3.25)(3.5,3.6)(4,3.5)
  \thicklines                 % below here, lines are twice as thick
  \put(2,3){\line(4,1){2}}
  \put(4.5,2.5){\framebox{Trapezoidal Rule}}
\end{picture}
```

8.19.1 \put

Synopsis:

```
\put(xcoord,ycoord){content}
```

Place *content* at the coordinate (*xcoord*,*ycoord*). See the discussion of coordinates and `\unitlength` in Section 8.19 [picture], page 67. The *content* is processed in LR mode (see Chapter 17 [Modes], page 149) so it cannot contain line breaks.

This includes the text into the `picture`.

```
\put(4.5,2.5){Apply the \textit{unpoke} move}
```

The reference point, the location (4.5,2.5), is the lower left of the text, at the bottom left of the '`A`'.

8.19.2 \multiput

Synopsis:

```
\multiput(x,y)(delta_x,delta_y){num-copies}{obj}
```

Copy *obj* a total of *num-copies* times, with an increment of *delta_x*,*delta_y*. The *obj* first appears at position (x, y), then at $(x + \delta_x, y + \delta_y)$, and so on.

This draws a simple grid with every fifth line in bold (see also Section 8.19.4 [\graphpaper], page 70).

```
\begin{picture}(10,10)
```

```
  \linethickness{0.05mm}
  \multiput(0,0)(1,0){10}{\line(0,1){10}}
  \multiput(0,0)(0,1){10}{\line(1,0){10}}
  \linethickness{0.5mm}
  \multiput(0,0)(5,0){3}{\line(0,1){10}}
  \multiput(0,0)(0,5){3}{\line(1,0){10}}
\end{picture}
```

8.19.3 \qbezier

Synopsis:

```
\qbezier(x1,y1)(x2,y2)(x3,y3)
\qbezier[num](x1,y1)(x2,y2)(x3,y3)
```

Draw a quadratic Bezier curve whose control points are given by the three required arguments `(x1,y1)`, `(x2,y2)`, and `(x3,y3)`. That is, the curve runs from *(x1,y1)* to *(x3,y3)*, is quadratic, and is such that the tangent line at *(x1,y1)* passes through *(x2,y2)*, as does the tangent line at *(x3,y3)*.

This draws a curve from the coordinate (1,1) to (1,0).

```
\qbezier(1,1)(1.25,0.75)(1,0)
```

The curve's tangent line at (1,1) contains (1.25,0.75), as does the curve's tangent line at (1,0).

The optional argument *num* gives the number of calculated intermediate points. The default is to draw a smooth curve whose maximum number of points is `\qbeziermax` (change this value with `\renewcommand`).

8.19.4 \graphpaper

Synopsis:

```
\graphpaper(x_init,y_init)(x_dimen,y_dimen)
\graphpaper[spacing](x_init,y_init)(x_dimen,y_dimen)
```

Draw a coordinate grid. Requires the `graphpap` package. The grid's origin is `(x_init,y_init)`. Grid lines come every *spacing* units (the default is 10). The grid extends *x_dimen* units to the right and *y_dimen* units up. All arguments must be positive integers.

This make a grid with seven vertical lines and eleven horizontal lines.

```
\usepackage{graphpap}    % in preamble
  ...
\begin{picture}(6,20)    % in document body
  \graphpaper[2](0,0)(12,20)
\end{picture}
```

The lines are numbered every ten units.

8.19.5 \line

Synopsis:

```
\line(x_run,y_rise){travel}
```

Draw a line. It slopes such that it vertically rises *y_rise* for every horizontal *x_run*. The *travel* is the total horizontal change — it is not the length of the vector, it is the change

in x. In the special case of vertical lines, where (*x_run*,*y_rise*)=(0,1), the *travel* gives the change in y.

This draws a line starting at coordinates (1,3).

```
\put(1,3){\line(2,5){4}}
```

For every over 2, this line will go up 5. Because *travel* specifies that this goes over 4, it must go up 10. Thus its endpoint is $(1,3)+(4,10)=(5,13)$. In particular, note that $travel = 4$ is not the length of the line, it is the change in x.

The arguments *x_run* and *y_rise* are integers that can be positive, negative, or zero. (If both are 0 then LaTeX treats the second as 1.) With `\put(x_init,y_init){\line(x_run,y_rise){travel}}`, if *x_run* is negative then the line's ending point has a first coordinate that is less than *x_init*. If *y_rise* is negative then the line's ending point has a second coordinate that is less than *y_init*.

If *travel* is negative then you get `LaTeX Error: Bad \line or \vector argument.`

Standard LaTeX can only draw lines with a limited range of slopes because these lines are made by putting together line segments from pre-made fonts. The two numbers *x_run* and *y_rise* must have integer values from -6 through 6. Also, they must be relatively prime, so that *(x_run,y_rise)* can be (2,1) but not (4,2) (if you choose the latter then instead of lines you get sequences of arrowheads; the solution is to switch to the former). To get lines of arbitrary slope and plenty of other shapes in a system like `picture`, see the package `pict2e` on CTAN. Another solution is to use a full-featured graphics system such as `TikZ`, or `PSTricks`, or `MetaPost`, or `Asymptote`

8.19.6 \linethickness

Synopsis:

```
\linethickness{dim}
```

Declares the thickness of subsequent horizontal and vertical lines in a picture to be *dim*, which must be a positive length (see Chapter 14 [Lengths], page 120). It differs from `\thinlines` and `\thicklines` in that it does not affect the thickness of slanted lines, circles, or ovals.

8.19.7 \thinlines

Declaration to set the thickness of subsequent lines, circles, and ovals in a picture environment to be 0.4 pt. This is the default thickness, so this command is unnecessary unless the thickness has been changed with either Section 8.19.6 [\linethickness], page 71, or Section 8.19.8 [\thicklines], page 71.

8.19.8 \thicklines

Declaration to set the thickness of subsequent lines, circles, and ovals in a picture environment to be 0.8 pt. See also Section 8.19.6 [\linethickness], page 71, and Section 8.19.7 [\thinlines], page 71. This command is illustrated in the Trapezoidal Rule example of Section 8.19 [picture], page 67.

8.19.9 \circle

Synopsis:

```
\circle{diameter}
```

```
\circle*{diameter}
```

Produces a circle with a diameter as close as possible to the specified one. The `*` form produces a filled-in circle.

This draws a circle of radius 6, centered at `(5,7)`.

```
\put(5,7){\circle{6}}
```

The available radii for `circle` are, in points, the even numbers from 2 to 20, inclusive. For `circle*` they are all the integers from 1 to 15.

8.19.10 \oval

Synopsis:

```
\oval(width,height)
\oval(width,height)[portion]
```

Produce a rectangle with rounded corners. The optional argument *portion* allows you to produce only half or a quarter of the oval. For half an oval take *portion* to be one of these.

`t` top half

`b` bottom half

`r` right half

`l` left half

Produce only one quarter of the oval by setting *portion* to `tr`, `br`, `bl`, or `tl`.

This draws the top half of an oval that is 3 wide and 7 tall.

```
\put(5,7){\oval(3,7)[t]}
```

The (5,7) is the center of the entire oval, not just the center of the top half.

These shapes are not ellipses. They are rectangles whose corners are made with quarter circles. These circles have a maximum radius of 20 pt (see Section 8.19.9 [\circle], page 71, for the sizes). Thus large ovals are just boxes with a small amount of corner rounding.

8.19.11 \shortstack

Synopsis:

```
\shortstack[position]{line 1 \\ ... }
```

Produce a vertical stack of objects.

This labels the y axis.

```
\put(0,0){\vector(1,0){4}}   % x axis
\put(0,0){\vector(0,1){2}}   % y
\put(-0.25,2){\makebox[0][r]{\shortstack[r]{$y$\\ axis}}}
```

For a short stack, the reference point is the lower left of the stack. In the above example the Section 20.1 [\mbox & \makebox], page 167, puts the stack flush right in a zero width box so in total the short stack sits slightly to the left of the y axis.

The valid positions are:

`r` Make objects flush right

`l` Make objects flush left

`c` Center objects (default)

Separate objects into lines with `\\`. These stacks are short in that, unlike in a `tabular` or `array` environment, here the rows are not spaced out to be of even heights. Thus, in `\shortstack{X\\o\\o\\X}` the first and last rows are taller than the middle two. You can adjust row heights either by putting in the usual interline spacing with `\shortstack{X\\ \strut o\\o\\X}`, or by hand, via an explicit zero-width box `\shortstack{X \\ \rule{0pt}{12pt} o\\o\\X}` or by using `\\`'s optional argument `\shortstack{X\\[2pt] o\\o\\X}`.

The `\shortstack` command is also available outside the `picture` environment.

8.19.12 \vector

Synopsis:

```
\vector(x_run,y_rise){travel}
```

Draw a line ending in an arrow. The slope of that line is: it vertically rises *y_rise* for every horizontal *x_run*. The *travel* is the total horizontal change — it is not the length of the vector, it is the change in x. In the special case of vertical vectors, if (*x_run*,*y_rise*)=(0,1), then *travel* gives the change in y.

For an example see Section 8.19 [picture], page 67.

For elaboration on *x_run* and *y_rise* see Section 8.19.5 [\line], page 70. As there, the values of *x_run* and *y_rise* are limited. For `\vector` you must chooses integers between −4 and 4, inclusive. Also, the two you choose must be relatively prime. Thus, `\vector(2,1){4}` is acceptable but `\vector(4,2){4}` is not (if you use the latter then you get a sequence of arrowheads).

8.19.13 \makebox (picture)

Synopsis:

```
\makebox(rec-width,rec-height){text}
\makebox(rec-width,rec-height)[position]{text}
```

Make a box to hold *text*. This command fits with the `picture` environment, although you can use it outside of there, because *rec-width* and *rec-height* are numbers specifying distances in terms of the `\unitlength` (see Section 8.19 [picture], page 67). This command is similar to the normal `\makebox` command (see Section 20.1 [\mbox & \makebox], page 167) except here that you must specify the width and height. This command is fragile (see Section 12.9 [\protect], page 113).

This makes a box of length 3.5 times `\unitlength` and height 4 times `\unitlength`.

```
\put(1,2){\makebox(3.5,4){...}}
```

The optional argument *position* specifies where in the box the *text* appears. The default is to center it, both horizontally and vertically. To place it somewhere else, use a string with one or two of these letters.

`t` Puts *text* the top of the box.

`b` Put *text* at the bottom.

`l` Put *text* on the left.

`r` Put *text* on the right.

8.19.14 \framebox (picture)

Synopsis:

```
\framebox(rec-width,rec-height){text}
\framebox(rec-width,rec-height)[position]{text}
```

This is the same as Section 8.19.13 [\makebox (picture)], page 73, except that it puts a frame around the outside of the box that it creates. The reference point is the bottom left corner of the frame. This command fits with the `picture` environment, although you can use it outside of there, because lengths are numbers specifying the distance in terms of the `\unitlength` (see Section 8.19 [picture], page 67). This command is fragile (see Section 12.9 [\protect], page 113).

This example creates a frame 2.5 inches by 3 inches and puts the text in the center.

```
\setlength{\unitlength}{1in}
\framebox(2.5,3){test text}
```

The required arguments are that the rectangle has overall width *rect-width* units and height *rect-height* units.

The optional argument *position* specifies the position of *text*; see Section 8.19.13 [\makebox (picture)], page 73, for the values that it can take.

The rule has thickness `\fboxrule` and there is a blank space `\fboxsep` between the frame and the contents of the box.

For this command, you must specify the *width* and *height*. If you want to just put a frame around some contents whose dimension is determined in some other way then either use `\fbox` (see Section 20.2 [\fbox & \framebox], page 168) or `\frame` (see Section 8.19.15 [\frame], page 74).

8.19.15 \frame

Synopsis:

```
\frame{contents}
```

Puts a rectangular frame around *contents*. The reference point is the bottom left corner of the frame. In contrast to `\framebox` (see Section 8.19.14 [\framebox (picture)], page 74), this command puts no extra space is put between the frame and the object. It is fragile (see Section 12.9 [\protect], page 113).

8.19.16 \dashbox

Synopsis:

```
\dashbox{dash-len}(rect-width,rect-height){text}
\dashbox{dash-len}(rect-width,rect-height)[position]{text}
```

Create a dashed rectangle around *text*. This command fits with the `picture` environment, although you can use it outside of there, because lengths are numbers specifying the distance in terms of the `\unitlength` (see Section 8.19 [picture], page 67).

The required arguments are: dashes are *dash-len* units long, with the same length gap, and the rectangle has overall width *rect-width* units and height *rect-height* units.

The optional argument *position* specifies the position of *text*; see Section 8.19.13 [\makebox (picture)], page 73, for the values that it can take.

This shows that you can use non-integer value for *dash-len*.

```
\put(0,0){\dashbox{0.1}(5,0.5){My hovercraft is full of eels.}}
```

Each dash will be `0.1\unitlength` long, the box's width is `5\unitlength` and its height is `0.5\unitlength`.

As in that example, a dashed box looks best when *rect-width* and *rect-height* are multiples of the *dash-len*.

8.20 quotation & quote

Synopsis:

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

or

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

Include a quotation. Both environments indent margins on both sides by `\leftmargin` and the text is right-justified.

They differ in how they treat paragraphs. In the `quotation` environment, paragraphs are indented by 1.5 em and the space between paragraphs is small, `0pt plus 1pt`. In the `quote` environment, paragraphs are not indented and there is vertical space between paragraphs (it is the rubber length `\parsep`).

```
\begin{quotation} \small\it
  Four score and seven years ago
  ... shall not perish from the earth.
  \hspace{1em plus 1fill}---Abraham Lincoln
\end{quotation}
```

8.21 tabbing

Synopsis:

```
\begin{tabbing}
row1col1 \= row1col2 ...  \\
row2col1 \> row2col2 ...  \\
...
\end{tabbing}
```

Align text in columns, by setting tab stops and tabbing to them much as was done on a typewriter. This is less often used than the environments `tabular` (see Section 8.23 [tabular], page 79) or `array` (see Section 8.2 [array], page 47) because in those the width of each column need not be constant and need not be known in advance.

This example has a first line where the tab stops are set to explicit widths, ended by a `\kill` command (which is described below):

```
\begin{tabbing}
\hspace{0.75in}     \= \hspace{0.40in}  \= \hspace{0.40in}    \kill
```

```
Ship                \> Guns            \> Year    \\
\textit{Sophie}     \> 14              \> 1800    \\
\textit{Polychrest} \> 24              \> 1803    \\
\textit{Lively}     \> 38              \> 1804    \\
\textit{Surprise}   \> 28              \> 1805    \\
\end{tabbing}
```

Both the `tabbing` environment and the more widely-used `tabular` environment put text in columns. The most important distinction is that in `tabular` the width of columns is determined automatically by LaTeX, while in `tabbing` the user sets the tab stops. Another distinction is that `tabular` generates a box, but `tabbing` can be broken across pages. Finally, while `tabular` can be used in any mode, `tabbing` can be used only in paragraph mode and it starts a new paragraph.

A `tabbing` environment always starts a new paragraph, without indentation. Moreover, as shown in the example above, there is no need to use the starred form of the `\hspace` command at the beginning of a tabbed row. The right margin of the `tabbing` environment is the end of line, so that the width of the environment is `\linewidth`.

The `tabbing` environment contains a sequence of *tabbed rows*. The first tabbed row begins immediately after `\begin{tabbing}` and each row ends with `\\` or `\kill`. The last row may omit the `\\` and end with just `\end{tabbing}`.

At any point the `tabbing` environment has a current tab stop pattern, a sequence of $n > 0$ tab stops, numbered 0, 1, etc. These create n corresponding columns. Tab stop 0 is always the left margin, defined by the enclosing environment. Tab stop number i is set if it is assigned a horizontal position on the page. Tab stop number i can only be set if all the stops $0, \ldots, i-1$ have already been set; normally later stops are to the right of earlier ones.

By default any text typeset in a `tabbing` environment is typeset ragged right and left-aligned on the current tab stop. Typesetting is done in LR mode (see Chapter 17 [Modes], page 149).

The following commands can be used inside a `tabbing` environment. They are all fragile (see Section 12.9 [\protect], page 113).

`\\` (tabbing)
: End a tabbed line and typeset it.

`\=` (tabbing)
: Sets a tab stop at the current position.

`\>` (tabbing)
: Advances to the next tab stop.

`\<`
: Put following text to the left of the local margin (without changing the margin). Can only be used at the start of the line.

`\+`
: Moves the left margin of the next and all the following commands one tab stop to the right, beginning tabbed line if necessary.

`\-`
: Moves the left margin of the next and all the following commands one tab stop to the left, beginning tabbed line if necessary.

`\'` (tabbing)
: Moves everything that you have typed so far in the current column, i.e., everything from the most recent `\>`, `\<`, `\'`, `\\`, or `\kill` command, to the previous column and aligned to the right, flush against the current column's tab stop.

`\`` (tabbing)
: Allows you to put text flush right against any tab stop, including tab stop 0. However, it can't move text to the right of the last column because there's no tab stop there. The `\`` command moves all the text that follows it, up to the `\\` or `\end{tabbing}` command that ends the line, to the right margin of the `tabbing` environment. There must be no `\>` or `\'` command between the `\`` and the `\\` or `\end{tabbing}` command that ends the line.

`\a` (tabbing)
: In a `tabbing` environment, the commands `\=`, `\'` and `\`` do not produce accents as usual (see Section 23.5 [Accents], page 192). Instead, use the commands `\a=`, `\a'` and `\a`.

`\kill` Sets tab stops without producing text. Works just like `\\` except that it throws away the current line instead of producing output for it. Any `\=`, `\+` or `\-` commands in that line remain in effect.

`\poptabs` Restores the tab stop positions saved by the last `\pushtabs`.

`\pushtabs`
: Saves all current tab stop positions. Useful for temporarily changing tab stop positions in the middle of a `tabbing` environment.

`\tabbingsep`
: Distance of the text moved by `\'` to left of current tab stop.

This example typesets a Pascal function:

```
\begin{tabbing}
function \= fact(n : integer) : integer;\\
         \> begin \= \+ \\
               \> if \= n > 1 then \+ \\
                        fact := n * fact(n-1) \- \\
                  else \+ \\
                        fact := 1; \-\- \\
            end;\\
\end{tabbing}
```

The output looks like this.

```
function fact(n : integer) : integer;
         begin
               if n > 1 then
                  fact := n * fact(n-1);
               else
                  fact := 1;
         end;
```

This example is just for illustration of the environment. To actually typeset computer code in typewriter like this, a verbatim environment (see Section 8.27 [verbatim], page 89) would normally be best. For pretty-printed code, there are quite a few packages, including `algorithm2e`, `fancyvrb`, `listings`, and `minted`.

8.22 `table`

Synopsis:

```
\begin{table}[placement]
  table body
  \caption[loftitle]{title}  % optional
  \label{label}              % also optional
\end{table}
```

A class of floats (see Section 5.6 [Floats], page 28). They cannot be split across pages and so they are not typeset in sequence with the normal text but instead are floated to a convenient place, such as the top of a following page.

This example `table` environment contains a `tabular`

```
\begin{table}
  \centering\small
  \begin{tabular}{ll}
    \multicolumn{1}{c}{\textit{Author}}
      &\multicolumn{1}{c}{\textit{Piece}}  \\ \hline
    Bach            &Cello Suite Number 1  \\
    Beethoven       &Cello Sonata Number 3 \\
    Brahms          &Cello Sonata Number 1
  \end{tabular}
  \caption{Top cello pieces}
  \label{tab:cello}
\end{table}
```

but you can put many different kinds of content in a `table`, including text, LaTeX commands, etc.

For the possible values of *placement* and their effect on the float placement algorithm, see Section 5.6 [Floats], page 28.

The table body is typeset in a `parbox` of width `\textwidth`. It can contain text, commands, graphics, etc.

The label is optional; it is used for cross references (see Chapter 7 [Cross references], page 43). The `\caption` command is also optional. It specifies caption text for the table. By default it is numbered. If its optional *lottitle* is present then that text is used in the list of tables instead of *title* (see Section 25.1 [Table of contents etc.], page 200).

In this example the table and caption will float to the bottom of a page, unless it is pushed to a float page at the end.

```
\begin{table}[b]
  \centering
  \begin{tabular}{r|p{2in}} \hline
    One &The loneliest number \\
```

```
    Two &Can be as sad as one.
         It's the loneliest number since the number one.
  \end{tabular}
  \caption{Cardinal virtues}
  \label{tab:CardinalVirtues}
\end{table}
```

8.23 tabular

Synopsis:

```
\begin{tabular}[pos]{cols}
  column 1 entry  &column 2 entry  ...  &column n entry \\
  ...
\end{tabular}
```

or

```
\begin{tabular*}{width}[pos]{cols}
  column 1 entry  &column 2 entry  ...  &column n entry \\
  ...
\end{tabular*}
```

Produce a table, a box consisting of a sequence of horizontal rows. Each row consists of items that are aligned vertically in columns. This illustrates many of the features.

```
\begin{tabular}{l|l}
  \textit{Player name}  &\textit{Career home runs}  \\
  \hline
  Hank Aaron  &755 \\
  Babe Ruth   &714
\end{tabular}
```

The output will have two left-aligned columns with a vertical bar between them. This is specified in `tabular`'s argument `{l|l}`. Put the entries into different columns by separating them with an ampersand, `&`. The end of each row is marked with a double backslash, `\\`. Put a horizontal rule below a row, after a double backslash, with `\hline`. This `\\` is optional after the last row unless an `\hline` command follows, to put a rule below the table.

The required and optional arguments to `tabular` consist of:

pos Optional. Specifies the table's vertical position. The default is to align the table so its vertical center matches the baseline of the surrounding text. There are two other possible alignments: `t` aligns the table so its top row matches the baseline of the surrounding text, and `b` aligns on the bottom row.

This only has an effect if there is other text. In the common case of a `tabular` alone in a `center` environment this option makes no difference.

cols Required. Specifies the formatting of columns. It consists of a sequence of the following specifiers, corresponding to the types of column and intercolumn material.

`l` A column of left-aligned items.

`r` A column of right-aligned items.

`c` A column of centered items.

`|` A vertical line the full height and depth of the environment.

`@{`*text or space*`}`

Insert *text or space* at this location in every row. The *text or space* material is typeset in LR mode. This text is fragile (see Section 12.9 [\protect], page 113).

If between two columns there is no @-expression then LaTeX's `book`, `article`, and `report` classes will put on either side of each column a space of length `\tabcolsep`, which by default is 6 pt. That is, by default adjacent columns are separated by 12 pt (so `\tabcolsep` is misleadingly named since it is only half of the separation between tabular columns). In addition, a space of 6 pt also comes before the first column and after the final column, unless you put a `@{...}` or `|` there.

If you override the default and use an @-expression then LaTeX does not insert `\tabcolsep` so you must insert any desired space yourself, as in `@{\hspace{1em}}`.

An empty expression `@{}` will eliminate the space. In particular, sometimes you want to eliminate the the space before the first column or after the last one, as in the example below where the tabular lines need to lie on the left margin.

```
\begin{flushleft}
  \begin{tabular}{@{}l}
    ...
  \end{tabular}
\end{flushleft}
```

The next example shows text, a decimal point between the columns, arranged so the numbers in the table are aligned on it.

```
\begin{tabular}{r@{$.$}l}
  $3$ &$14$  \\
  $9$ &$80665$
\end{tabular}
```

An `\extracolsep{`*wd*`}` command in an @-expression causes an extra space of width *wd* to appear to the left of all subsequent columns, until countermanded by another `\extracolsep`. Unlike ordinary intercolumn space, this extra space is not suppressed by an @-expression. An `\extracolsep` command can be used only in an @-expression in the `cols` argument. Below, LaTeX inserts the right amount of intercolumn space to make the entire table 4 inches wide.

```
\begin{tabular*}{4in}{l@{\extracolsep{\fill}}l}
  Seven times down, eight times up \ldots
  &such is life!
\end{tabular*}
```

To insert commands that are automatically executed before a given column, load the `array` package and use the `>{...}` specifier.

`p{`*wd*`}` Each item in the column is typeset in a parbox of width *wd*, as if it were the argument of a `\parbox[t]{wd}{...}` command.

A line break double backslash `\\` may not appear in the item, except inside an environment like `minipage`, `array`, or `tabular`, or inside an explicit `\parbox`, or in the scope of a `\centering`, `\raggedright`, or `\raggedleft` declaration (when used in a `p`-column element these declarations must appear inside braces, as with `{\centering .. \\ ..}`). Otherwise LaTeX will misinterpret the double backslash as ending the row. Instead, to get a line break in there use `\newline` (see Section 9.3 [\newline], page 94).

`*{`*num*`}{`*cols*`}`
Equivalent to *num* copies of *cols*, where *num* is a positive integer and *cols* is a list of specifiers. Thus the specifier `\begin{tabular}{|*{3}{l|r}|}` is equivalent to the specifier `\begin{tabular}{|l|rl|rl|r|}`. Note that *cols* may contain another `*`-expression.

width Required for `tabular*`, not allowed for `tabular`. Specifies the width of the `tabular*` environment. The space between columns should be rubber, as with `@{\extracolsep{\fill}}`, to allow the table to stretch or shrink to make the specified width, or else you are likely to get the `Underfull \hbox (badness 10000) in alignment ...` warning.

Parameters that control formatting:

`\arrayrulewidth`
A length that is the thickness of the rule created by `|`, `\hline`, and `\vline` in the `tabular` and `array` environments. The default is '`.4pt`'. Change it as in `\setlength{\arrayrulewidth}{0.8pt}`.

`\arraystretch`
A factor by which the spacing between rows in the `tabular` and `array` environments is multiplied. The default is '`1`', for no scaling. Change it as `\renewcommand{\arraystretch}{1.2}`.

`\doublerulesep`
A length that is the distance between the vertical rules produced by the `||` specifier. The default is '`2pt`'.

`\tabcolsep`
A length that is half of the space between columns. The default is '`6pt`'. Change it with `\setlength`.

The following commands can be used inside the body of a `tabular` environment, the first two inside an entry and the second two between lines:

8.23.1 \multicolumn

Synopsis:

```
\multicolumn{numcols}{cols}{text}
```

Make an `array` or `tabular` entry that spans several columns. The first argument *numcols* gives the number of columns to span. The second argument *cols* specifies the formatting of the entry, with `c` for centered, `l` for flush left, or `r` for flush right. The third argument *text* gives the contents of that entry.

In this example, in the first row, the second and third columns are spanned by the single heading 'Name'.

```
\begin{tabular}{lccl}
  \textit{ID}       &\multicolumn{2}{c}{\textit{Name}} &\textit{Age} \\
  \hline
  978-0-393-03701-2 &O'Brian &Patrick                  &55           \\
    ...
\end{tabular}
```

What counts as a column is: the column format specifier for the `array` or `tabular` environment is broken into parts, where each part (except the first) begins with `l`, `c`, `r`, or `p`. So from `\begin{tabular}{|r|ccp{1.5in}|}` the parts are `|r|`, `c`, `c`, and `p{1.5in}|`.

The *cols* argument overrides the `array` or `tabular` environment's intercolumn area default adjoining this multicolumn entry. To affect that area, this argument can contain vertical bars `|` indicating the placement of vertical rules, and `@{...}` expressions. Thus if *cols* is '`|c|`' then this multicolumn entry will be centered and a vertical rule will come in the intercolumn area before it and after it. This table details the exact behavior.

```
\begin{tabular}{|cc|c|c|}
  \multicolumn{1}{r}{w}       % entry one
    &\multicolumn{1}{|r|}{x}  % entry two
    &\multicolumn{1}{|r}{y}   % entry three
    &z                        % entry four
\end{tabular}
```

Before the first entry the output will not have a vertical rule because the `\multicolumn` has the *cols* specifier '`r`' with no initial vertical bar. Between entry one and entry two there will be a vertical rule; although the first *cols* does not have an ending vertical bar, the second *cols* does have a starting one. Between entry two and entry three there is a single vertical rule; despite that the *cols* in both of the surrounding `multicolumn`'s call for a vertical rule, you only get one rule. Between entry three and entry four there is no vertical rule; the default calls for one but the *cols* in the entry three `\multicolumn` leaves it out, and that takes precedence. Finally, following entry four there is a vertical rule because of the default.

The number of spanned columns *numcols* can be 1. Besides giving the ability to change the horizontal alignment, this also is useful to override for one row the `tabular` definition's default intercolumn area specification, including the placement of vertical rules.

In the example below, in the `tabular` definition the first column is specified to default to left justified but in the first row the entry is centered with `\multicolumn{1}{c}{\textsc{Period}}`. Also in the first row, the second and third

columns are spanned by a single entry with `\multicolumn{2}{c}{\textsc{Span}}`, overriding the specification to center those two columns on the page range en-dash.

```
\begin{tabular}{l|r@{--}l}
  \multicolumn{1}{c}{\textsc{Period}}
    &\multicolumn{2}{c}{\textsc{Span}} \\ \hline
  Baroque          &1600          &1760         \\
  Classical        &1730          &1820         \\
  Romantic         &1780          &1910         \\
  Impressionistic  &1875          &1925
\end{tabular}
```

Note that although the `tabular` specification by default puts a vertical rule between the first and second columns, because there is no vertical bar in the *cols* of either of the first row's `\multicolumn` commands, no rule appears in the first row.

8.23.2 \vline

Draw a vertical line in a `tabular` or `array` environment extending the full height and depth of an entry's row. Can also be used in an @-expression, although its synonym vertical bar `|` is more common. This command is rarely used in the body of a table; typically a table's vertical lines are specified in `tabular`'s *cols* argument and overridden as needed with `\multicolumn` (see Section 8.23 [tabular], page 79).

The example below illustrates some pitfalls. In the first row's second entry the `\hfill` moves the `\vline` to the left edge of the cell. But that is different than putting it halfway between the two columns, so between the first and second columns there are two vertical rules, with the one from the `{c|cc}` specifier coming before the one produced by the `\vline\hfill`. In contrast, the first row's third entry shows the usual way to put a vertical bar between two columns. In the second row, the `ghi` is the widest entry in its column so in the `\vline\hfill` the `\hfill` has no effect and the vertical line in that entry appears immediately next to the `g`, with no whitespace.

```
\begin{tabular}{c|cc}
  x   &\vline\hfill y   &\multicolumn{1}{|r}{z} \\ % row 1
  abc &def &\vline\hfill ghi                       % row 2
\end{tabular}
```

8.23.3 \cline

Synopsis:

```
\cline{i-j}
```

In an `array` or `tabular` environment, draw a horizontal rule beginning in column *i* and ending in column *j*. The dash, `-`, must appear in the mandatory argument. To span a single column use the number twice, as with `\cline{2-2}`.

This example puts two horizontal lines between the first and second rows, one line in the first column only, and the other spanning the third and fourth columns. The two lines are side-by-side, at the same height.

```
\begin{tabular}{llrr}
  a &b &c &d \\ \cline{1-1} \cline{3-4}
  e &f &g &h
```

```
\end{tabular}
```

8.23.4 \hline

Draw a horizontal line the width of the enclosing `tabular` or `array` environment. It's most commonly used to draw a line at the top, bottom, and between the rows of a table.

In this example the top of the table has two horizontal rules, one above the other, that span both columns. The bottom of the table has a single rule spanning both columns. Because of the `\hline`, the `tabular` second row's line ending double backslash `\\` is required.

```
\begin{tabular}{ll} \hline\hline
  Baseball   &Red Sox  \\
  Basketball &Celtics  \\ \hline
\end{tabular}
```

8.24 thebibliography

Synopsis:

```
\begin{thebibliography}{widest-label}
  \bibitem[label]{cite_key}
  ...
\end{thebibliography}
```

Produce a bibliography or reference list. There are two ways to produce bibliographic lists. This environment is suitable when you have only a few references and can maintain the list by hand. See Section 8.24.4 [Using BibTeX], page 87, for a more sophisticated approach.

This shows the environment with two entries.

```
This work is based on \cite{latexdps}.
Together they are \cite{latexdps, texbook}.
  ...
\begin{thebibliography}{9}
\bibitem{latexdps}
  Leslie Lamport.
  \textit{\LaTeX{}: a document preparation system}.
  Addison-Wesley, Reading, Massachusetts, 1993.
\bibitem{texbook}
  Donald Ervin Knuth.
  \textit{The \TeX book}.
  Addison-Wesley, Reading, Massachusetts, 1983.
\end{thebibliography}
```

This styles the first reference as '`[1] Leslie ...`', and so that `\cite{latexdps}` produces the matching '`... based on [1]`'. The second `\cite` produces '`[1, 2]`'. You must compile the document twice to resolve these references.

The mandatory argument *widest-label* is text that, when typeset, is as wide as the widest item label produced by the `\bibitem` commands. The tradition is to use `9` for bibliographies with less than 10 references, `99` for ones with less than 100, etc.

The bibliographic list is headed by a title such as '`Bibliography`'. To change it there are two cases. In the `book` and `report` classes, where the top level sectioning is `\chapter` and the default title is '`Bibliography`', that title is in the macro `\bibname`. For `article`, where the class's top level sectioning is `\section` and the default is '`References`', the title is in macro `\refname`. Change it by redefining the command, as with `\renewcommand{\refname}{Cited references}` after `\begin{document}`.

Language support packages such as `babel` will automatically redefine `\refname` or `\bibname` to fit the selected language.

8.24.1 `\bibitem`

Synopsis:

```
\bibitem{cite_key}
```

or

```
\bibitem[label]{cite_key}
```

Generate an entry labeled by *label*. The default is for LaTeX to generates a number using the `enumi` counter. The *citation key* *cite_key* is a string of letters, numbers, and punctuation symbols (but not comma).

See Section 8.24 [thebibliography], page 84, for an example.

The optional *label* changes the default label from an integer to the given string. With this

```
\begin{thebibliography}
\bibitem[Lamport 1993]{latexdps}
  Leslie Lamport.
  \textit{\LaTeX{}: a document preparation system}.
  Addison-Wesley, Reading, Massachusetts, 1993.
\bibitem{texbook}
  Donald Ervin Knuth.
  \textit{The \TeX book}.
  Addison-Wesley, Reading, Massachusetts, 1983.
\end{thebibliography}
```

the first entry will be styled as '`[Lamport 1993] Leslie ...`' (The amount of horizontal space that LaTeX leaves for the label depends on the *widest-label* argument of the `thebibliography` environment; see Section 8.24 [thebibliography], page 84.) Similarly, `... based on \cite{latexdps}` will produce '`... based on [Lamport 1994]`'.

If you mix `\bibitem` entries having a *label* with those that do not then LaTeX will number the unlabelled ones sequentially. In the example above the `texbook` entry will appear as '`[1] Donald ...`', despite that it is the second entry.

If you use the same *cite_key* twice then you get '`LaTeX Warning: There were multiply-defined labels`'.

Under the hood, LaTeX remembers the *cite_key* and *label* information because `\bibitem` writes it to the auxiliary file *`filename`*`.aux`. For instance, the above example causes `\bibcite{latexdps}{Lamport, 1993}` and `\bibcite{texbook}{1}` to appear in that file. The `.aux` file is read by the `\begin{document}` command and then the information is

available for `\cite` commands. This explains why you need to run LaTeX twice to resolve references: once to write it out and once to read it in.

Because of this two-pass algorithm, when you add a `\bibitem` or change its *cite_key* you may get '`LaTeX Warning: Label(s) may have changed. Rerun to get cross-references right`'. Fix it by recompiling.

8.24.2 `\cite`

Synopsis:

```
\cite{keys}
```

or

```
\cite[subcite]{keys}
```

Generate as output a citation to the references associated with *keys*. The mandatory *keys* is a citation key, or a comma-separated list of citation keys (see Section 8.24.1 [\bibitem], page 85).

This

```
The ultimate source is \cite{texbook}.
  ...
\begin{thebibliography}
\bibitem{texbook}
  Donald Ervin Knuth.
  \textit{The \TeX book}.
  Addison-Wesley, Reading, Massachusetts, 1983.
\end{thebibliography}
```

produces the output '`... source is [1]`'.

The optional argument *subcite* is appended to the citation. For example, `See 14.3 in \cite[p.~314]{texbook}` might produce '`See 14.3 in [1, p. 314]`'.

If *keys* is not in your bibliography information then you get '`LaTeX Warning: There were undefined references`', and in the output the citation shows as a boldface question mark between square brackets. There are two possible causes. If you have mistyped something, as in `\cite{texbok}` then you need to correct the spelling. On the other hand, if you have just added or modified the bibliographic information and so changed the `.aux` file (see Section 8.24.1 [\bibitem], page 85) then the fix may be to just run LaTeX again.

In addition to what appears in the output, `\cite` writes information to the auxiliary file *filename*`.aux`. For instance, `\cite{latexdps}` writes '`\citation{latexdps}`' to that file. This information is used by BibTeX to include in your reference list only those works that you have actually cited; see Section 8.24.3 [\nocite], page 86, also.

8.24.3 `\nocite`

Synopsis:

```
\nocite{keys}
```

Produces no output but writes *keys* to the auxiliary file *doc-filename*`.aux`.

The mandatory argument *keys* is a comma-separated list of one or more citation keys (see Section 8.24.1 [\bibitem], page 85). This information is used by BibTeX to include

these works in your reference list even though you have not cited them (see Section 8.24.2 [\cite], page 86).

8.24.4 Using BibTEX

As described in `thebibliography` (see Section 8.24 [thebibliography], page 84), a sophisticated approach to managing bibliographies is provided by the BibTEX program. This is only an introduction; see the full documentation on CTAN.

With BibTEX, you don't use `thebibliography` (see Section 8.24 [thebibliography], page 84). Instead, include these lines.

```
\bibliographystyle{bibstyle}
\bibliography{bibfile1, bibfile2, ...}
```

The *bibstyle* refers to a file `bibstyle.bst`, which defines how your citations will look. The standard *bibstyle*'s distributed with BibTEX are:

`alpha` Labels are formed from name of author and year of publication. The bibliographic items are sorted alphabetically.

`plain` Labels are integers. Sort the bibliographic items alphabetically.

`unsrt` Like `plain`, but entries are in order of citation.

`abbrv` Like `plain`, but more compact labels.

Many, many other BibTEX style files exist, tailored to the demands of various publications. See CTAN's listing `http://mirror.ctan.org/biblio/bibtex/contrib`.

The `\bibliography` command is what actually produces the bibliography. Its argument is a comma-separated list, referring to files named *bibfile1*`.bib`, *bibfile2*`.bib`, ... These contain your database in BibTEX format. This shows a typical couple of entries in that format.

```
@book{texbook,
  title     = {The {{\TeX}}book},
  author    = {D.E. Knuth},
  isbn      = {0201134489},
  series    = {Computers \& typesetting},
  year      = {1983},
  publisher = {Addison-Wesley}
}
@book{sexbook,
    author    = {W.H. Masters and V.E. Johnson},
    title     = {Human Sexual Response},
    year      = {1966},
    publisher = {Bantam Books}
}
```

Only the bibliographic entries referred to via `\cite` and `\nocite` will be listed in the document's bibliography. Thus you can keep all your sources together in one file, or a small number of files, and rely on BibTEX to include in this document only those that you used.

8.25 theorem

Synopsis:

```
\begin{theorem}
  theorem body
\end{theorem}
```

Produces 'Theorem *n*' in boldface followed by *theorem body* in italics. The numbering possibilities for *n* are described under `\newtheorem` (see Section 12.7 [\newtheorem], page 111).

```
\newtheorem{lem}{Lemma}      % in preamble
\newtheorem{thm}{Theorem}
  ...
\begin{lem}                  % in  document body
  text of lemma
\end{lem}

The next result follows immediately.
\begin{thm}[Gauss]   %  put 'Gauss' in parens after theorem head
  text of theorem
\end{thm}
```

Most new documents use the packages `amsthm` and `amsmath` from the American Mathematical Society. Among other things these packages include a large number of options for theorem environments, such as styling options.

8.26 titlepage

Synopsis:

```
\begin{titlepage}
  ... text and spacing ...
\end{titlepage}
```

Create a title page, a page with no printed page number or heading and with succeeding pages numbered starting with page one.

In this example all formatting, including vertical spacing, is left to the author.

```
\begin{titlepage}
\vspace*{\stretch{1}}
\begin{center}
  {\huge\bfseries Thesis \\[1ex]
                  title}                  \\[6.5ex]
  {\large\bfseries Author name}           \\
  \vspace{4ex}
  Thesis  submitted to                    \\[5pt]
  \textit{University name}                \\[2cm]
  in partial fulfilment for the award of the degree of \\[2cm]
  \textsc{\Large Doctor of Philosophy}    \\[2ex]
  \textsc{\large Mathematics}             \\[12ex]
  \vfill
```

```
  Department of Mathematics                \\
  Address                                  \\
  \vfill
  \today
\end{center}
\vspace{\stretch{2}}
\end{titlepage}
```

To instead produce a standard title page without a `titlepage` environment, use `\maketitle` (see Section 18.1 [\maketitle], page 151).

8.27 verbatim

Synopsis:

```
\begin{verbatim}
literal-text
\end{verbatim}
```

A paragraph-making environment in which LaTeX produces as output exactly what you type as input. For instance inside *literal-text* the backslash `\` character does not start commands, it produces a printed '\', and carriage returns and blanks are taken literally. The output appears in a monospaced typewriter-like font (`\tt`).

```
\begin{verbatim}
Symbol swearing: %&$#?!.
\end{verbatim}
```

The only restriction on `literal-text` is that it cannot include the string `\end{verbatim}`.

You cannot use the verbatim environment in the argument to macros, for instance in the argument to a `\section`. This is not the same as commands being fragile (see Section 12.9 [\protect], page 113), instead it just cannot appear there. (But the `cprotect` package can help with this.)

One common use of verbatim input is to typeset computer code. There are packages that are an improvement the `verbatim` environment. For instance, one improvement is to allow the verbatim inclusion of external files, or parts of those files. Such packages include `listings`, and `minted`.

A package that provides many more options for verbatim environments is `fancyvrb`. Another is `verbatimbox`.

For a list of all the relevant packages, see CTAN.

8.27.1 \verb

Synopsis:

```
\verb char literal-text char
\verb* char literal-text char
```

Typeset *literal-text* as it is input, including special characters and spaces, using the typewriter (`\tt`) font.

This example shows two different invocations of `\verb`.

```
This is \verb!literally! the biggest pumpkin ever.
```

```
And this is the best squash, \verb+literally!+
```

The first `\verb` has its *literal-text* surrounded with exclamation point, `!`. The second instead uses plus, `+`, because the exclamation point is part of `literal-text`.

The single-character delimiter *char* surrounds *literal-text* — it must be the same character before and after. No spaces come between `\verb` or `\verb*` and *char*, or between *char* and *literal-text*, or between *literal-text* and the second occurrence of *char* (the synopsis shows a space only to distinguish one component from the other). The delimiter must not appear in *literal-text*. The *literal-text* cannot include a line break.

The `*`-form differs only in that spaces are printed with a visible space character. (Namely, ␣.)

The output from this will include a character showing the spaces.

```
The commands's first argument is \verb*!filename with extension! and ...
```

For typesetting Internet addresses, urls, the package `url` provides an option that is better than the `\verb` command, since it allows line breaks.

For computer code there are many packages with advantages over `\verb`. One is `listings`, another is `minted`.

You cannot use `\verb` in the argument to a macro, for instance in the argument to a `\section`. It is not a question of `\verb` being fragile (see Section 12.9 [\protect], page 113), instead it just cannot appear there. (But the `cprotect` package can help with this.)

8.28 `verse`

Synopsis:

```
\begin{verse}
  line1 \\
  line2 \\
  ...
\end{verse}
```

An environment for poetry.

Here are two lines from Shakespeare's Romeo and Juliet.

```
Then plainly know my heart's dear love is set \\
On the fair daughter of rich Capulet.
```

Separate the lines of each stanza with `\\`, and use one or more blank lines to separate the stanzas.

```
\begin{verse}
\makebox[\linewidth][c]{\textit{Shut Not Your Doors} ---Walt Whitman}
  \\[1\baselineskip]
Shut not your doors to me proud libraries,                  \\
For that which was lacking on all your well-fill'd shelves, \\
\qquad yet needed most, I bring,                             \\
Forth from the war emerging, a book I have made,            \\
The words of my book nothing, the drift of it every thing,  \\
A book separate, not link'd with the rest nor felt by the intellect, \\
But you ye untold latencies will thrill to every page.
```

```
\end{verse}
```

The output has margins indented on the left and the right, paragraphs are not indented, and the text is not right-justified.

9 Line breaking

The first thing LaTeX does when processing ordinary text is to translate your input file into a sequence of glyphs and spaces. To produce a printed document, this sequence must be broken into lines (and these lines must be broken into pages).

LaTeX usually does the line (and page) breaking in the text body for you but in some environments you manually force line breaks.

A common workflow is to get a final version of the document content before taking a final pass through and considering line breaks (and page breaks). This differs from word processing, where you are formatting text as you input it. Putting these off until the end prevents a lot of fiddling with breaks that will change anyway.

9.1 \\

Synopsis, one of:

```
\\
\\[morespace]
```

or one of:

```
\\*
\\*[morespace]
```

End the current line. The optional argument *morespace* specifies extra vertical space to be inserted before the next line. This is a rubber length (see Chapter 14 [Lengths], page 120) and can be negative. The text before the line break is set at its normal length, that is, it is not stretched to fill out the line width. This command is fragile (see Section 12.9 [\protect], page 113).

The starred form, `\\*`, tells LaTeX not to start a new page between the two lines, by issuing a `\nobreak`.

```
\title{My story: \\[0.25in]
       a tale of woe}
```

Explicit line breaks in the main text body are unusual in LaTeX. In particular, don't start new paragraphs with `\\`. Instead leave a blank line between the two paragraphs. And don't put in a sequence of `\\`'s to make vertical space. Instead use `\vspace{`*`length`*`}`, or `\leavevmode\vspace{`*`length`*`}`, or `\vspace*{`*`length`*`}` if you want the space to not be thrown out at the top of a new page (see Section 19.14 [\vspace], page 164).

The `\\` command is mostly used outside of the main flow of text such as in a `tabular` or `array` environment or in an equation environment.

The `\\` command is a synonym for `\newline` (see Section 9.3 [\newline], page 94) under ordinary circumstances (an example of an exception is the `p{...}` column in a `tabular` environment; see Section 8.23 [tabular], page 79).

The `\\` command is a macro, and its definition changes by context so that its definition in normal text, a `center` environment, a `flushleft` environment, and a `tabular` are all different. In normal text when it forces a linebreak it is essentially a shorthand for `\newline`. It does not end horizontal mode or end the paragraph, it just inserts some glue and penalties so that when the paragraph does end a linebreak will occur at that point, with the short line padded with white space.

You get '`LaTeX Error: There's no line here to end`' if you use `\\` to ask for a new line, rather than to end the current line. An example is if you have `\begin{document}\\` or, more likely, something like this.

```
\begin{center}
  \begin{minipage}{0.5\textwidth}
  \\
  In that vertical space put your mark.
  \end{minipage}
\end{center}
```

Fix it by replacing the double backslash with something like `\vspace{\baselineskip}`.

9.2 \obeycr & \restorecr

The `\obeycr` command makes a return in the input file ('`^^M`', internally) the same as `\\`, followed by `\relax`. So each new line in the input will also be a new line in the output. The `\restorecr` command restores normal line-breaking behavior.

This is not the way to show verbatim text or computer code. See Section 8.27 [verbatim], page 89, instead.

With LaTeX's usual defaults, this

```
aaa
bbb

\obeycr
ccc
ddd
   eee

\restorecr
fff
ggg

hhh
iii
```

produces output like this.

```
  aaa bbb
  ccc
ddd
eee

fff ggg
  hhh iii
```

The indents are paragraph indents.

9.3 \newline

In ordinary text, this ends a line in a way that does not right-justify the line, so the prior text is not stretched. That is, in paragraph mode (see Chapter 17 [Modes], page 149), the `\newline` command is equivalent to double-backslash (see Section 9.1 [\\], page 92). This command is fragile (see Section 12.9 [\protect], page 113).

However, the two commands are different inside a `tabular` or `array` environment. In a column with a specifier producing a paragraph box such as typically `p{...}`, `\newline` will insert a line end inside of the column; that is, it does not break the entire tabular row. To break the entire row use `\\` or its equivalent `\tabularnewline`.

This will print '`Name:`' and '`Address:`' as two lines in a single cell of the table.

```
\begin{tabular}{p{1in}{\hspace{2in}}p{1in}}
  Name: \newline Address: &Date: \\ \hline
\end{tabular}
```

The '`Date:`' will be baseline-aligned with '`Name:`'.

9.4 \- (discretionary hyphen)

Tell LaTeX that it may hyphenate the word at that point. When you insert `\-` commands in a word, the word will only be hyphenated at those points and not at any of the hyphenation points that LaTeX might otherwise have chosen. This command is robust (see Section 12.9 [\protect], page 113).

LaTeX is good at hyphenating and usually finds most of the correct hyphenation points, while almost never using an incorrect one. The `\-` command is for exceptional cases.

For example, LaTeX does not ordinarily hyphenate words containing a hyphen. Below, the long and hyphenated word means LaTeX has to put in unacceptably large spaces to set the narrow column.

```
\begin{tabular}{rp{1.75in}}
  Isaac Asimov &The strain of
               anti-intellectualism
               % an\-ti-in\-tel\-lec\-tu\-al\-ism
               has been a constant thread winding its way through our
               political and cultural life, nurtured by
               the false notion that democracy means that
               ‘my ignorance is just as good as your knowledge’.
\end{tabular}
```

Commenting out the third line and uncommenting the fourth makes a much better fit.

The `\-` command only allows LaTeX to break there, it does not require that it break there. You can insist on a split with something like `Hef-\linebreak feron`. Of course, if you later change the text then this forced break may look very odd, so this approach requires care.

9.5 \discretionary (generalized hyphenation point)

Synopsis:

```
\discretionary{pre-break}{post-break}{no-break}
```

Handle word changes around hyphens. This command is not often used in LaTeX documents.

If a line break occurs at the point where `\discretionary` appears then TeX puts *pre-break* at the end of the current line and puts *post-break* at the start of the next line. If there is no line break here then TeX puts *no-break*

In '`difficult`' the three letters `ffi` form a ligature. But TeX can nonetheless break between the two f's with this.

```
di\discretionary{f-}{fi}{ffi}cult
```

Note that users do not have to do this. It is typically handled automatically by TeX's hyphenation algorithm.

9.6 `\fussy` & `\sloppy`

Declarations to make TeX more picky or less picky about line breaking. Declaring `\fussy` usually avoids too much space between words, at the cost of an occasional overfull box. Conversely, `\sloppy` avoids overfull boxes while suffering loose interword spacing.

The default is `\fussy`. Line breaking in a paragraph is controlled by whichever declaration is current at the blank line, or `\par`, or displayed equation ending that paragraph. So to affect the line breaks, include that paragraph-ending material in the scope of the command.

9.6.1 `sloppypar`

Synopsis:

```
\begin{sloppypar}
  ... paragraphs ...
\end{sloppypar}
```

Typeset the paragraphs with `\sloppy` in effect (see Section 9.6 [\fussy & \sloppy], page 95). Use this to locally adjust line breaking, to avoid '`Overfull box`' or '`Underfull box`' errors.

The example is simple.

```
\begin{sloppypar}
  Her plan for the morning thus settled, she sat quietly down to her
  book after breakfast, resolving to remain in the same place and the
  same employment till the clock struck one; and from habitude very
  little incommoded by the remarks and ejaculations of Mrs.\ Allen,
  whose vacancy of mind and incapacity for thinking were such, that
  as she never talked a great deal, so she could never be entirely
  silent; and, therefore, while she sat at her work, if she lost her
  needle or broke her thread, if she heard a carriage in the street,
  or saw a speck upon her gown, she must observe it aloud, whether
  there were anyone at leisure to answer her or not.
\end{sloppypar}
```

9.7 \hyphenation

Synopsis:

```
\hyphenation{word1 ...}
```

Declares allowed hyphenation points within the words in the list. The words in that list are separated by spaces. Show permitted points for hyphenation with a dash character, `-`.

Here is an example:

```
\hyphenation{hat-er il-lit-e-ra-ti tru-th-i-ness}
```

Use lowercase letters. TEX will only hyphenate if the word matches exactly. Multiple `\hyphenation` commands accumulate.

9.8 \linebreak & \nolinebreak

Synopses, one of:

```
\linebreak
\linebreak[zero-to-four]
```

or one of these.

```
\nolinebreak
\nolinebreak[zero-to-four]
```

Encourage or discourage a line break. The optional *zero-to-four* is an integer that allows you to soften the instruction. The default is 4, so that without the optional argument these commands entirely force or prevent the break. But for instance, `\nolinebreak[1]` is a suggestion that another place may be better. The higher the number, the more insistent the request. Both commands are fragile (see Section 12.9 [\protect], page 113).

Here we tell LATEX that a good place to put a linebreak is after the standard legal text.

```
\boilerplatelegal{} \linebreak[2]
We especially encourage applications from members of traditionally
underrepresented groups.
```

When you issue `\linebreak`, the spaces in the line are stretched out so that it extends to the right margin. See Section 9.1 [\\], page 92, and Section 9.3 [\newline], page 94, to have the spaces not stretched out.

10 Page breaking

Ordinarily LaTeX automatically takes care of breaking output into pages with its usual aplomb. But if you are writing commands, or tweaking the final version of a document, then you may need to understand how to influence its actions.

LaTeX's algorithm for splitting a document into pages is more complex than just waiting until there is enough material to fill a page and outputting the result. Instead, LaTeX typesets more material than would fit on the page and then chooses a break that is optimal in some way (it has the smallest badness). An example of the advantage of this approach is that if the page has some vertical space that can be stretched or shrunk, such as with rubber lengths between paragraphs, then LaTeX can use that to avoid widow lines (where a new page starts with the last line of a paragraph; LaTeX can squeeze the extra line onto the first page) and orphans (where the first line of paragraph is at the end of a page; LaTeX can stretch the material of the first page so the extra line falls on the second page). Another example is where LaTeX uses available vertical shrinkage to fit on a page not just the header for a new section but also the first two lines of that section.

But LaTeX does not optimize over the entire document's set of page breaks. So it can happen that the first page break is great but the second one is lousy; to break the current page LaTeX doesn't look as far ahead as the next page break. So occasionally you may want to influence page breaks while preparing a final version of a document.

See Chapter 5 [Layout], page 24, for more material that is relevant to page breaking.

10.1 `\clearpage` & `\cleardoublepage`

Synopsis:

```
\clearpage
```

or

```
\cleardoublepage
```

End the current page and output all of the pending floating figures and tables (see Section 5.6 [Floats], page 28). If there are too many floats to fit on the page then LaTeX will put in extra pages containing only floats. In two-sided printing, `\cleardoublepage` also makes the next page of content a right-hand page, an odd-numbered page, if necessary inserting a blank page. The `\clearpage` command is robust while `\cleardoublepage` is fragile (see Section 12.9 [\protect], page 113).

LaTeX's page breaks are optimized so ordinarily you only use this command in a document body to polish the final version, or inside commands.

The `\cleardoublepage` command will put in a blank page, but it will have the running headers and footers. To get a really blank page, use this command.

```
\let\origdoublepage\cleardoublepage
\newcommand{\clearemptydoublepage}{%
  \clearpage
  {\pagestyle{empty}\origdoublepage}%
}
```

If you want LaTeX's standard `\chapter` command to do this then add the line `\let\cleardoublepage\clearemptydoublepage`.

The command `\newpage` (see Section 10.2 [\newpage], page 98) also ends the current page, but without clearing pending floats. And, if LaTeX is in two-column mode then `\newpage` ends the current column while `\clearpage` and `\cleardoublepage` end the current page.

10.2 \newpage

Synopsis:

```
\newpage
```

End the current page. This command is robust (see Section 12.9 [\protect], page 113).

LaTeX's page breaks are optimized so ordinarily you only use this command in a document body to polish the final version, or inside commands.

While the commands `\clearpage` and `\cleardoublepage` also end the current page, in addition they clear pending floats (see Section 10.1 [\clearpage & \cleardoublepage], page 97). And, if LaTeX is in two-column mode then `\clearpage` and `\cleardoublepage` end the current page, possibly leaving an empty column, while `\newpage` only ends the current column.

In contrast with `\pagebreak` (see Section 10.4 [\pagebreak & \nopagebreak], page 99), the `\newpage` command will cause the new page to start right where requested. This

```
Four score and seven years ago our fathers brought forth on this
continent,
\newpage
\noindent a new nation, conceived in Liberty, and dedicated to the
proposition that all men are created equal.
```

makes a new page start after '`continent,`' and the cut-off line is not right justified. In addition, `\newpage` does not vertically stretch out the page, as `\pagebreak` does.

10.3 \enlargethispage

Synopsis, one of:

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

Enlarge the `\textheight` for the current page. The required argument *size* must be a rigid length (see Chapter 14 [Lengths], page 120). It may be positive or negative. This command is fragile (see Section 12.9 [\protect], page 113).

A common strategy is to wait until you have the final text of a document, and then pass through it tweaking line and page breaks. This command allows you some page size leeway.

This will allow one extra line on the current page.

```
\enlargethispage{\baselineskip}
```

The starred form `\enlargesthispage*` tries to squeeze the material together on the page as much as possible, for the common use case of getting one more line on the page. This is often used together with an explicit `\pagebreak`.

10.4 \pagebreak & \nopagebreak

Synopses:

```
\pagebreak
\pagebreak[zero-to-four]
```

or

```
\nopagebreak
\nopagebreak[zero-to-four]
```

Encourage or discourage a page break. The optional *zero-to-four* is an integer that allows you to soften the request. The default is 4, so that without the optional argument these commands entirely force or prevent the break. But for instance `\nopagebreak[1]` suggests to LaTeX that another spot might be preferable. The higher the number, the more insistent the request. Both commands are fragile (see Section 12.9 [\protect], page 113).

LaTeX's page endings are optimized so ordinarily you only use this command in a document body to polish the final version, or inside commands.

If you use these inside a paragraph, they apply to the point following the line in which they appear. So this

```
Four score and seven years ago our fathers brought forth on this
continent,
\pagebreak
a new nation, conceived in Liberty, and dedicated to the proposition
that all men are created equal.
```

does not give a page break at '`continent,`' but instead at '`nation,`' since that is where LaTeX breaks that line. In addition, with `\pagebreak` the vertical space on the page is stretched out where possible so that it extends to the normal bottom margin. This can look strange, and if `\flushbottom` is in effect this can cause you to get '`Underfull \vbox (badness 10000) has occurred while \output is active`'. See Section 10.2 [\newpage], page 98, for a command that does not have these effects.

11 Footnotes

Place a footnote at the bottom of the current page, as here.

```
Noël Coward quipped that having to read a footnote is like having
to go downstairs to answer the door, while in the midst of making
love.\footnote{%
  I wouldn't know, I don't read footnotes.}
```

You can put multiple footnotes on a page. If the footnote text becomes too long then it will flow to the next page.

You can also produce footnotes by combining the `\footnotemark` and the `\footnotetext` commands, which is useful in special circumstances.

To make bibliographic references come out as footnotes you need to include a bibliographic style with that behavior (see Section 8.24.4 [Using BibTeX], page 87).

11.1 `\footnote`

Synopsis, one of:

```
\footnote{text}
\footnote[number]{text}
```

Place a footnote *text* at the bottom of the current page.

```
There are over a thousand footnotes in Gibbon's
\textit{Decline and Fall of the Roman Empire}.\footnote{%
  After reading an early version with endnotes David Hume complained,
  ``One is also plagued with his Notes, according to the present Method
  of printing the Book'' and suggested that they ``only to be printed
  at the Margin or the Bottom of the Page.''}
```

The optional argument *number* allows you to specify the number of the footnote. If you use this then LaTeX does not increment the `footnote` counter.

By default, LaTeX uses arabic numbers as footnote markers. Change this with something like `\renewcommand{\thefootnote}{\fnsymbol{footnote}}`, which uses a sequence of symbols (see Section 13.1 [\alph \Alph \arabic \roman \Roman \fnsymbol], page 116). To make this change global put that in the preamble. If you make the change local then you may want to reset the counter with `\setcounter{footnote}{0}`.

LaTeX determines the spacing of footnotes with two parameters.

`\footnoterule`

Produces the rule separating the main text on a page from the page's footnotes. Default dimensions in the standard document classes (except `slides`, where it does not appear) is: vertical thickness of `0.4pt`, and horizontal size of `0.4\columnwidth` long. Change the rule with something like this.

```
\renewcommand{\footnoterule}{% Kerns avoid vertical space
  \kern -3pt                   % This -3 is negative
  \hrule width \textwidth height 1pt % of the sum of this 1
  \kern 2pt}                   % and this 2
```

`\footnotesep`

The height of the strut placed at the beginning of the footnote (see Section 19.13 [\strut], page 163). By default, this is set to the normal strut for `\footnotesize` fonts (see Section 4.2 [Font sizes], page 20), therefore there is no extra space between footnotes. This is '`6.65pt`' for '`10pt`', '`7.7pt`' for '`11pt`', and '`8.4pt`' for '`12pt`'. Change it as with `\setlength{\footnotesep}{11pt}`.

The `\footnote` command is fragile (see Section 12.9 [\protect], page 113).

LaTeX's default puts many restrictions on where you can use a `\footnote`; for instance, you cannot use it in an argument to a sectioning command such as `\chapter` (it can only be used in outer paragraph mode; see Chapter 17 [Modes], page 149). There are some workarounds; see following sections.

In a `minipage` environment the `\footnote` command uses the `mpfootnote` counter instead of the `footnote` counter, so they are numbered independently. They are shown at the bottom of the environment, not at the bottom of the page. And by default they are shown alphabetically. See Section 8.18 [minipage], page 65, and Section 11.5 [Footnotes in a table], page 102.

11.2 `\footnotemark`

Synopsis, one of:

```
\footnotemark
\footnotemark[number]
```

Put the current footnote mark in the text. To specify associated text for the footnote see Section 11.3 [\footnotetext], page 102. The optional argument *number* causes the command to use that number to determine the footnote mark. This command can be used in inner paragraph mode (see Chapter 17 [Modes], page 149).

If you use `\footnotemark` without the optional argument then it increments the footnote counter but if you use the optional *number* then it does not. The next example produces several consecutive footnote markers referring to the same footnote.

```
The first theorem\footnote{Due to Gauss.}
and the second theorem\footnotemark[\value{footnote}]
and the third theorem.\footnotemark[\value{footnote}]
```

If there are intervening footnotes then you must remember the value of the common mark. This example gives the same institutional affiliation to both the first and third authors (`\thanks` is a version of `footnote`), by-hand giving the number of the footnote.

```
\title{A Treatise on the Binomial Theorem}
\author{J Moriarty\thanks{University of Leeds}
  \and A C Doyle\thanks{Durham University}
  \and S Holmes\footnotemark[1]}
\begin{document}
\maketitle
```

This uses a counter to remember the footnote number. The third sentence is followed by the same footnote marker as the first.

```
\newcounter{footnoteValueSaver}
```

```
All babies are illogical.\footnote{%
  Lewis Carroll.}\setcounter{footnoteValueSaver}{\value{footnote}}
Nobody is despised who can manage a crocodile.\footnote{%
  Captain Hook.}
Illogical persons are despised.\footnotemark[\value{footnoteValueSaver}]
Therefore, anyone who can manage a crocodile is not a baby.
```

This example accomplishes the same by using the package `cleveref`.

```
\usepackage{cleveref}[2012/02/15]   % in preamble
\crefformat{footnote}{#2\footnotemark[#1]#3}
...
The theorem is from Evers.\footnote{\label{fn:TE}Tinker, Evers, 1994.}
The corollary is from Chance.\footnote{Evers, Chance, 1990.}
But the key lemma is from Tinker.\cref{fn:TE}
```

It will work with the package `hyperref`.

11.3 \footnotetext

Synopsis, one of:

```
\footnotetext{text}
\footnotetext[number]{text}
```

Place *text* at the bottom of the page as a footnote. It pairs with `\footnotemark` (see Section 11.2 [\footnotemark], page 101) and can come anywhere after that command, but must appear in outer paragraph mode (see Chapter 17 [Modes], page 149). The optional argument *number* changes the number of the footnote mark.

See Section 11.2 [\footnotemark], page 101, and Section 11.5 [Footnotes in a table], page 102, for usage examples.

11.4 Footnotes in section headings

Putting a footnote in a section heading, as in:

```
\section{Full sets\protect\footnote{This material due to ...}}
```

causes the footnote to appear at the bottom of the page where the section starts, as usual, but also at the bottom of the table of contents, where it is not likely to be desired. The simplest way to have it not appear on the table of contents is to use the optional argument to `\section`

```
\section[Please]{Please\footnote{%
  Don't footnote in chapter and section headers!}}
```

No `\protect` is needed in front of `\footnote` here because what gets moved to the table of contents is the optional argument.

11.5 Footnotes in a table

Inside a `tabular` or `array` environment the `\footnote` command does not work; there is a footnote mark in the table cell but the footnote text does not appear. The solution is to use a `minipage` environment as here (see Section 8.18 [minipage], page 65).

```
\begin{center}
```

```
  \begin{minipage}{\textwidth} \centering
     \begin{tabular}{l|l}
       \textsc{Ship}           &\textsc{Book} \\ \hline
       \textit{HMS Sophie}     &Master and Commander  \\
       \textit{HMS Polychrest} &Post Captain  \\
       \textit{HMS Lively}     &Post Captain \\
       \textit{HMS Surprise}   &A number of books\footnote{%
                                  Starting with HMS Surprise.}
     \end{tabular}
  \end{minipage}
\end{center}
```

Inside a `minipage`, footnote marks are lowercase letters. Change that with something like `\renewcommand{\thempfootnote}{\arabic{mpfootnote}}` (see Section 13.1 [\alph \Alph \arabic \roman \Roman \fnsymbol], page 116).

The footnotes in the prior example appear at the bottom of the `minipage`. To have them appear at the bottom of the main page, as part of the regular footnote sequence, use the `\footnotemark` and `\footnotetext` pair and make a new counter.

```
\newcounter{mpFootnoteValueSaver}
\begin{center}
  \begin{minipage}{\textwidth}
    \setcounter{mpFootnoteValueSaver}{\value{footnote}} \centering
     \begin{tabular}{l|l}
       \textsc{Woman}             &\textsc{Relationship} \\ \hline
       Mona                       &Attached\footnotemark  \\
       Diana Villiers             &Eventual wife  \\
       Christine Hatherleigh Wood &Fiance\footnotemark
     \end{tabular}
  \end{minipage}%  percent sign keeps footnote text close to minipage
  \stepcounter{mpFootnoteValueSaver}%
    \footnotetext[\value{mpFootnoteValueSaver}]{%
      Little is known other than her death.}%
  \stepcounter{mpFootnoteValueSaver}%
    \footnotetext[\value{mpFootnoteValueSaver}]{%
      Relationship is unresolved in XXI.}
\end{center}
```

For a floating `table` environment (see Section 8.22 [table], page 78), use the `tablefootnote` package.

```
\usepackage{tablefootnote}  % in preamble
   ...
\begin{table}
  \centering
     \begin{tabular}{l|l}
     \textsc{Date}  &\textsc{Campaign} \\ \hline
     1862           &Fort Donelson \\
     1863           &Vicksburg     \\
     1865           &Army of Northern Virginia\tablefootnote{%
```

```
                        Ending the war.}
     \end{tabular}
    \caption{Forces captured by US Grant}
\end{table}
```

The footnote appears at the page bottom and is numbered in sequence with other footnotes.

11.6 Footnotes of footnotes

Particularly in the humanities, authors can have multiple classes of footnotes, including having footnotes of footnotes. The package `bigfoot` extends LaTeX's default footnote mechanism in many ways, including allow these two, as in this example.

```
\usepackage{bigfoot}    % in preamble
\DeclareNewFootnote{Default}
\DeclareNewFootnote{from}[alph]   % create class \footnotefrom{}
 ...
The third theorem is a partial converse of the
second.\footnotefrom{%
  First noted in Wilson.\footnote{Second edition only.}}
```

12 Definitions

LaTeX has support for making new commands of many different kinds.

12.1 \newcommand & \renewcommand

Synopses, one of:

```
\newcommand{\cmd}{defn}
\newcommand{\cmd}[nargs]{defn}
\newcommand{\cmd}[nargs][optargdefault]{defn}
\newcommand*{\cmd}{defn}
\newcommand*{\cmd}[nargs]{defn}
\newcommand*{\cmd}[nargs][optargdefault]{defn}
```

or one of these.

```
\renewcommand{\cmd}[nargs]{defn}
\renewcommand{\cmd}[nargs]{defn}
\renewcommand{\cmd}[nargs][optargdefault]{defn}
\renewcommand*{\cmd}{defn}
\renewcommand*{\cmd}[nargs]{defn}
\renewcommand*{\cmd}[nargs][optargdefault]{defn}
```

Define or redefine a command. See also the discussion of `\DeclareRobustCommand` in Section 3.3.2 [Class and package commands], page 12. The starred form of these two requires that the arguments not contain multiple paragraphs of text (in plain TeX terms that it not be `\long`).

These are the parameters:

cmd

Required; the command name. It must begin with a backslash, `\`, and must not begin with the four letter string `\end`. For `\newcommand`, it must not be already defined. For `\renewcommand`, this name must already be defined.

nargs

Optional; an integer from 0 to 9, specifying the number of arguments that the command takes, including any optional argument. Omitting this argument is the same as specifying 0, meaning that the command has no arguments. If you redefine a command, the new version can have a different number of arguments than the old version.

optargdefault

Optional; if this argument is present then the first argument of `\cmd` is optional, with default value *optargdefault* (which may be the empty string). If this argument is not present then `\cmd` does not take an optional argument.

That is, if `\cmd` is used with square brackets, as in `\cmd[optval]{...}...`, then within *defn* the parameter `#1` is set to the value of *optval*. On the other hand, if `\cmd` is called without the square brackets then within *defn* the parameter `#1` is set to the value of *optargdefault*. In either case, the required arguments start with `#2`.

Omitting `[optargdefault]` is different from having the square brackets with no contents, as in `[]`. The former sets `#1` to the value of *optargdefault*; the latter sets `#1` to the empty string.

defn Required; the text to be substituted for every occurrence of `\cmd`. The parameters `#1`, `#2`, ... `#nargs` are replaced by the values that you supply when you call the command (or by the default value if there is an optional argument and you don't exercise the option).

TEX ignores spaces in the source following an alphabetic control sequence, as in '`\cmd `'. If you actually want a space there, one solution is to type `{}` after the command ('`\cmd{} `', and another solution is to use an explicit control space ('`\cmd\ `').

A simple example of defining a new command: `\newcommand{\RS}{Robin Smith}` results in `\RS` being replaced by the longer text. Redefining an existing command is similar: `\renewcommand{\qedsymbol}{{\small QED}}`.

If you try to define a command and the name has already been used then you get something like '`LaTeX Error: Command \fred already defined. Or name \end... illegal, see p.192 of the manual`'. If you try to redefine a command and the name has not yet been used then you get something like '`LaTeX Error: \hank undefined`'.

Here the first command definition has no arguments, and the second has one required argument.

```
\newcommand{\student}{Ms~O'Leary}
\newcommand{\defref}[1]{Definition~\ref{#1}}
```

Use the first as in `I highly recommend \student{} to you`. The second has a variable, so that `\defref{def:basis}` expands to `Definition~\ref{def:basis}`, which ultimately expands to something like '`Definition~3.14`'.

Similarly, but with two required arguments: `\newcommand{\nbym}[2]{$#1 \times #2$}` is invoked as `\nbym{2}{k}`.

This example has an optional argument.

```
\newcommand{\salutation}[1][Sir or Madam]{Dear #1:}
```

Then `\salutation` gives '`Dear Sir or Madam:`' while `\salutation[John]` gives '`Dear John:`'. And `\salutation[]` gives '`Dear :`'.

This example has an optional argument and two required arguments.

```
\newcommand{\lawyers}[3][company]{#2, #3, and~#1}
I employ \lawyers[Howe]{Dewey}{Cheatem}.
```

The output is '`I employ Dewey, Cheatem, and Howe`'. The optional argument, the `Howe`, is associated with `#1`, while `Dewey` and `Cheatem` are associated with `#2` and `#3`. Because of the optional argument, `\lawyers{Dewey}{Cheatem}` will give the output '`I employ Dewey, Cheatem, and company`'.

The braces around *defn* do not define a group, that is, they do not delimit the scope of the result of expanding *defn*. For example, with `\newcommand{\shipname}[1]{\it #1}`, in this sentence,

```
The \shipname{Monitor} met the \shipname{Merrimac}.
```

the words '`met the`' would incorrectly be in italics. The solution is to put another pair of braces inside the definition: `\newcommand{\shipname}[1]{{\it #1}}`.

12.2 \providecommand

Synopses, one of:

```
\providecommand{cmd}{defn}
\providecommand{cmd}[nargs]{defn}
\providecommand{cmd}[nargs][optargdefault]{defn}
\providecommand*{cmd}{defn}
\providecommand*{cmd}[nargs]{defn}
\providecommand*{cmd}[nargs][optargdefault]{defn}
```

Defines a command, as long as no command of this name already exists. If no command of this name already exists then this has the same effect as `\newcommand`. If a command of this name already exists then this definition does nothing. This is particularly useful in a file that may be loaded more than once, such as a style file. See Section 12.1 [\newcommand & \renewcommand], page 105, for the description of the arguments.

This example

```
\providecommand{\myaffiliation}{Saint Michael's College}
\providecommand{\myaffiliation}{Saint Michael's College}
From \myaffiliation.
```

outputs '`From Saint Michael's College`'. Unlike `\newcommand`, the repeated use of `\providecommand` does not give an error.

12.3 \newcounter: Allocating a counter

Synopsis, one of:

```
\newcounter{countername}
\newcounter{countername}[supercounter]
```

Globally defines a new counter named *countername* and initialize it to zero (see Chapter 13 [Counters], page 116).

The name *countername* must consist of letters only. It does not begin with a backslash. This name must not already be in use by another counter.

When you use the optional argument `[supercounter]` then the counter *countername* will be reset to zero whenever *supercounter* is incremented. For example, ordinarily `subsection` is numbered within `section` so that any time you increment *section*, either with `\stepcounter` (see Section 13.7 [\stepcounter], page 119) or `\refstepcounter` (see Section 13.6 [\refstepcounter], page 118), then LaTeX will reset *subsection* to zero.

This example

```
\newcounter{asuper}  \setcounter{asuper}{1}
\newcounter{asub}[asuper] \setcounter{asub}{3}   % Note 'asuper'
The value of asuper is \arabic{asuper} and of asub is \arabic{asub}.
\stepcounter{asuper}
Now asuper is \arabic{asuper} while asub is \arabic{asub}.
```

produces '`The value of asuper is 1 and that of asub is 3`' and '`Now asuper is 2 while asub is 0`'.

If the counter already exists, for instance by entering `asuper` twice, then you get something like '`LaTeX Error: Command \c@asuper already defined. Or name \end... illegal, see p.192 of the manual.`'.

If you use the optional argument then the super counter must already exist. Entering `\newcounter{jh}[lh]` when `lh` is not a defined counter will get you '`LaTeX Error: No counter 'lh' defined.`'

12.4 \newlength

Synopsis:

```
\newlength{arg}
```

Allocate a new length register (see Chapter 14 [Lengths], page 120). The required argument *arg* must begin with a backslash, `\`. The new register holds rubber lengths such as `72.27pt` or `1in plus.2in minus.1in` (a LaTeX length register is what plain TeX calls a `skip` register). The initial value is zero. The control sequence `\arg` must not be already defined.

An example:

```
\newlength{\graphichgt}
```

If you forget the backslash then you get '`Missing control sequence inserted`'. If the command sequence already exists then you get something like '`LaTeX Error: Command \graphichgt already defined. Or name \end... illegal, see p.192 of the manual`'.

12.5 \newsavebox

Synopsis:

```
\newsavebox{cmd}
```

Define `\cmd` to refer to a new "bin" for storing boxes. Such a box is for holding typeset material, to use multiple times or to measure or manipulate (see Chapter 20 [Boxes], page 167). The required bin name *cmd* must start with a backslash, `\`, and must not already be defined. This command is fragile (see Section 12.9 [\protect], page 113).

The first line here sets you up to save the material for later use.

```
\newsavebox{\logobox}
\savebox{\logobox}{LoGo}
Our logo is \usebox{\logobox}.
```

The output is '`Our logo is LoGo`'.

If there is an already defined bin then you get something like '`LaTeX Error: Command \logobox already defined. Or name \end... illegal, see p.192 of the manual`'.

The allocation of a box is global.

12.6 \newenvironment & \renewenvironment

Synopses, one of:

```
\newenvironment{env}{begdef}{enddef}
\newenvironment{env}[nargs]{begdef}{enddef}
\newenvironment{env}[nargs][optargdefault]{begdef}{enddef}
\newenvironment*{env}{begdef}{enddef}
\newenvironment*{env}[nargs]{begdef}{enddef}
\newenvironment*{env}[nargs][optargdefault]{begdef}{enddef}
```

or one of these.

```
\renewenvironment{env}{begdef}{enddef}
\renewenvironment{env}[nargs]{begdef}{enddef}
\renewenvironment{env}[nargs][optargdefault]{begdef}{enddef}
\renewenvironment*{env}{begdef}{enddef}
\renewenvironment*{env}[nargs]{begdef}{enddef}
\renewenvironment*{env}[nargs][optargdefault]{begdef}{enddef}
```

Define or redefine the environment *env*, that is, create the construct `\begin{env} ... body ... \end{env}`.

The starred form of these commands requires that the arguments not contain multiple paragraphs of text. However, the body of these environments can contain multiple paragraphs.

env Required; the environment name. It consists only of letters or the `*` character, and thus does not begin with backslash, `\`. It must not begin with the string `end`. For `\newenvironment`, the name *env* must not be the name of an already existing environment, and also the command `\env` must be undefined. For `\renewenvironment`, *env* must be the name of an existing environment.

nargs Optional; an integer from 0 to 9 denoting the number of arguments of that the environment takes. When you use the environment these arguments appear after the `\begin`, as in `\begin{env}{arg1} ... {argn}`. Omitting this is equivalent to setting it to 0; the environment will have no arguments. When redefining an environment, the new version can have a different number of arguments than the old version.

optargdefault

Optional; if this is present then the first argument of the defined environment is optional, with default value *optargdefault* (which may be the empty string). If this is not in the definition then the environment does not take an optional argument.

That is, when *optargdefault* is present in the definition of the environment then you can start the environment with square brackets, as in `\begin{env}[optval]{...} ... \end{env}`. In this case, within *begdefn* the parameter `#1` is set to the value of *optval*. If you call `\begin{env}` without square brackets, then within *begdefn* the parameter `#1` is set to the value of the default *optargdefault*. In either case, any required arguments start with `#2`.

Omitting `[myval]` in the call is different than having the square brackets with no contents, as in `[]`. The former results in `#1` expanding to *optargdefault*; the latter results in `#1` expanding to the empty string.

begdef Required; the text expanded at every occurrence of `\begin{env}`. Within *begdef*, the parameters `#1`, `#2`, ... `#nargs`, are replaced by the values that you supply when you call the environment; see the examples below.

enddef Required; the text expanded at every occurrence of `\end{env}`. This may not contain any parameters, that is, you cannot use `#1`, `#2`, etc., here (but see the final example below).

All environments, that is to say the *begdef* code, the environment body, and the *enddef* code, are processed within a group. Thus, in the first example below, the effect of the `\small` is limited to the quote and does not extend to material following the environment.

If you try to define an environment and the name has already been used then you get something like '`LaTeX Error: Command \fred already defined. Or name \end... illegal, see p.192 of the manual`'. If you try to redefine an environment and the name has not yet been used then you get something like '`LaTeX Error: Environment hank undefined.`'.

This example gives an environment like LaTeX's `quotation` except that it will be set in smaller type.

```
\newenvironment{smallquote}{%
  \small\begin{quotation}
}{%
  \end{quotation}
}
```

This has an argument, which is set in boldface at the start of a paragraph.

```
\newenvironment{point}[1]{%
  \noindent\textbf{#1}
}{%
}
```

This one shows the use of a optional argument; it gives a quotation environment that cites the author.

```
\newenvironment{citequote}[1][Shakespeare]{%
  \begin{quotation}
  \noindent\textit{#1}:
}{%
  \end{quotation}
}
```

The author's name is optional, and defaults to '`Shakespeare`'. In the document, use the environment like this.

```
\begin{citequote}[Lincoln]
  ...
\end{citequote}
```

The final example shows how to save the value of an argument to use in *enddef*, in this case in a box (see Section 20.5 [\sbox & \savebox], page 171).

```
\newsavebox{\quoteauthor}
\newenvironment{citequote}[1][Shakespeare]{%
  \sbox\quoteauthor{#1}%
  \begin{quotation}
}{%
  \hspace{1em plus 1fill}---\usebox{\quoteauthor}
  \end{quotation}
}
```

12.7 \newtheorem

Synopses:

```
\newtheorem{name}{title}
\newtheorem{name}{title}[numbered_within]
\newtheorem{name}[numbered_like]{title}
```

Define a new theorem-like environment. You can specify one of *numbered_within* and *numbered_like*, or neither, but not both.

The first form, `\newtheorem{name}{title}`, creates an environment that will be labelled with *title*; see the first example below.

The second form, `\newtheorem{name}{title}[numbered_within]`, creates an environment whose counter is subordinate to the existing counter *numbered_within*, so this counter will be reset when *numbered_within* is reset. See the second example below.

The third form `\newtheorem{name}[numbered_like]{title}`, with optional argument between the two required arguments, creates an environment whose counter will share the previously defined counter *numbered_like*. See the third example.

This command creates a counter named *name*. In addition, unless the optional argument *numbered_like* is used, inside of the theorem-like environment the current `\ref` value will be that of `\the`*numbered_within* (see Section 7.3 [\ref], page 44).

This declaration is global. It is fragile (see Section 12.9 [\protect], page 113).

Arguments:

name The name of the environment. It is a string of letters. It must not begin with a backslash, `\`. It must not be the name of an existing environment, and the command name `\`*name* must not already be defined.

title The text to be printed at the beginning of the environment, before the number. For example, '`Theorem`'.

numbered_within
Optional; the name of an already defined counter, usually a sectional unit such as `chapter` or `section`. When the *numbered_within* counter is reset then the *name* environment's counter will also be reset.

If this optional argument is not used then the command `\the`*name* is set to `\arabic{`*name*`}`.

numbered_like
Optional; the name of an already defined theorem-like environment. The new environment will be numbered in sequence with *numbered_like*.

Without any optional arguments the environments are numbered sequentially. The example below has a declaration in the preamble that results in '`Definition 1`' and '`Definition 2`' in the output.

```
\newtheorem{defn}{Definition}
\begin{document}
\section{...}
\begin{defn}
  First def
```

```
\end{defn}

\section{...}
\begin{defn}
  Second def
\end{defn}
```

This example has the same document body as the prior one. But here `\newtheorem`'s optional argument *numbered_within* is given as `section`, so the output is like '`Definition 1.1`' and '`Definition 2.1`'.

```
\newtheorem{defn}{Definition}[section]
\begin{document}
\section{...}
\begin{defn}
  First def
\end{defn}

\section{...}
\begin{defn}
  Second def
\end{defn}
```

In the next example there are two declarations in the preamble, the second of which calls for the new `thm` environment to use the same counter as `defn`. It gives '`Definition 1.1`', followed by '`Theorem 2.1`' and '`Definition 2.2`'.

```
\newtheorem{defn}{Definition}[section]
\newtheorem{thm}[defn]{Theorem}
\begin{document}
\section{...}
\begin{defn}
  First def
\end{defn}

\section{...}
\begin{thm}
  First thm
\end{thm}

\begin{defn}
  Second def
\end{defn}
```

12.8 \newfont

This command is obsolete. This description is here only to help with old documents. New documents should define fonts in families through the New Font Selection Scheme which allows you to, for example, associate a boldface with a roman (see Chapter 4 [Fonts], page 18).

Synopsis:

```
\newfont{\cmd}{font description}
```

Define a command `\cmd` that will change the current font. The control sequence must must not already be defined. It must begin with a backslash, `\`.

The *font description* consists of a *fontname* and an optional *at clause*. LaTeX will look on your system for a file named `fontname.tfm`. The at clause can have the form either `at dimen` or `scaled factor`, where a *factor* of '1000' means no scaling. For LaTeX's purposes, all this does is scale all the character and other font dimensions relative to the font's design size, which is a value defined in the `.tfm` file.

This defines two equivalent fonts and typesets a few characters in each.

```
\newfont{\testfontat}{cmb10 at 11pt}
\newfont{\testfontscaled}{cmb10 scaled 1100}
\testfontat abc
\testfontscaled abc
```

12.9 \protect

All LaTeX commands are either *fragile* or *robust*. A fragile command can break when it is used in the argument to certain other commands. Commands that contain data that LaTeX writes to an auxiliary file and re-reads later are fragile. This includes material that goes into a table of contents, list of figures, list of tables, etc. Fragile commands also include line breaks, any command that has an optional argument, and many more. To prevent such commands from breaking, one solution is to preceded them with the command `\protect`.

For example, when LaTeX runs the `\section{section name}` command it writes the *section name* text to the `.aux` auxiliary file, moving it there for use elsewhere in the document such as in the table of contents. Any argument that is internally expanded by LaTeX without typesetting it directly is referred to as a *moving argument*. A command is fragile if it can expand during this process into invalid TeX code. Some examples of moving arguments are those that appear in the `\caption{...}` command (see Section 8.10 [figure], page 54), in the `\thanks{...}` command (see Section 18.1 [\maketitle], page 151), and in @-expressions in the `tabular` and `array` environments (see Section 8.23 [tabular], page 79).

If you get strange errors from commands used in moving arguments, try preceding it with `\protect`. Every fragile commands must be protected with their own `\protect`.

Although usually a `\protect` command doesn't hurt, length commands are robust and should not be preceded by a `\protect` command. Nor can a `\protect` command be used in the argument to `\addtocounter` or `\setcounter` command.

In this example the `\caption` command gives a mysterious error about an extra curly brace. Fix the problem by preceding each `\raisebox` command with `\protect`.

```
\begin{figure}
  ...
  \caption{Company headquarters of A\raisebox{1pt}{B}\raisebox{-1pt}{C}}
\end{figure}
```

In the next example the `\tableofcontents` command gives an error because the `\(..\)` in the section title expands to illegal TeX in the `.toc` file. You can solve this by changing `\(..\)` to `\protect\(..\protect\)`.

```
\begin{document}
\tableofcontents
...
\section{Einstein's \( e=mc^2 \)}
...
```

12.10 \ignorespaces & \ignorespacesafterend

Synopsis:

```
\ignorespaces
```

or

```
\ignorespacesafterend
```

Both commands cause LaTeX to ignore spaces after the end of the command up until the first non-space character. The first is a command from Plain TeX, and the second is LaTeX-specific.

The `ignorespaces` is often used when defining commands via `\newcommand`, or `\newenvironment`, or `\def`. The example below illustrates. It allows a user to show the points values for quiz questions in the margin but it is inconvenient because, as shown in the `enumerate` list, users must not put any space between the command and the question text.

```
\newcommand{\points}[1]{\makebox[0pt]{\makebox[10em][l]{#1~pts}}
\begin{enumerate}
  \item\points{10}no extra space output here
  \item\points{15} extra space between the number and the 'extra'
\end{enumerate}
```

The solution is to change to this.

```
\newcommand{\points}[1]{%
  \makebox[0pt]{\makebox[10em][l]{#1~pts}}\ignorespaces}
```

A second example shows spaces being removed from the front of text. The commands below allow a user to uniformly attach a title to names. But, as given, if a title accidentally starts with a space then `\fullname` will reproduce that.

```
\makeatletter
\newcommand{\honorific}[1]{\def\@honorific{#1}} % remember title
\newcommand{\fullname}[1]{\@honorific~#1}       % put title before name
\makeatother
\begin{tabular}{|l|}
\honorific{Mr/Ms}  \fullname{Jones} \\  % no extra space here
\honorific{ Mr/Ms} \fullname{Jones}     % extra space before title
\end{tabular}
```

To fix this, change to `\newcommand{\fullname}[1]{\ignorespaces\@honorific~#1}`.

The `\ignorespaces` is also often used in a `\newenvironment` at the end of the *begin* clause, that is, as part of the second argument, as in `\begin{newenvironment}{`*env name*`}{... \ignorespaces}{...}`.

To strip spaces off the end of an environment use `\ignorespacesafterend`. An example is that this will show a much larger vertical space between the first and second environments than between the second and third.

```
\newenvironment{eq}{\begin{equation}}{\end{equation}}
\begin{eq}
e=mc^2
\end{eq}
\begin{equation}
F=ma
\end{equation}
\begin{equation}
E=IR
\end{equation}
```

Putting a comment character `%` immediately after the `\end{eq}` will make the vertical space disappear, but that is inconvenient. The solution is to change to `\newenvironment{eq}{\begin{equation}}{\end{equation}\ignorespacesafterend}`.

13 Counters

Everything LaTeX numbers for you has a counter associated with it. The name of the counter is often the same as the name of the environment or command associated with the number, except that the counter's name has no backslash \. Thus, associated with the `\chapter` command is the `chapter` counter that keeps track of the chapter number.

Below is a list of the counters used in LaTeX's standard document classes to control numbering.

`part`	`paragraph`	`figure`	`enumi`
`chapter`	`subparagraph`	`table`	`enumii`
`section`	`page`	`footnote`	`enumiii`
`subsection`	`equation`	`mpfootnote`	`enumiv`
`subsubsection`			

The `mpfootnote` counter is used by the `\footnote` command inside of a minipage (see Section 8.18 [minipage], page 65). The counters `enumi` through `enumiv` are used in the `enumerate` environment, for up to four levels of nesting (see Section 8.7 [enumerate], page 51).

Counters can have any integer value but they are typically positive.

New counters are created with `\newcounter`. See Section 12.3 [\newcounter], page 107.

13.1 \alph \Alph \arabic \roman \Roman \fnsymbol: Printing counters

Print the value of a counter, in a specified style. For instance, if the counter *counter* has the value 1 then a `\alph{`*counter*`}` in your source will result in a lowercase letter a appearing in the output.

All of these commands take a single counter as an argument, for instance, `\alph{enumi}`. Note that the counter name does not start with a backslash.

`\alph{`*counter*`}`
: Print the value of *counter* in lowercase letters: 'a', 'b', ... If the counter's value is less than 1 or more than 26 then you get '`LaTeX Error: Counter too large.`'

`\Alph{`*counter*`}`
: Print in uppercase letters: 'A', 'B', ... If the counter's value is less than 1 or more than 26 then you get '`LaTeX Error: Counter too large.`'

`\arabic{`*counter*`}`
: Print in Arabic numbers such as '`5`' or '`-2`'.

`\roman{`*counter*`}`
: Print in lowercase roman numerals: 'i', 'ii', ... If the counter's value is less than 1 then you get no warning or error but LaTeX does not print anything in the output.

`\Roman{`*counter*`}`
: Print in uppercase roman numerals: 'I', 'II', ... If the counter's value is less than 1 then you get no warning or error but LaTeX does not print anything in the output.

`\fnsymbol{`*counter*`}`

Prints the value of *counter* using a sequence of nine symbols that are traditionally used for labeling footnotes. The value of *counter* should be between 1 and 9, inclusive. If the counter's value is less than 0 or more than 9 then you get '`LaTeX Error: Counter too large`', while if it is 0 then you get no error or warning but LaTeX does not output anything.

Here are the symbols:

Number	Name	Command	Symbol
1	asterisk	`\ast`	*
2	dagger	`\dagger`	†
3	ddagger	`\ddagger`	‡
4	section-sign	`\S`	§
5	paragraph-sign	`\P`	¶
6	double-vert	`\parallel`	‖
7	double-asterisk	`\ast\ast`	**
8	double-dagger	`\dagger\dagger`	††
9	double-ddagger	`\ddagger\ddagger`	‡‡

13.2 `\usecounter`

Synopsis:

```
\usecounter{counter}
```

Used in the second argument of the `list` environment (see Section 8.16 [list], page 59), this declares that list items will be numbered by *counter*. It initializes *counter* to zero, and arranges that when `\item` is called without its optional argument then *counter* is incremented by `\refstepcounter`, making its value be the current `ref` value (see Section 7.3 [\ref], page 44). This command is fragile (see Section 12.9 [\protect], page 113).

Put in the document preamble, this example makes a new list environment enumerated with *testcounter*:

```
\newcounter{testcounter}
\newenvironment{test}{%
  \begin{list}{}{%
    \usecounter{testcounter}
  }
}{%
  \end{list}
}
```

13.3 `\value`

Synopsis:

```
\value{counter}
```

Expands to the value of the counter *counter*. (Note that the name of a counter does not begin with a backslash.)

This example outputs '`Test counter is 6. Other counter is 5.`'.

```
\newcounter{test} \setcounter{test}{5}
\newcounter{other} \setcounter{other}{\value{test}}
\addtocounter{test}{1}

Test counter is \arabic{test}.
Other counter is \arabic{other}.
```

The `\value` command is not used for typesetting the value of the counter. For that, see Section 13.1 [\alph \Alph \arabic \roman \Roman \fnsymbol], page 116.

It is often used in `\setcounter` or `\addtocounter` but `\value` can be used anywhere that LaTeX expects a number, such as in `\hspace{\value{foo}\parindent}`. It must not be preceded by `\protect` (see Section 12.9 [\protect], page 113).

This example inserts `\hspace{4\parindent}`.

```
\setcounter{myctr}{3} \addtocounter{myctr}{1}
\hspace{\value{myctr}\parindent}
```

13.4 \setcounter

Synopsis:

```
\setcounter{counter}{value}
```

Globally set the counter *counter* to have the value of the *value* argument, which must be an integer. Thus, you can set a counter's value as `\setcounter{section}{5}`. Note that the counter name does not start with a backslash.

In this example if the counter `theorem` has value 12 then the second line will print '`XII`'.

```
\setcounter{exercise}{\value{theorem}}
Here it is in Roman: \Roman{exercise}.
```

13.5 \addtocounter

Synopsis:

```
\addtocounter{counter}{value
```

Globally increment *counter* by the amount specified by the *value* argument, which may be negative.

In this example the section value appears as '`VII`'.

```
\setcounter{section}{5}
\addtocounter{section}{2}
Here it is in Roman: \Roman{section}.
```

13.6 \refstepcounter

Synopsis:

```
\refstepcounter{counter}
```

Globally increments the value of *counter* by one, as does `\stepcounter` (see Section 13.7 [\stepcounter], page 119). The difference is that this command resets the value of any

counter numbered within it. (For the definition of "counters numbered within", see Section 12.3 [\newcounter], page 107.)

In addition, this command also defines the current `\ref` value to be the result of `\thecounter`.

While the counter value is set globally, the `\ref` value is set locally, i.e., inside the current group.

13.7 \stepcounter

Synopsis:

```
\stepcounter{counter}
```

Globally adds one to *counter* and resets all counters numbered within it. (For the definition of "counters numbered within", see Section 12.3 [\newcounter], page 107.)

This command differs from `\refstepcounter` in that this one does not influence references — it does not define the current `\ref` value to be the result of `\thecounter` (see Section 13.6 [\refstepcounter], page 118).

13.8 \day & \month & \year

LaTeX defines the counter `\day` for the day of the month (nominally with value between 1 and 31), `\month` for the month of the year (nominally with value between 1 and 12), and year `\year`. When TeX starts up, they are set from the current values on the system. The related command `\today` produces a string representing the current day (see Section 23.8 [\today], page 195).

They counters are not updated as the job progresses so in principle they could be incorrect by the end. In addition, TeX does no sanity check:

```
\day=-2 \month=13 \year=-4 \today
```

gives no error or warning and results in the output '`-2, -4`' (the bogus month value produces no output).

14 Lengths

A *length* is a measure of distance. Many LaTeX commands take a length as an argument.

This shows a box of the given length.

```
\newcommand{\blackbar}[1]{\rule{#1}{10pt}}   % make a bar
\newcommand{\showhbox}[2]{\fboxsep=0pt\fbox{\hbox to #1{#2}}} % box it
XXX\showhbox{100pt}{\blackbar{100pt}}YYY
```

It produces a black bar 100 points long between '`XXX`' and '`YYY`'.

Lengths come in two types. A *rigid length* (what Plain TeX calls a *dimen*) such as `10pt` does not contain a `plus` or `minus` component. The above example shows a rigid length. A *rubber length* (what Plain TeX calls a *skip*) can contain those components, as with `1cm plus0.05cm minus0.01cm`. Here the `1cm` is the *natural length* while the other two, the `plus` and `minus` components, allow the length to stretch or shrink.

Shrinking is simpler: with `1cm minus 0.05cm`, the natural length is 1 cm but if smaller is needed then TeX can shrink it down as far as 0.95 cm. Beyond that, TeX refuses to shrink any more. Thus, below the first one works fine, producing a space of 98 points between the two bars.

```
XXX\showhbox{300pt}{%
  \blackbar{101pt}\hspace{100pt minus 2pt}\blackbar{101pt}}YYY

XXX\showhbox{300pt}{%
  \blackbar{105pt}\hspace{100pt minus 1pt}\blackbar{105pt}}YYY
```

But the second one gets a warning like '`Overfull \hbox (1.0pt too wide) detected at line 17`'. In the output the first '`Y`' is overwritten by the end of the black bar, because the box's material is wider than the 300 pt allocated, as TeX has refused to shrink the total to less than 309 points.

Stretching is like shrinking except that if TeX is asked to stretch beyond the given amount, it won't refuse. Here the first line is fine, producing a space of 110 points between the bars.

```
XXX\showhbox{300pt}{%
  \blackbar{95pt}\hspace{100pt plus 10pt}\blackbar{95pt}}YYY

XXX\showhbox{300pt}{%
  \blackbar{95pt}\hspace{100pt plus 1pt}\blackbar{95pt}}YYY
```

In the second line TeX needs a stretch of 10 points and only 1 point was specified. In this situation, TeX stretches the space to the required length, but it complains with a warning like '`Underfull \hbox (badness 10000) detected at line 22`'. (We won't discuss badness; the point is that the system was not given as much stretch as needed.)

You can put both stretch and shrink in the same length, as in `1ex plus 0.05ex minus 0.02ex`.

If TeX is setting two or more rubber lengths then it allocates the stretch or shrink in proportion.

```
XXX\showhbox{300pt}{\blackbar{100pt}%  left
  \hspace{0pt plus 50pt}\blackbar{80pt}\hspace{0pt plus 10pt}%  middle
```

```
\blackbar{100pt}}YYY  % right
```

The outside bars take up 100 points, so the middle needs another 100. In the middle the bar takes up 80 points, so the two `\hspace`'s must stretch 20 points. Because the two say `plus 50pt` and `plus 10pt`, TEX gets 5/6 of the stretch from the first space and 1/6 from the second.

The `plus` or `minus` component of a rubber length can contain a *fill* component, as in `1in plus2fill`. This gives the length infinite stretchability or shrinkability so that TEX could set it to any distance. Here the two figures will be equal-spaced across the page.

```
\begin{minipage}{\linewidth}
  \hspace{0pt plus 1fill}\includegraphics{godel.png}%
  \hspace{0pt plus 1fill}\includegraphics{einstein.png}%
  \hspace{0pt plus 1fill}
\end{minipage}
```

TEX actually has three infinite glue components `fil`, `fill`, and `filll`. The later ones are more infinite than the earlier ones. Ordinarily document authors only use the middle one (see Section 19.3 [\hfill], page 156, and see Section 19.15 [\vfill], page 165).

Multiplying a rubber length by a number turns it into a rigid length, so that after `\setlength{\ylength}{1in plus 0.2in}` and `\setlength{\zlength}{3\ylength}` then the value of `\zlength` is `3in`.

14.1 Units of length

TEX and LATEX know about these units both inside and outside of math mode.

`pt` Point 1/72.27 inch. The conversion to metric units, to two decimal places, is 1 point = 2.85 mm = 28.45 cm.

`pc` Pica, 12 pt

`in` Inch, 72.27 pt

`bp` Big point, 1/72 inch. This length is the definition of a point in PostScript and many desktop publishing systems.

`cm` Centimeter

`mm` Millimeter

`dd` Didot point, 1.07 pt

`cc` Cicero, 12 dd

`sp` Scaled point, 1/65536 pt

Two other lengths that are often used are values set by the designer of the font. The x-height of the current font *ex*, traditionally the height of the lowercase letter x, is often used for vertical lengths. Similarly *em*, traditionally the width of the capital letter M, is often used for horizontal lengths (there is also `\enspace`, which is `0.5em`). Use of these can help make a definition work better across font changes. For example, a definition of the vertical space between list items given as `\setlength{\itemsep}{1ex plus 0.05ex minus 0.01ex}` is more likely to still be reasonable if the font is changed than a definition given in points.

In math mode, many definitions are expressed in terms of the math unit *mu* given by 1 em = 18 mu, where the em is taken from the current math symbols family. See Section 16.6 [Spacing in math mode], page 145.

14.2 \setlength

Synopsis:

```
\setlength{len}{amount}
```

Set the length *len* to *amount*. The length name *len* must begin with a backslash, `\`. The `amount` can be a rubber length (see Chapter 14 [Lengths], page 120). It can be positive, negative or zero, and can be in any units that LaTeX understands (see Section 14.1 [Units of length], page 121).

Below, with LaTeX's defaults the first paragraph will be indented while the second will not.

```
I told the doctor I broke my leg in two places.

\setlength{\parindent}{0em}
He said stop going to those places.
```

If there is no such length *len* then you get something like '`Undefined control sequence. <argument> \praindent`'.

14.3 \addtolength

Synopsis:

```
\addtolength{len}{amount}
```

Increment the length *len* by *amount*. The length name *len* begins with a backslash, `\`. The `amount` is a rubber length (see Chapter 14 [Lengths], page 120). It can be positive, negative or zero, and can be in any units that LaTeX understands (see Section 14.1 [Units of length], page 121).

Below, if `\parskip` starts with the value `0pt plus 1pt`

```
\addtolength{\parskip}{1pt}
Doctor: how is the boy who swallowed the silver dollar?

Nurse: no change.
```

then it has the value `1pt plus 1pt` for the second paragraph.

If there is no such length *len* then you get something like '`Undefined control sequence. <argument> \praindent`'. If you leave off the backslash at the start of *len*, as in `\addtolength{parindent}{1pt}`, then you get something like '`You can't use 'the letter p' after \advance`'.

14.4 \settodepth

Synopsis:

```
\settodepth{len}{text}
```

Set the length *len* to the depth of box that LaTeX gets on typesetting the *text* argument. The length name *len* must begin with a backslash, \.

This will show how low the character descenders go.

```
\newlength{\alphabetdepth}
\settodepth{\alphabetdepth}{abcdefghijklmnopqrstuvwxyz}
\the\alphabetdepth
```

If there is no such length *len* then you get something like '`Undefined control sequence. <argument> \alphabetdepth`'. If you leave the backslash out of *len*, as in `\settodepth{alphabetdepth}{...}` then you get something like '`Missing number, treated as zero. <to be read again> \setbox`'.

14.5 \settoheight

Synopsis:

```
\settoheight{len}{text}
```

Sets the length *len* to the height of box that LaTeX gets on typesetting the `text` argument. The length name *len* must begin with a backslash, \.

This will show how high the characters go.

```
\newlength{\alphabetheight}
\settoheight{\alphabetheight}{abcdefghijklmnopqrstuvwxyz}
\the\alphabetheight
```

If there is no such length *len* then you get something like '`Undefined control sequence. <argument> \alphabetheight`'. If you leave the backslash out of *len*, as in `\settoheight{alphabetheight}{...}` then you get something like '`Missing number, treated as zero. <to be read again> \setbox`'.

14.6 \settowidth

Synopsis:

```
\settowidth{len}{text}
```

Set the length *len* to the width of the box that LaTeX gets on typesetting the *text* argument. The length name *len* must begin with a backslash, \.

This measures the width of the lowercase ASCII alphabet.

```
\newlength{\alphabetwidth}
\settowidth{\alphabetwidth}{abcdefghijklmnopqrstuvwxyz}
\the\alphabetwidth
```

If there is no such length *len* then you get something like '`Undefined control sequence. <argument> \alphabetwidth`'. If you leave the backslash out of *len*, as in `\settoheight{alphabetwidth}{...}` then you get something like '`Missing number, treated as zero. <to be read again> \setbox`'.

15 Making paragraphs

Once LaTeX has all of a paragraph's contents it divides it into lines, in a way that is optimized over the entire paragraph (see Chapter 9 [Line breaking], page 92). To end the current paragraph, put an empty line.

```
It is a truth universally acknowledged, that a single man in possession
of a good fortune, must be in want of a wife.

However little known the feelings or views of such a man may be on his
first entering a neighbourhood, this truth is so well fixed in the minds
of the surrounding families, that he is considered the rightful property
of some one or other of their daughters.

``My dear Mr. Bennet,'' said his lady to him one day,
``have you heard that Netherfield Park is let at last?''
```

The separator lines must be empty, including not containing a comment character, `%`.

There are places where a new paragraph is not permitted. Don't put a blank line in math mode (see Chapter 17 [Modes], page 149); here the line before the `\end{equation}`

```
\begin{equation}
  2^{|S|} > |S|

\end{equation}
```

will get you the error '`Missing $ inserted`'. Similarly, the blank line in this `section` argument

```
\section{aaa

bbb}
```

gets '`Runaway argument? {aaa ! Paragraph ended before \@sect was complete`'.

15.1 \par

Synopsis (note that while reading the input TeX, converts two consecutive newlines to a `\par`):

```
\par
```

End the current paragraph. The usual way to separate paragraphs is with a blank line but the `\par` command is entirely equivalent. This command is robust (see Section 12.9 [\protect], page 113).

This example uses `\par` rather than a blank line simply for readability.

```
\newcommand{\syllabusLegalese}{%
  \whatCheatingIs\par\whatHappensWhenICatchYou}
```

The `\par` command does nothing in LR mode or a vertical mode but it terminates paragraph mode, bringing LaTeX to vertical mode (see Chapter 17 [Modes], page 149).

You cannot use the `\par` command in math mode or in the argument of many commands, such as the `\section` command (see Chapter 15 [Making paragraphs], page 124, and see Section 12.1 [\newcommand & \renewcommand], page 105).

The `\par` command differs from the `\paragraph` command in that the latter is, like `\section` or `\subsection`, a sectioning unit used by the standard LaTeX documents.

The `\par` command differs from `\newline` and the line break double backslash, `\\`, in that \par ends the paragraph not just the line. It also triggers the addition of the between-paragraph vertical space `\parskip` (see Section 15.3 [\parindent & \parskip], page 126).

The output from this example

```
xyz

\setlength{\parindent}{3in}
\setlength{\parskip}{5in}
\noindent test\indent test1\par test2
```

is: after '`xyz`' there is a vertical skip of 5 inches and then '`test`' appears, aligned with the left margin. On the same line, there is an empty horizontal space of 3 inches and then '`test1`' appears. Finally. there is a vertical space of 5 inches, followed by a fresh paragraph with a paragraph indent of 3 inches, and then LaTeX puts the text '`test2`'.

15.2 \indent & \noindent

Synopsis:

```
\indent
```

or

```
\noindent
```

Go into horizontal mode (see Chapter 17 [Modes], page 149). The `\indent` command first outputs an empty box whose width is `\parindent`. These commands are robust (see Section 12.9 [\protect], page 113).

Ordinarily you create a new paragraph by putting in a blank line. See Section 15.1 [\par], page 124, for the difference between this command and `\par`. To start a paragraph without an indent, or to continue an interrupted paragraph, use `\noindent`.

In the middle of a paragraph the `\noindent` command has no effect, because LaTeX is already in horizontal mode there. The `\indent` command's only effect is to output a space.

This example starts a fresh paragraph.

```
... end of the prior paragraph.

\noindent This paragraph is not indented.
```

and this continues an interrupted paragraph.

```
The data

\begin{center}
  \begin{tabular}{rl} ... \end{tabular}
\end{center}

\noindent shows this clearly.
```

To omit indentation in the entire document put `\setlength{\parindent}{0pt}` in the preamble. If you do that, you may want to also set the length of spaces between paragraphs, `\parskip` (see Section 15.3 [\parindent & \parskip], page 126).

Default LaTeX styles have the first paragraph after a section that is not indented, as is traditional typesetting in English. To change that, look on CTAN for the package `indentfirst`.

15.3 \parindent & \parskip

Synopsis:

```
\setlength{\parskip}{horizontal len}
\setlength{\parinden}{vertical len}
```

Both are a rubber lengths (see Chapter 14 [Lengths], page 120). They give the indentation of ordinary paragraphs, not paragraphs inside minipages (see Section 8.18 [minipage], page 65), and the vertical space between paragraphs.

This, put in the preamble,

```
\setlength{\parindent}{0em}
\setlength{\parskip}{1ex}
```

arranges that the document will have paragraphs that are not indented, but instead are vertically separated by about the height of a lowercase 'x'.

In standard LaTeX documents, the default value for `\parindent` in one-column documents is `15pt` when the default text size is `10pt` , `17pt` for `11pt`, and `1.5em` for `12pt`. In two-column documents it is `1em`. The default value for `\parskip` in LaTeX's standard document styles is `0pt plus1pt`.

15.4 Marginal notes

Synopsis, one of:

```
\marginpar{right}
\marginpar[left]{right}
```

Create a note in the margin. The first line of the note will have the same baseline as the line in the text where the `\marginpar` occurs.

The margin that LaTeX uses for the note depends on the current layout (see Section 3.1 [Document class options], page 9) and also on `\reversemarginpar` (see below). If you are using one-sided layout (document option `oneside`) then it goes in the right margin. If you are using two-sided layout (document option `twoside`) then it goes in the outside margin. If you are in two-column layout (document option `twocolumn`) then it goes in the nearest margin.

If you declare `\reversemarginpar` then LaTeX will place subsequent marginal notes in the opposite margin to that given in the prior paragraph. Revert that to the default position with `\normalmarginpar`.

When you specify the optional argument *left* then it is used for a note in the left margin, while the mandatory argument *right* is used for a note in the the right margin.

Normally, a note's first word will not be hyphenated. You can enable hyphenation there by beginning *left* or *right* with `\hspace{0pt}`.

These parameters affect the formatting of the note:

`\marginparpush`
: Minimum vertical space between notes; default '`7pt`' for '`12pt`' documents, '`5pt`' else.

`\marginparsep`
: Horizontal space between the main text and the note; default '`11pt`' for '`10pt`' documents, '`10pt`' else.

`\marginparwidth`
: Width of the note itself; default for a one-sided '`10pt`' document is '`90pt`', '`83pt`' for '`11pt`', and '`68pt`' for '`12pt`'; '`17pt`' more in each case for a two-sided document. In two column mode, the default is '`48pt`'.

The standard LaTeX routine for marginal notes does not prevent notes from falling off the bottom of the page.

16 Math formulas

Produce mathematical text by putting LaTeX into math mode or display math mode (see Chapter 17 [Modes], page 149). This example shows both.

```
The wave equation for \( u \) is
\begin{displaymath}
  \frac{\partial^2u}{\partial t^2} = c^2\nabla^2u
\end{displaymath}
where \( \nabla^2 \) is the spatial Laplacian and \( c \) is constant.
```

Math mode is for inline mathematics. In the above example it is invoked by the starting `\(` and finished by the matching ending `\)`. Display math mode is for displayed equations and here is invoked by the `displaymath` environment. Note that any mathematical text whatever, including mathematical text consisting of just one character, is handled in math mode.

When in math mode or display math mode, LaTeX handles many aspects of your input text differently than in other text modes. For example,

```
contrast x+y with \( x+y \)
```

in math mode the letters are in italics and the spacing around the plus sign is different.

There are three ways to make inline formulas, to put LaTeX in math mode.

```
\( mathematical material \)
$ mathematical material $
\begin{math} mathematical material \end{math}
```

The first form is preferred and the second is quite common, but the third form is rarely used. You can sometimes use one and sometimes another, as in `\(x\) and $y$`. You can use these in paragraph mode or in LR mode (see Chapter 17 [Modes], page 149).

To make displayed formulas, put LaTeX into display math mode with either:

```
\begin{displaymath}
  mathematical material
\end{displaymath}
```

or

```
\begin{equation}
  mathematical material
\end{equation}
```

(see Section 8.5 [displaymath], page 50, see Section 8.9 [equation], page 53). The only difference is that with the `equation` environment, LaTeX puts a formula number alongside the formula. The construct `\[` *math* `\]` is equivalent to `\begin{displaymath}` *math* `\end{displaymath}`. These environments can only be used in paragraph mode (see Chapter 17 [Modes], page 149).

The two mathematics modes are similar, but there are some differences. One involves the placement of subscripts and superscripts; in display math mode they are further apart and in inline math mode they are closer together.

Sometimes you want the display math typographical treatment to happen in the inline math mode. For this, the `\displaystyle` declaration forces the size and style of the formula

to be that of `displaymath`. Thus `\(\displaystyle \sum_{n=0}^\infty x_n\)` will have the limits above and below the summation sign, not next to it. Another example is that

```
\begin{tabular}{r|cc}
  \textsc{Name}  &\textsc{Series}  &\textsc{Sum}  \\  \hline
  Arithmetic     &\( a+(a+b)+(a+2b)+\cdots+(a+(n-1)b) \)
                   &\( na+(n-1)n\cdot\frac{b}{2}\)  \\
  Geometric      &\( a+ab+ab^2+\cdots+ab^{n-1} \)
                   &\(\displaystyle a\cdot\frac{1-b^n}{1-b}\)  \\
\end{tabular}
```

because it has no `\displaystyle`, the '`Arithmetic`' line's fraction will be scrunched. But, because of its `\displaystyle`, the '`Geometric`' line's fraction will be easy to read, with characters the same size as in the rest of the line.

The American Mathematical Society has made freely available a set of packages that greatly expand your options for writing mathematics, `amsmath` and `amssymb` (also be aware of the `mathtools` package that is an extension to, and loads, `amsmath`). New documents that will have mathematical text should use these packages. Descriptions of these packages is outside the scope of this document; see their documentation on CTAN.

16.1 Subscripts & superscripts

Synopsis (in math mode or display math mode), one of:

```
base^exp
base^{exp}
```

or, one of:

```
base_exp
base_{exp}
```

Make *exp* appear as a superscript of *base* (with the caret character, `^`) or a subscript (with underscore, `_`).

In this example the `0`'s and `1`'s are subscripts while the `2`'s are superscripts.

```
\( (x_0+x_1)^2 \leq (x_0)^2+(x_1)^2 \)
```

To have the subscript or superscript contain more than one character, surround the expression with curly braces, as in `e^{-2x}`. This example's fourth line shows curly braces used to group an expression for the exponent.

```
\begin{displaymath}
  (3^3)^3=27^3=19\,683
  \qquad
  3^{(3^3)}=3^{27}=7\,625\,597\,484\,987
\end{displaymath}
```

LaTeX knows how to handle a superscript on a superscript, or a subscript on a subscript, or supers on subs, or subs on supers. So, expressions such as `e^{x^2}` and `x_{i_0}` give correct output. Note the use in those expressions of curly braces to give the *base* a determined *exp*. If you enter `\(3^3^3\)` then you get '`Double superscript`'.

LaTeX does the right thing when something has both a subscript and a superscript. In this example the integral has both. They come out in the correct place without any author intervention.

```
\begin{displaymath}
  \int_{x=a}^b f'(x)\,dx = f(b)-f(a)
\end{displaymath}
```

Note the parentheses around `x=a` to make the entire expression a subscript.

To put a superscript or subscript before a symbol, use a construct like `{}_t K^2`. The empty curly braces `{}` give the subscript something to attach to and keeps it from accidentally attaching to a prior symbols.

Using the subscript or superscript command outside of math mode or display math mode, as in `the expression x^2`, will get you the error '`Missing $ inserted`'.

A common reason to want subscripts outside of a mathematics mode is to typeset chemical formulas. There are packages for that such as `mhchem`; see CTAN.

16.2 Math symbols

LaTeX provides almost any mathematical or technical symbol that anyone uses. For example, if you include `$\pi$` in your source, you will get the pi symbol π. See the `Comprehensive LaTeX Symbol List` at `https://ctan.org/tex-archive/info/symbols/comprehensive/`.

Here is a list of commonly-used symbols. It is by no means exhaustive. Each symbol is described with a short phrase, and its symbol class, which determines the spacing around it, is given in parenthesis. Unless said otherwise, the commands for these symbols can be used only in math mode. To redefine a command so that it can be used whatever the current mode, see Section 17.1 [\ensuremath], page 149.

`\|` $\|$ Parallel (relation). Synonym: `\parallel`.

`\aleph` $\aleph$ Aleph, transfinite cardinal (ordinary).

`\alpha` α Lowercase Greek letter alpha (ordinary).

`\amalg` $\amalg$ Disjoint union (binary)

`\angle` $\angle$ Geometric angle (ordinary). Similar: less-than sign `<` and angle bracket `\langle`.

`\approx` $\approx$ Almost equal to (relation).

`\ast` $*$ Asterisk operator, convolution, six-pointed (binary). Synonym: `*`, which is often a superscript or subscript, as in the Kleene star. Similar: `\star`, which is five-pointed, and is sometimes used as a general binary operation, and sometimes reserved for cross-correlation.

`\asymp` $\asymp$ Asymptotically equivalent (relation).

`\backslash`
$\backslash$ Backslash (ordinary). Similar: set minus `\setminus`, and `\textbackslash` for backslash outside of math mode.

`\beta` β Lowercase Greek letter beta (ordinary).

`\bigcap` $\bigcap$ Variable-sized, or n-ary, intersection (operator). Similar: binary intersection `\cap`.

`\bigcirc` $\bigcirc$ Circle, larger (binary). Similar: function composition `\circ`.

`\bigcup` $\bigcup$ Variable-sized, or n-ary, union (operator). Similar: binary union `\cup`.

`\bigodot` $\bigodot$ Variable-sized, or n-ary, circled dot operator (operator).

`\bigoplus`
$\bigoplus$ Variable-sized, or n-ary, circled plus operator (operator).

`\bigotimes`
$\bigotimes$ Variable-sized, or n-ary, circled times operator (operator).

`\bigtriangledown`
$\bigtriangledown$ Variable-sized, or n-ary, open triangle pointing down (operator).

`\bigtriangleup`
$\bigtriangleup$ Variable-sized, or n-ary, open triangle pointing up (operator).

`\bigsqcup`
$\bigsqcup$ Variable-sized, or n-ary, square union (operator).

`\biguplus`
$\biguplus$ Variable-sized, or n-ary, union operator with a plus (operator). (Note that the name has only one p.)

`\bigvee` $\bigvee$ Variable-sized, or n-ary, logical-and (operator).

`\bigwedge`
$\bigwedge$ Variable-sized, or n-ary, logical-or (operator).

`\bot` $\bot$ Up tack, bottom, least element of a partially ordered set, or a contradiction (ordinary). See also `\top`.

`\bowtie` $\bowtie$ Natural join of two relations (relation).

`\Box` $\Box$ Modal operator for necessity; square open box (ordinary). Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\bullet` $\bullet$ Bullet (binary). Similar: multiplication dot `\cdot`.

`\cap` $\cap$ Intersection of two sets (binary). Similar: variable-sized operator `\bigcap`.

`\cdot` $\cdot$ Multiplication (binary). Similar: Bullet dot `\bullet`.

`\chi` χ Lowercase Greek chi (ordinary).

`\circ` $\circ$ Function composition, ring operator (binary). Similar: variable-sized operator `\bigcirc`.

`\clubsuit`
$\clubsuit$ Club card suit (ordinary).

`\complement`
$\complement$ Set complement, used as a superscript as in `$S^\complement$` (ordinary). Not available in plain TEX. In LATEX you need to load the `amssymb` package. Also used: `$S^{\mathsf{c}}$` or `$\bar{S}$`.

`\cong` $\cong$ Congruent (relation).

`\coprod` $\coprod$ Coproduct (operator).

`\cup` $\cup$ Union of two sets (binary). Similar: variable-sized operator `\bigcup`.

`\dagger` $\dagger$ Dagger relation (binary).

`\dashv` $\dashv$ Dash with vertical, reversed turnstile (relation). Similar: turnstile `\vdash`.

`\ddagger` $\ddagger$ Double dagger relation (binary).

`\Delta` Δ Greek uppercase delta, used for increment (ordinary).

`\delta` δ Greek lowercase delta (ordinary).

`\Diamond` $\Diamond$ Large diamond operator (ordinary). Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\diamond` $\diamond$ Diamond operator (binary). Similar: large diamond `\Diamond`, circle bullet `\bullet`.

`\diamondsuit`
$\diamondsuit$ Diamond card suit (ordinary).

`\div` $\div$ Division sign (binary).

`\doteq` $\doteq$ Approaches the limit (relation). Similar: geometrically equal to `\Doteq`.

`\downarrow`
$\downarrow$ Down arrow, converges (relation). Similar: `\Downarrow` double line down arrow.

`\Downarrow`
$\Downarrow$ Double line down arrow (relation). Similar: `\downarrow` single line down arrow.

`\ell` ℓ Lowercase cursive letter l (ordinary).

`\emptyset`
$\emptyset$ Empty set symbol (ordinary). The variant form is `\varnothing`.

`\epsilon` ϵ Lowercase lunate epsilon (ordinary). Similar to Greek text letter. More widely used in mathematics is the script small letter epsilon `\varepsilon` ε. Related: the set membership relation `\in` $\in$.

`\equiv` $\equiv$ Equivalence (relation).

`\eta` η Lowercase Greek letter (ordinary).

`\exists` $\exists$ Existential quantifier (ordinary).

`\flat` $\flat$ Musical flat (ordinary).

`\forall` $\forall$ Universal quantifier (ordinary).

`\frown` $\frown$ Downward curving arc (ordinary).

`\Gamma` Γ uppercase Greek letter (ordinary).

`\gamma` γ Lowercase Greek letter (ordinary).

`\ge` $\geq$ Greater than or equal to (relation). This is a synonym for `\geq`.

`\geq` $\geq$ Greater than or equal to (relation). This is a synonym for `\ge`.

`\gets` ← Is assigned the value (relation). Synonym: `\leftarrow`.

`\gg` ≫ Much greater than (relation). Similar: much less than `\ll`.

`\hbar` ℏ Planck constant over two pi (ordinary).

`\heartsuit`
♡ Heart card suit (ordinary).

`\hookleftarrow`
↩ Hooked left arrow (relation).

`\hookrightarrow`
↪ Hooked right arrow (relation).

`\iff` ⟺ If and only if (relation). It is `\Longleftrightarrow` with a `\thickmuskip` on either side.

`\Im` ℑ Imaginary part (ordinary). See: real part `\Re`.

`\imath` Dotless i; used when you are putting an accent on an i (see Section 16.4 [Math accents], page 144).

`\in` ∈ Set element (relation). See also: lowercase lunate epsilon `\epsilon`ϵ and small letter script epsilon `\varepsilon`.

`\infty` ∞ Infinity (ordinary).

`\int` ∫ Integral (operator).

`\iota` ι Lowercase Greek letter (ordinary).

`\Join` Condensed bowtie symbol (relation). Not available in Plain TEX.

`\jmath` Dotless j; used when you are putting an accent on a j (see Section 16.4 [Math accents], page 144).

`\kappa` κ Lowercase Greek letter (ordinary).

`\Lambda` Λ uppercase Greek letter (ordinary).

`\lambda` λ Lowercase Greek letter (ordinary).

`\land` ∧ Logical and (binary). This is a synonym for `\wedge`. See also logical or `\lor`.

`\langle` ⟨ Left angle, or sequence, bracket (opening). Similar: less-than `<`. Matches `\rangle`.

`\lbrace` { Left curly brace (opening). Synonym: `\{`. Matches `\rbrace`.

`\lbrack` [Left square bracket (opening). Synonym: `[`. Matches `\rbrack`.

`\lceil` ⌈ Left ceiling bracket, like a square bracket but with the bottom shaved off (opening). Matches `\rceil`.

`\le` ≤ Less than or equal to (relation). This is a synonym for `\leq`.

`\leadsto` Squiggly right arrow (relation). Not available in plain TEX. In LATEX you need to load the `amssymb` package. To get this symbol outside of math mode you can put `\newcommand*{\Leadsto}{\ensuremath{\leadsto}}` in the preamble and then use `\Leadsto` instead.

`\Leftarrow`
: ⇐ Is implied by, double-line left arrow (relation). Similar: single-line left arrow `\leftarrow`.

`\leftarrow`
: ← Single-line left arrow (relation). Synonym: `\gets`. Similar: double-line left arrow `\Leftarrow`.

`\leftharpoondown`
: ↽ Single-line left harpoon, barb under bar (relation).

`\leftharpoonup`
: ↼ Single-line left harpoon, barb over bar (relation).

`\Leftrightarrow`
: ⇔ Bi-implication; double-line double-headed arrow (relation). Similar: single-line double headed arrow `\leftrightarrow`.

`\leftrightarrow`
: ↔ Single-line double-headed arrow (relation). Similar: double-line double headed arrow `\Leftrightarrow`.

`\leq` ≤ Less than or equal to (relation). This is a synonym for `\le`.

`\lfloor` ⌊ Left floor bracket (opening). Matches: `\floor`.

`\lhd` Arrowhead, that is, triangle, pointing left (binary). Not available in plain TEX. In LATEX you need to load the `amssymb` package. For the normal subgroup symbol you should load `amssymb` and use `\vartriangleleft` (which is a relation and so gives better spacing).

`\ll` ≪ Much less than (relation). Similar: much greater than `\gg`.

`\lnot` ¬ Logical negation (ordinary). Synonym: `\neg`.

`\longleftarrow`
: ⟵ Long single-line left arrow (relation). Similar: long double-line left arrow `\Longleftarrow`.

`\longleftrightarrow`
: ⟷ Long single-line double-headed arrow (relation). Similar: long double-line double-headed arrow `\Longleftrightarrow`.

`\longmapsto`
: ⟼ Long single-line left arrow starting with vertical bar (relation). Similar: shorter version `\mapsto`.

`\longrightarrow`
: ⟶ Long single-line right arrow (relation). Similar: long double-line right arrow `\Longrightarrow`.

`\lor` ∨ Logical or (binary). Synonym: wedge `\wedge`.

`\mapsto` ↦ Single-line left arrow starting with vertical bar (relation). Similar: longer version `\longmapsto`.

`\mho` Conductance, half-circle rotated capital omega (ordinary). Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\mid` | Single-line vertical bar (relation). A typical use of `\mid` is for a set `\{\, x \mid x\geq 5 \,\}`.

Similar: `\vert` and `|` produce the same single-line vertical bar symbol but without any spacing (they fall in class ordinary) and you should not use them as relations but instead only as ordinals, i.e., footnote symbols. For absolute value, see the entry for `\vert` and for norm see the entry for `\Vert`.

`\models` ⊨ Entails, or satisfies; double turnstile, short double dash (relation). Similar: long double dash `\vDash`.

`\mp` ∓ Minus or plus (relation).

`\mu` μ Lowercase Greek letter (ordinary).

`\nabla` ∇ Hamilton's del, or differential, operator (ordinary).

`\natural` ♮ Musical natural notation (ordinary).

`\ne` ≠ Not equal (relation). Synonym: `\neq`.

`\nearrow` ↗ North-east arrow (relation).

`\neg` ¬ Logical negation (ordinary). Synonym: `\lnot`. Sometimes instead used for negation: `\sim`.

`\neq` ≠ Not equal (relation). Synonym: `\ne`.

`\ni` ∋ Reflected membership epsilon; has the member (relation). Synonym: `\owns`. Similar: is a member of `\in`.

`\not` / Long solidus, or slash, used to overstrike a following operator (relation).

Many negated operators are available that don't require `\not`, particularly with the `amssymb` package. For example, `\notin` is typographically preferable to `\not\in`.

`\notin` ∉ Not an element of (relation). Similar: not subset of `\nsubseteq`.

`\nu` ν Lowercase Greek letter (ordinary).

`\nwarrow` ↖ North-west arrow (relation).

`\odot` ⊙ Dot inside a circle (binary). Similar: variable-sized operator `\bigodot`.

`\oint` ∮ Contour integral, integral with circle in the middle (operator).

`\Omega` Ω uppercase Greek letter (ordinary).

`\omega` ω Lowercase Greek letter (ordinary).

`\ominus` ⊖ Minus sign, or dash, inside a circle (binary).

`\oplus` ⊕ Plus sign inside a circle (binary). Similar: variable-sized operator `\bigoplus`.

`\oslash` ⊘ Solidus, or slash, inside a circle (binary).

`\otimes` ⊗ Times sign, or cross, inside a circle (binary). Similar: variable-sized operator `\bigotimes`.

`\owns` $\ni$ Reflected membership epsilon; has the member (relation). Synonym: `\ni`. Similar: is a member of `\in`.

`\parallel`
$\parallel$ Parallel (relation). Synonym: `\|`.

`\partial` ∂ Partial differential (ordinary).

`\perp` $\perp$ Perpendicular (relation). Similar: `\bot` uses the same glyph but the spacing is different because it is in the class ordinary.

`\phi` ϕ Lowercase Greek letter (ordinary). The variant form is `\varphi` φ.

`\Pi` Π uppercase Greek letter (ordinary).

`\pi` π Lowercase Greek letter (ordinary). The variant form is `\varpi` ϖ.

`\pm` $\pm$ Plus or minus (binary).

`\prec` $\prec$ Precedes (relation). Similar: less than `<`.

`\preceq` $\preceq$ Precedes or equals (relation). Similar: less than or equals `\leq`.

`\prime` $\prime$ Prime, or minute in a time expression (ordinary). Typically used as a superscript: `$f^\prime$`; `$f^\prime$` and `$f'$` produce the same result. An advantage of the second is that `$f'''$` produces the desired symbol, that is, the same result as `$f^{\prime\prime\prime}$`, but uses rather less typing. You can only use `\prime` in math mode. Using the right single quote `'` in text mode produces a different character (apostrophe).

`\prod` $\prod$ Product (operator).

`\propto` $\propto$ Is proportional to (relation)

`\Psi` Ψ uppercase Greek letter (ordinary).

`\psi` ψ Lowercase Greek letter (ordinary).

`\rangle` $\rangle$ Right angle, or sequence, bracket (closing). Similar: greater than `>`. Matches:`\langle`.

`\rbrace` $\}$ Right curly brace (closing). Synonym: `\}`. Matches `\lbrace`.

`\rbrack` $]$ Right square bracket (closing). Synonym: `]`. Matches `\lbrack`.

`\rceil` $\rceil$ Right ceiling bracket (closing). Matches `\lceil`.

`\Re` $\Re$ Real part, real numbers, cursive capital R (ordinary). Related: double-line, or blackboard bold, R `\mathbb{R}`; to access this, load the `amsfonts` package.

`\restriction`
$\restriction$ Restriction of a function (relation). Synonym: `\upharpoonright`. Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\revemptyset`
$\revemptyset$ Reversed empty set symbol (ordinary). Related: `\varnothing`. Not available in plain TEX. In LATEX you need to load the `stix` package.

`\rfloor` $\rfloor$ Right floor bracket, a right square bracket with the top cut off (closing). Matches `\lfloor`.

`\rhd` Arrowhead, that is, triangle, pointing right (binary). Not available in plain TEX. In LATEX you need to load the `amssymb` package. For the normal subgroup symbol you should instead load `amssymb` and use `\vartriangleright` (which is a relation and so gives better spacing).

`\rho` ρ Lowercase Greek letter (ordinary). The variant form is `\varrho` ϱ.

`\Rightarrow`
$\Rightarrow$ Implies, right-pointing double line arrow (relation). Similar: right single-line arrow `\rightarrow`.

`\rightarrow`
$\rightarrow$ Right-pointing single line arrow (relation). Synonym: `\to`. Similar: right double line arrow `\Rightarrow`.

`\rightharpoondown`
$\rightharpoondown$ Right-pointing harpoon with barb below the line (relation).

`\rightharpoonup`
$\rightharpoonup$ Right-pointing harpoon with barb above the line (relation).

`\rightleftharpoons`
$\rightleftharpoons$ Right harpoon up above left harpoon down (relation).

`\searrow` $\searrow$ Arrow pointing southeast (relation).

`\setminus`
$\setminus$ Set difference, reverse solidus or reverse slash, like `\` (binary). Similar: backslash `\backslash` and also `\textbackslash` outside of math mode.

`\sharp` $\sharp$ Musical sharp (ordinary).

`\Sigma` Σ uppercase Greek letter (ordinary).

`\sigma` σ Lowercase Greek letter (ordinary). The variant form is `\varsigma` ς.

`\sim` $\sim$ Similar, in a relation (relation).

`\simeq` $\simeq$ Similar or equal to, in a relation (relation).

`\smallint`
$\smallint$ Integral sign that does not change to a larger size in a display (operator).

`\smile` $\smile$ Upward curving arc, smile (ordinary).

`\spadesuit`
$\spadesuit$ Spade card suit (ordinary).

`\sqcap` $\sqcap$ Square intersection symbol (binary). Similar: intersection `cap`.

`\sqcup` $\sqcup$ Square union symbol (binary). Similar: union `cup`. Related: variable-sized operator `\bigsqcup`.

`\sqsubset`
$\sqsubset$ Square subset symbol (relation). Similar: subset `\subset`. Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\sqsubseteq`
: $\sqsubseteq$ Square subset or equal symbol (binary). Similar: subset or equal to `\subseteq`.

`\sqsupset`
: $\sqsupset$ Square superset symbol (relation). Similar: superset `\supset`. Not available in plain TeX. In LaTeX you need to load the `amssymb` package.

`\sqsupseteq`
: $\sqsupseteq$ Square superset or equal symbol (binary). Similar: superset or equal `\supseteq`.

`\star` $\star$ Five-pointed star, sometimes used as a general binary operation but sometimes reserved for cross-correlation (binary). Similar: the synonyms asterisk `*` and `\ast`, which are six-pointed, and more often appear as a superscript or subscript, as with the Kleene star.

`\subset` $\subset$ Subset (occasionally, is implied by) (relation).

`\subseteq`
: $\subseteq$ Subset or equal to (relation).

`\succ` $\succ$ Comes after, succeeds (relation). Similar: is less than `>`.

`\succeq` $\succeq$ Succeeds or is equal to (relation). Similar: less than or equal to `\leq`.

`\sum` $\sum$ Summation (operator). Similar: Greek capital sigma `\Sigma`.

`\supset` $\supset$ Superset (relation).

`\supseteq`
: $\supseteq$ Superset or equal to (relation).

`\surd` $\surd$ Radical symbol (ordinary). The LaTeX command `\sqrt{...}` typesets the square root of the argument, with a bar that extends to cover the argument.

`\swarrow` $\swarrow$ Southwest-pointing arrow (relation).

`\tau` τ Lowercase Greek letter (ordinary).

`\theta` θ Lowercase Greek letter (ordinary). The variant form is `\vartheta` ϑ.

`\times` $\times$ Primary school multiplication sign (binary). See also `\cdot`.

`\to` $\to$ Right-pointing single line arrow (relation). Synonym: `\rightarrow`.

`\top` $\top$ Top, greatest element of a partially ordered set (ordinary). See also `\bot`.

`\triangle`
: $\triangle$ Triangle (ordinary).

`\triangleleft`
: $\triangleleft$ Not-filled triangle pointing left (binary). Similar: `\lhd`. For the normal subgroup symbol you should load `amssymb` and use `\vartriangleleft` (which is a relation and so gives better spacing).

`\triangleright`
: $\triangleright$ Not-filled triangle pointing right (binary). For the normal subgroup symbol you should instead load `amssymb` and use `\vartriangleright` (which is a relation and so gives better spacing).

`\unlhd` Left-pointing not-filled underlined arrowhead, that is, triangle, with a line under (binary). Not available in plain TEX. In LATEX you need to load the `amssymb` package. For the normal subgroup symbol load `amssymb` and use `\vartrianglelefteq` (which is a relation and so gives better spacing).

`\unrhd` Right-pointing not-filled underlined arrowhead, that is, triangle, with a line under (binary). Not available in plain TEX. In LATEX you need to load the `amssymb` package. For the normal subgroup symbol load `amssymb` and use `\vartrianglerighteq` (which is a relation and so gives better spacing).

`\Uparrow` ⇑ Double-line upward-pointing arrow (relation). Similar: single-line up-pointing arrow `\uparrow`.

`\uparrow` ↑ Single-line upward-pointing arrow, diverges (relation). Similar: double-line up-pointing arrow `\Uparrow`.

`\Updownarrow`
⇕ Double-line upward-and-downward-pointing arrow (relation). Similar: single-line upward-and-downward-pointing arrow `\updownarrow`.

`\updownarrow`
↕ Single-line upward-and-downward-pointing arrow (relation). Similar: double-line upward-and-downward-pointing arrow `\Updownarrow`.

`\upharpoonright`
Up harpoon, with barb on right side (relation). Synonym: `\restriction`. Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\uplus` ⊎ Multiset union, a union symbol with a plus symbol in the middle (binary). Similar: union `\cup`. Related: variable-sized operator `\biguplus`.

`\Upsilon` Υ uppercase Greek letter (ordinary).

`\upsilon` υ Lowercase Greek letter (ordinary).

`\varepsilon`
ε Small letter script epsilon (ordinary). This is more widely used in mathematics than the non-variant lunate epsilon form `\epsilon` ϵ. Related: set membership `\in`.

`\vanothing`
Empty set symbol. Similar: `\emptyset`. Related: `\revemptyset`. Not available in plain TEX. In LATEX you need to load the `amssymb` package.

`\varphi` φ Variant on the lowercase Greek letter (ordinary). The non-variant form is `\phi` ϕ.

`\varpi` ϖ Variant on the lowercase Greek letter (ordinary). The non-variant form is `\pi` π.

`\varrho` ϱ Variant on the lowercase Greek letter (ordinary). The non-variant form is `\rho` ρ.

`\varsigma`
ς Variant on the lowercase Greek letter (ordinary). The non-variant form is `\sigma` σ.

`\vartheta`
: ϑ Variant on the lowercase Greek letter (ordinary). The non-variant form is `\theta` θ.

`\vdash` $\vdash$ Provable; turnstile, vertical and a dash (relation). Similar: turnstile rotated a half-circle `\dashv`.

`\vee` $\vee$ Logical or; a downwards v shape (binary). Related: logical and `\wedge`. Similar: variable-sized operator `\bigvee`.

`\Vert` $\Vert$ Vertical double bar (ordinary). Similar: vertical single bar `\vert`.

For a norm symbol, you can use the `mathtools` package and put in your preamble `\DeclarePairedDelimiter\norm{\lVert}{\rVert}`. This gives you three command variants for double-line vertical bars that are correctly horizontally spaced: if in the document body you write the starred version `$\norm*{M^\perp}$` then the height of the vertical bars will match the height of the argument, whereas with `\norm{M^\perp}` the bars do not grow with the height of the argument but instead are the default height, and `\norm[`*`size command`*`]{M^\perp}` also gives bars that do not grow but are set to the size given in the *size command*, e.g., `\Bigg`.

`\vert` | Single line vertical bar (ordinary). Similar: double-line vertical bar `\Vert`. For such that, as in the definition of a set, use `\mid` because it is a relation.

For absolute value you can use the `mathtools` package and in your preamble put `\DeclarePairedDelimiter\abs{\lvert}{\rvert}`. This gives you three command variants for single-line vertical bars that are correctly horizontally spaced: if in the document body you write the starred version `$\abs*{\frac{22}{7}}$` then the height of the vertical bars will match the height of the argument, whereas with `\abs{\frac{22}{7}}` the bars do not grow with the height of the argument but instead are the default height, and `\abs[`*`size command`*`]{\frac{22}{7}}` also gives bars that do not grow but are set to the size given in the *size command*, e.g., `\Bigg`.

`\wedge` $\wedge$ Logical and (binary). Synonym: `\land`. See also logical or `\vee`. Similar: variable-sized operator `\bigwedge`.

`\wp` $\wp$ Weierstrass p (ordinary).

`\wr` $\wr$ Wreath product (binary).

`\Xi` Ξ uppercase Greek letter (ordinary).

`\xi` ξ Lowercase Greek letter (ordinary).

`\zeta` ζ Lowercase Greek letter (ordinary).

The following symbols are most often used in plain text but LaTeX provides versions to use in mathematical text.

`\mathdollar`
: Dollar sign in math mode: $.

`\mathparagraph`
: Paragraph sign (pilcrow) in math mode, ¶.

`\mathsection`
: Section sign in math mode §.

`\mathsterling`
: Sterling sign in math mode: £.

`\mathunderscore`
: Underscore in math mode: _.

16.2.1 Blackboard bold

Synopsis:

```
\usepackage{amssymb}   % in preamble
  ...
\mathbb{uppercase-letter}
```

Provide blackboard bold symbols, sometimes also known as doublestruck letters, used to denote number sets such as the natural numbers, the integers, etc.

Here

```
\( \forall n \in \mathbb{N}, n^2 \geq 0 \)
```

the `\mathbb{N}` gives blackboard bold symbol representing the natural numbers.

If you use other than an uppercase letter then you do not get an error but you get strange results, including unexpected characters.

There are packages that give access to symbols other than just the capital letters; look on CTAN.

16.2.2 Calligraphic

Synopsis:

```
\mathcal{uppercase-letters}
```

Use a script-like font.

In this example the graph identifier is output in a cursive font.

```
Let the graph be \( \mathcal{G} \).
```

If you use something other than an uppercase letter then you do not get an error. Instead you get unexpected output. For instance, `\mathcal{g}` outputs a close curly brace symbol, while `\mathcal{+}` outputs a plus sign.

16.2.3 `\boldmath` & `\unboldmath`

Synopsis (used in paragraph mode or LR mode):

```
\boldmath \( math \)
```

or

```
\unboldmath \( math \)
```

Declarations to change the letters and symbols in *math* to be in a bold font, or to countermand that and bring back the regular (non-bold) default. They must be used when not in math mode or display math mode (see Chapter 17 [Modes], page 149). Both commands are fragile (see Section 12.9 [\protect], page 113).

In this example each `\boldmath` command takes place inside an `\mbox`,

```
we have $\mbox{\boldmath \( v \)} = 5\cdot\mbox{\boldmath \( u \)$}$
```

which means `\boldmath` is only called in a text mode, here LR mode, and explains why LaTeX must switch to math mode to set `v` and `u`.

If you use either command inside math mode, as with `Trouble: \( \boldmath x \)`, then you get something like '`LaTeX Font Warning: Command \boldmath invalid in math mode on input line 11`' and '`LaTeX Font Warning: Command \mathversion invalid in math mode on input line 11`'.

There are many issues with `\boldmath`. New documents should use the `bm` package provided by the LaTeX Project team. A complete description is outside the scope of this document (see the full documentation on CTAN) but even this small example

```
\usepackage{bm}   % in preamble
...
we have $\bm{v} = 5\cdot\bm{u}$
```

shows that it is an improvement over `\boldmath`.

16.2.4 Dots, horizontal or vertical

Ellipses are the three dots (usually three) indicating that a pattern continues.

```
\begin{array}{cccc}
  a_{0,0}    &a_{0,1}   &a_{0,2} &\ldots \\
  a_{1,0}    &\ddots                      \\
  \vdots
\end{array}
```

LaTeX provides these.

`\cdots` Horizontal ellipsis with the dots raised to the center of the line, as in $\cdots$. Used as: `\( a_0\cdot a_1\cdots a_{n-1} \)`.

`\ddots` Diagonal ellipsis, $\ddots$. See the above array example for a usage.

`\ldots` Ellipsis on the baseline, $\ldots$. Used as: `\( x_0,\ldots x_{n-1} \)`. Another example is the above array example. A synonym is `\mathellipsis`. A synonym from the `amsmath` package is `\hdots`.

You can also use this command outside of mathematical text, as in `The gears, brakes, \ldots{} are all broken`. (In a paragraph mode or LR mode a synonym for `\ldots` is `\dots`.)

`\vdots` Vertical ellipsis, $\vdots$. See the above array example for a usage.

The `amsmath` package has the command `\dots` to semantically mark up ellipses. This example produces two different-looking outputs for the first two uses of the `\dots` command.

```
\usepackage{amsmath}  % in preamble
  ...
Suppose that \( p_0, p_1, \dots, p_{n-1} \) lists all of the primes.
Observe that \( p_0\cdot p_1 \dots \cdot p_{n-1} +1 \) is not a
  multiple of any \( p_i \).
```

```
Conclusion: there are infinitely many primes \( p_0, p_1, \dotsc \).
```

In the first line LaTeX looks to the comma following `\dots` to determine that it should output an ellipsis on the baseline. The second line has a `\cdot` following `\dots` so LaTeX outputs an ellipsis that is on the math axis, vertically centered. However, the third usage has no follow-on character so you have to tell LaTeX what to do. You can use one of the commands: `\dotsc` if you need the ellipsis appropriate for a comma following, `\dotsb` if you need the ellipses that fits when the dots are followed by a binary operator or relation symbol, `\dotsi` for dots with integrals, or `\dotso` for others.

16.3 Math functions

These commands produce roman function names in math mode with proper spacing.

`\arccos` Inverse cosine arccos

`\arcsin` Inverse sine arcsin

`\arctan` Inverse tangent arctan

`\arg` Angle between the real axis and a point in the complex plane arg

`\bmod` Binary modulo operator, used as in `\( 5\bmod 3=2 \)` $5 \bmod 3$

`\cos` Cosine cos

`\cosh` Hyperbolic cosine cosh

`\cot` Cotangent cot

`\coth` Hyperbolic cotangent coth

`\csc` Cosecant csc

`\deg` Degrees deg

`\det` Determinant det

`\dim` Dimension dim

`\exp` Exponential exp

`\gcd` Greatest common divisor gcd

`\hom` Homomorphism hom

`\inf` Infinum inf

`\ker` Kernel ker

`\lg` Base 2 logarithm lg

`\lim` Limit lim

`\liminf` Limit inferior $\liminf$

`\limsup` Limit superior $\limsup$

`\ln` Natural logarithm ln

`\log` Logarithm log

`\max` Maximum max

`\min` Minimum min

`\pmod` Parenthesized modulus, as used in `\( 5\equiv 2\pmod 3 \)` $5 \equiv 2 \pmod 3$

`\Pr` Probability Pr

`\sec` Secant sec

`\sin` Sine sin

`\sinh` Hyperbolic sine sinh

`\sup` Supremum sup

`\tan` Tangent tan

`\tanh` Hyperbolic tangent tanh

The `amsmath` package adds improvements on some of these, and also allows you to define your own. The full documentation is on CTAN, but briefly, you can define an identity operator with `\DeclareMathOperator{\identity}{id}` that is like the ones above but prints as 'id'. The starred form `\DeclareMathOperator*{\op}{op}` sets any limits above and below, as is traditional with `\lim`, `\sup`, or `\max`.

16.4 Math accents

LaTeX provides a variety of commands for producing accented letters in math. These are different from accents in normal text (see Section 23.5 [Accents], page 192).

`\acute` Math acute accent $\acute{x}$.

`\bar` Math bar-over accent $\bar{x}$

`\breve` Math breve accent $\breve{x}$

`\check` Math háček (check) accent $\check{x}$

`\ddot` Math dieresis accent $\ddot{x}$

`\dot` Math dot accent $\dot{x}$

`\grave` Math grave accent $\grave{x}$

`\hat` Math hat (circumflex) accent $\hat{x}$

`\mathring` Math ring accent $\mathring{\mathrm{x}}$

`\tilde` Math tilde accent $\tilde{x}$

`\vec` Math vector symbol $\vec{x}$

`\widehat` Math wide hat accent $\widehat{x+y}$

`\widetilde` Math wide tilde accent $\widetilde{x+y}$

When you are putting an accent on an i or a j, the tradition is to use one without a dot, `\imath` or `jmath` (see Section 16.2 [Math symbols], page 130).

16.5 Over- and Underlining

LaTeX provides commands for making overlines or underlines, or putting braces over or under some material.

`\underline{`*text*`}`

Underline *text*. Works inside math mode, and outside. The result of `\underline{xyz}` is $\underline{xyz}$. The line is always completely below the text, taking account of descenders, so in `\(\underline{y}\)` the line is lower than in `\(\underline{x}\)`. This command is fragile (see Section 12.9 [\protect], page 113).

Note that the package `ulem` does text mode underlining and allows line breaking as well as a number of other features. See the documentation on CTAN. See also Section 19.10 [\hrulefill & \dotfill], page 161, for producing a line, for such things as a signature.

`\overline{`*text*`}`

Put a horizontal line over *text*. Works inside math mode, and outside. For example, `\overline{x+y}`. The result looks like: $\overline{x+y}$. Note that this differs from the command `\bar` (see Section 16.4 [Math accents], page 144).

`\underbrace{`*math*`}`

Put a brace under *math*. For example, this `(1-\underbrace{1/2)+(1/2}-1/3)` emphasizes the telescoping part. The result looks like this: $(1-\underbrace{1/2)+(1/2}-1/3)$. Attach text to the brace by using subscript, `_`, or superscript, `^`, as here.

```
\begin{displaymath}
  1+1/2+\underbrace{1/3+1/4}_{>1/2}+
       \underbrace{1/5+1/6+1/7+1/8}_{>1/2}+\cdots
\end{displaymath}
```

The superscript appears on top of the expression, and so can look unconnected to the underbrace.

`\overbrace{`*math*`}`

Put a brace over *math*, as with `\overbrace{x+x+\cdots+x}^{\mbox{\(k\) times}}`. See also `\underbrace`.

The package `mathtools` adds an over- and underbrace, as well as some improvements on the braces. See the documentation on CTAN.

16.6 Spacing in math mode

When typesetting mathematics, LaTeX puts in spacing according to the normal rules for mathematics texts. If you enter `y=m x` then LaTeX ignores the space and in the output the m is next to the x, as $y=mx$.

But LaTeX's rules sometimes need tweaking. For example, in an integral the tradition is to put a small extra space between the `f(x)` and the `dx`, here done with the `\,` command.

```
\int_0^1 f(x)\,dx
```

LaTeX provides the commands that follow for use in math mode. Many of these spacing definitions are expressed in terms of the math unit *mu*. It is defined as 1/18 em, where the em is taken from the current math symbols family (see Section 14.1 [Units of length], page 121). Thus, a `\thickspace` is something like 5/18 times the width of a 'M'.

`\;` Synonym: `\thickspace`. Normally `5.0mu plus 5.0mu`. Math mode only.

`\:`
`\>` Synonym: `\medspace`. Normally `4.0mu plus 2.0mu minus 4.0mu`. Math mode only.

`\,` Synonym: `\thinspace`. Normally `3mu`, which is 1/6 em. Can be used in both math mode and text mode (see Section 19.8 [\thinspace & \negthinspace], page 160).

This space is widely used, for instance between the function and the infinitesimal in an integral `\int f(x)\,dx` and, if an author does this, before punctuation in a displayed equation.

```
The antiderivative is
\begin{equation}
  3x^{-1/2}+3^{1/2}\,.
\end{equation}
```

`\!` A negative thin space. Normally `-3mu`. The `\!` command is math mode only but the `\negthinspace` command is available for text mode (see Section 19.8 [\thinspace & \negthinspace], page 160).

`\quad` This is 18 mu, that is, 1 em. This is often used for space surrounding equations or expressions, for instance for the space between two equations inside a `displaymath` environment. It is available in both text and math mode.

`\qquad` A length of 2 quads, that is, 36 mu = 2 em. It is available in both text and math mode.

16.7 Math miscellany

LaTeX contains a wide variety of mathematics facilities. Here are some that don't fit into other categories.

16.7.1 Colon character : & `\colon`

Synopsis, one of:

```
:
\colon
```

In mathematics, the colon character, `:`, is a relation.

```
With side ratios \( 3:4 \) and \( 4:5 \), the triangle is right.
```

Ordinary LaTeX defines `\colon` to produce the colon character with the spacing appropriate for punctuation, as in set-builder notation `\{x\colon 0\leq x<1\}`.

But the widely-used `amsmath` package defines `\colon` for use in the definition of functions `f\colon D\to C`. So if you want the colon character as a punctuation then use `\mathpunct{:}`.

16.7.2 *

Synopsis:

```
\*
```

A multiplication symbol that allows a line break. If there is a break then LaTeX puts a `\times` symbol, $\times$, before that break.

In `\( A_1\* A_2\* A_3\* A_4 \)`, if there is no line break then LaTeX outputs it as though it were `\( A_1 A_2 A_3 A_4 \)`. If a line break does happen, for example between the two middle ones, then LaTeX sets it like `\( A_1 A_2 \times \)`, followed by the break, followed by `\( A_3 A_4 \)`.

16.7.3 \frac

Synopsis:

```
\frac{numerator}{denominator}
```

Produces the fraction. Used as: `\begin{displaymath} \frac{1}{\sqrt{2\pi\sigma}} \end{displaymath}`. In inline math mode it comes out small; see the discussion of `\displaystyle` (see Chapter 16 [Math formulas], page 128).

16.7.4 \left & \right

Synopsis:

```
\left delimiter1 ... \right delimiter2
```

Make matching parentheses, braces, or other delimiters. The delimiters are sized according to the math they enclose. This makes a unit vector surrounded by appropriate-height parentheses.

```
\begin{equation}
  \left(\begin{array}{c}
    1   \\
    0   \\
  \end{array}\right)
```

Every `\left` must have a matching `\right`. Leaving out the `\left(` in the above gets '`Extra \right`'. Leaving off the `\right)` gets '`You can't use `\eqno' in math mode`'.

However, the two delimiters *delimiter1* and *delimiter2* need not match. A common case is that you want an unmatched brace, as below. Use a period, '`.`', as a null delimiter.

```
\begin{equation}
  f(n)=\left\{\begin{array}{ll}
                1             &\mbox{--if \(n=0\)} \\
                f(n-1)+3n^2   &\mbox{--else}
        \end{array}\right.
\end{equation}
```

Note that to get a curly brace as a delimiter you must prefix it with a backslash, `\{`.

16.7.5 \sqrt

Synopsis, one of:

```
\sqrt{arg}
```

`\sqrt[`*root-number*`]{`*arg*`}`

The square root, or optionally other roots, of *arg*. The optional argument *root-number* gives the root, i.e., enter the cube root of `x+y` as `\sqrt[3]{x+y}`. It comes out like this: $\sqrt[3]{x+y}$. The radical grows with the size of *arg* (as the height of the radical grows, the angle on the leftmost part gets steeper, until for a large enough `arg`, it is vertical).

LaTeX has a separate `\surd` character (see Section 16.2 [Math symbols], page 130).

16.7.6 `\stackrel`

Synopsis, one of:

`\stackrel{`*text*`}{`*relation*`}`

Put *text* above *relation*. To put a function name above an arrow enter `\stackrel{f}{\longrightarrow}`. The result looks like this: $\stackrel{f}{\longrightarrow}$.

17 Modes

As LaTeX processes your document, at any point it is in one of six modes. They fall into three categories of two each, the horizontal modes, the math modes, and the vertical modes. Some commands only work in one mode or another (in particular, many commands only work in one of the math modes), and error messages will refer to these.

- *Paragraph mode* is what LaTeX is in when processing ordinary text. It breaks the input text into lines and breaks the lines into pages. This is the mode LaTeX is in most of the time.

  LR mode (for left-to-right mode; in plain TeX this is called *restricted horizontal mode*) is in effect when LaTeX starts making a box with an `\mbox` command. As in paragraph mode, LaTeX's output is a string of words with spaces between them. Unlike in paragraph mode, in LR mode LaTeX never starts a new line, it just keeps going from left to right. (Although LaTeX will not complain that the LR box is too long, when it is finished and next tries to put that box into a line, it could very well complain that the finished LR box won't fit there.)

- *Math mode* is when LaTeX is generating an inline mathematical formula.

  Display math mode is when LaTeX is generating a displayed mathematical formula. (Displayed formulas differ somewhat from inline ones. One example is that the placement of the subscript on `\int` differs in the two situations.)

- *Vertical mode* is when LaTeX is building the list of lines and other material making the output page. This is the mode LaTeX is in when it starts a document.

  Internal vertical mode is in effect when LaTeX starts making a `\vbox`. This is the vertical analogue of LR mode.

For instance, if you begin a LaTeX article with '`Let \( x \) be ...`' then these are the modes: first LaTeX starts every document in vertical mode, then it reads the '`L`' and switches to paragraph mode, then the next switch happens at the '`\(`' where LaTeX changes to math mode, and then when it leaves the formula it pops back to paragraph mode.

Paragraph mode has two subcases. If you use a `\parbox` command or or a `minipage` then LaTeX is put into paragraph mode. But it will not put a page break here. Inside one of these boxes, called a *parbox*, LaTeX is in *inner paragraph mode*. Its more usual situation, where it can put page breaks, is *outer paragraph mode* (see Chapter 10 [Page breaking], page 97).

17.1 `\ensuremath`

Synopsis:

```
\ensuremath{formula}
```

Ensure that *formula* is typeset in math mode.

For instance, you can redefine commands that ordinarily can be used only in math mode, so that they can be used both in math and in plain text.

```
\newcommand{\dx}{\ensuremath{dx}}
In $\int f(x)\, \dx$, the \dx{} is an infinitesimal.
```

Caution: the `\ensuremath` command is useful but not a panacea.

```
\newcommand{\alf}{\ensuremath{\alpha}}
You get an alpha in text mode: \alf.
But compare the correct spacing in $\alf+\alf$ with that in \alf+\alf.
```

Best is to typeset math things in a math mode.

18 Page styles

The style of a page determines where LaTeX places the components of that page, such as headers and footers, and the text body. This includes pages in the main part of the document but also includes special pages such as the title page of a book, a page from an index, or the first page of an article.

The package `fancyhdr` is very helpful for constructing page styles. See its documentation on CTAN.

18.1 `\maketitle`

Synopsis:

```
\maketitle
```

Generate a title. In the standard classes the title appears on a separate page, except in the `article` class where it is at the top of the first page. (See Section 3.1 [Document class options], page 9, for information about the `titlepage` document class option.)

This example shows `\maketitle` appearing in its usual place, immediately after `\begin{document}`.

```
\documentclass{article}
\title{Constructing a Nuclear Reactor Using Only Coconuts}
\author{Jonas Grumby\thanks{%
    With the support of a Ginger Grant from the Roy Hinkley Society.} \\
  Skipper, \textit{Minnow}
  \and
  Willy Gilligan\thanks{%
    Thanks to the Mary Ann Summers foundation
    and to Thurston and Lovey Howell.}           \\
  Mate, \textit{Minnow}
  }
\date{1964-Sep-26}
\begin{document}
\maketitle
Just sit right back and you'll hear a tale, a tale of a fateful trip.
That started from this tropic port, aboard this tiny ship. The mate was
a mighty sailin' man, the Skipper brave and sure. Five passengers set
sail that day for a three hour tour. A three hour tour.
  ...
```

You tell LaTeX the information used to produce the title by making the following declarations. These must come before the `\maketitle`, either in the preamble or in the document body.

`\author{`*name1* `\and` *name2* `\and ...}`

> Required. Declare the document author or authors. The argument is a list of authors separated by `\and` commands. To separate lines within a single author's entry, for instance to give the author's institution or address, use a double backslash, `\\`. If you omit the `\author` declaration then you get '`LaTeX Warning: No \author given`'.

`\date{`*text*`}`
: Optional. Declare *text* to be the document's date. The *text* doesn't need to be in a date format; it can be any text at all. If you omit `\date` then LaTeX uses the current date (see Section 23.8 [\today], page 195). To have no date, instead use `\date{}`.

`\thanks{`*text*`}`
: Optional. Produce a footnote. You can use it in the author information for acknowledgements, as illustrated below, but you can also use it in the title, or any place a footnote makes sense. It can be any text so you can use it to print an email address, or for any purpose.

`\title{`*text*`}`
: Required. Declare *text* to be the title of the document. Get line breaks inside *text* with a double backslash, `\\`. If you omit the `\title` declaration then you get '`LaTeX Error: No \title given`'.

Many publishers will provide a class to use in place of `article` in that example, that formats the title according to their house requirements. To make your own, see Section 8.26 [titlepage], page 88. You can either create this as a one-off or you can include it as part of a renewed `\maketitle` command.

18.2 \pagenumbering

Synopsis:

```
\pagenumbering{number-style}
```

Specifies the style of page numbers, and resets the page number. The numbering style is reflected on the page, and also in the table of contents and other page references. This declaration has global scope so its effect is not delimited by braces or environments.

In this example, before the Main section the pages are numbered '`a`', etc. Starting on the page containing that section, the pages are numbered '`1`', etc.

```
\begin{document}\pagenumbering{alph}
  ...
\section{Main}\pagenumbering{arabic}
  ...
```

The argument *number-style* is one of the following (see also Section 13.1 [\alph \Alph \arabic \roman \Roman \fnsymbol], page 116).

`arabic` arabic numerals: 1, 2, ...

`roman` lowercase Roman numerals: i, ii, ...

`Roman` uppercase Roman numerals: I, II, ...

`alph` lowercase letters: a, b, ... If you have more than 26 pages then you get '`LaTeX Error: Counter too large`'.

`Alph` uppercase letters: A, B, ... If you have more than 26 pages then you get '`LaTeX Error: Counter too large`'.

`gobble` LaTeX does not output a page number, although it does get reset. References to that page also are blank. (This does not work with the popular package `hyperref` so to have the page number not appear you may want to instead use `\pagestyle{empty}` or `\thispagestyle{empty}`.)

Traditionally, if a document has front matter—preface, table of contents, etc.—then it is numbered with lowercase Roman numerals. The main matter of a document uses arabic. See Section 6.7 [\frontmatter & \mainmatter & \backmatter], page 39.

If you want to address where the page number appears on the page, see Section 18.3 [\pagestyle], page 153. If you want to change the value of page number then you will manipulate the `page` counter (see Chapter 13 [Counters], page 116).

18.3 \pagestyle

Synopsis:

```
\pagestyle{style}
```

Declaration that specifies how the page headers and footers are typeset, from the current page onwards.

A discussion with an example is below. Note first that the package `fancyhdr` is now the standard way to manipulate headers and footers. New documents that need to do anything other than one of the standard options below should use this package. See its documentation on CTAN.

Values for *style*:

`plain` The header is empty. The footer contains only a page number, centered.

`empty` The header and footer is empty.

`headings` Put running headers and footers on each page. The document style specifies what goes in there; see the discussion below.

`myheadings`
Custom headers, specified via the `\markboth` or the `\markright` commands.

Some discussion of the motivation for LaTeX's mechanism will help you work with the options `headings` or `myheadings`. The document source below produces an article, two-sided, with the pagestyle `headings`. On this document's left hand pages, LaTeX wants (in addition to the page number) the title of the current section. On its right hand pages LaTeX wants the title of the current subsection. When it makes up a page, LaTeX gets this information from the commands `\leftmark` and `\rightmark`. So it is up to `\section` and `\subsection` to store that information there.

```
\documentclass[twoside]{article}
\pagestyle{headings}
\begin{document}
  ... \section{Section 1} ... \subsection{Subsection 1.1} ...
\section{Section 2}
  ...
\subsection{Subsection 2.1}
  ...
```

```
\subsection{Subsection 2.2}
  ...
```

Suppose that the second section falls on a left page. Although when the page starts it is in the first section, LaTeX will put '`Section 2`' in the left page header. As to the right header, if no subsection starts before the end of the right page then LaTeX blanks the right hand header. If a subsection does appear before the right page finishes then there are two cases. If at least one subsection starts on the right hand page then LaTeX will put in the right header the title of the first subsection starting on that right page. If at least one of 2.1, 2.2, ..., starts on the left page but none starts on the right then LaTeX puts in the right hand header the title of the last subsection to start, that is, the one in effect during the right hand page.

To accomplish this, in a two-sided article, LaTeX has `\section` issue a command `\markboth`, setting `\leftmark` to '`Section 2`' and setting `\rightmark` to blank. And, LaTeX has `\subsection` issue a command `\markright`, setting `\rightmark` to '`Subsection 2.1`', etc.

Here are the descriptions of `\markboth` and `\markright`:

`\markboth{`*left-head*`}{`*right-head*`}`
: Sets both the right hand and left hand heading information for either a page style of `headings` or `myheadings`. A left hand page heading *left-head* is generated by the last `\markboth` command before the end of the page. A right hand page heading *right-head* is generated by the first `\markboth` or `\markright` that comes on the page if there is one, otherwise by the last one that came before that page.

`\markright{`*right*`}`
: Sets the right hand page heading, leaving the left unchanged.

18.4 \thispagestyle

Synopsis:

```
\thispagestyle{style}
```

Works in the same way as the `\pagestyle` (see Section 18.3 [\pagestyle], page 153), except that it changes to *style* for the current page only. This declaration has global scope, so its effect is not delimited by braces or environments.

Often the first page of a chapter or section has a different style. For example, this LaTeX book document has the first page of the first chapter in in `plain` style, as is the default (see Chapter 18 [Page styles], page 151).

```
\documentclass{book}
\pagestyle{headings}
\begin{document}
\chapter{First chapter}
  ...
\chapter{Second chapter}\thispagestyle{empty}
  ...
```

The `plain` style has a page number on it, centered in the footer. To make the page entirely empty, the command `\thispagestyle{empty}` immediately follows the second `\chapter`.

19 Spaces

LaTeX has many ways to produce white (or filled) space. Some of these are best suited to mathematical text; see Section 16.6 [Spacing in math mode], page 145. Some spacing commands are suitable for both regular text and mathematical text; versions of some of these commands are in this chapter.

19.1 \enspace & \quad & \qquad

Synopsis, one of:

```
\enspace
\quad
\qquad
```

Insert a horizontal space of 1/2 em, 1 em, or 2 em. The em is a length defined by a font designer, often thought of as being the width of a capital M. One advantage of describing space in ems is that it can be more portable across documents than an absolute measurement such as points (see [Lengths/em], page 121).

This puts a suitable gap between two graphics.

```
\begin{center}
  \includegraphics{womensmile.png}%
  \qquad\includegraphics{mensmile.png}
\end{center}
```

See Section 16.6 [Spacing in math mode], page 145, for `\quad` and `\qquad`. These are lengths from centuries of typesetting and so may be a better choice in many circumstances than arbitrary lengths, such as you get with `\hspace`.

19.2 \hspace

Synopsis, one of:

```
\hspace{length}
\hspace*{length}
```

Insert the horizontal space *length*. The *length* can be positive, negative, or zero; adding negative space is like backspacing. It is a rubber length, that is, it may contain a `plus` or `minus` component, or both (see Chapter 14 [Lengths], page 120). Because the space is stretchable and shrinkable, it is sometimes called *glue*.

This makes a line with '`Name:`' an inch from the right margin.

```
\noindent\makebox[\linewidth][r]{Name:\hspace{1in}}
```

The `*`-version inserts horizontal space that non-discardable. More precisely, when TeX breaks a paragraph into lines any white space—glues and kerns—that come at a line break are discarded. The `*`-version avoids that (technically, it adds a non-discardable invisible item in front of the space).

In this example

```
\parbox{0.8\linewidth}{%
  Fill in each blank: Four \hspace*{1in} and seven years ago our
  fathers brought forth on this continent, a new \hspace*{1in},
```

```
  conceived in \hspace*{1in}, and dedicated to the proposition
  that all men are created \hspace*{1in}.}
```

the 1 inch blank following '`conceived in`' falls at the start of a line. If you erase the `*` then LaTeX discards the blank.

Here, the `\hspace` separates the three graphics.

```
\begin{center}
  \includegraphics{lion.png}%   comment keeps out extra space
  \hspace{1cm minus 0.25cm}\includegraphics{tiger.png}%
  \hspace{1cm minus 0.25cm}\includegraphics{bear.png}
\end{center}
```

Because the argument to each `\hspace` has `minus 0.25cm`, each can shrink a little if the three figures are too wide. But each space won't shrink more than 0.25 cm (see Chapter 14 [Lengths], page 120).

19.3 \hfill

Synopsis:

```
\hfill
```

Produce a rubber length which has no natural space but that can stretch horizontally as far as needed (see Chapter 14 [Lengths], page 120).

This creates a one-line paragraph with '`Name:`' on the left side of the page and '`Quiz One`' on the right.

```
\noindent Name:\hfill Quiz One
```

The `\hfill` command is equivalent to `\hspace{\fill}` and so the space can be discarded at line breaks. To avoid that instead use `\hspace*{\fill}` (see Section 19.2 [\hspace], page 155).

Here the graphs are evenly spaced in the middle of the figure.

```
\newcommand*{\vcenteredhbox}[1]{\begin{tabular}{@{}c@{}}#1\end{tabular}}
  ...
\begin{figure}
  \hspace*{\fill}%
  \vcenteredhbox{\includegraphics{graph0.png}}%
    \hfill\vcenteredhbox{\includegraphics{graph1.png}}%
  \hspace*{\fill}%
  \caption{Comparison of two graphs} \label{fig:twographs}
\end{figure}
```

Note the `\hspace*`'s where the space could otherwise be dropped.

19.4 \hss

Synopsis:

```
\hss
```

Produce a horizontal space that is infinitely shrinkable as well as infinitely stretchable (this command is a TeX primitive). LaTeX authors should reach first for the `\makebox` command to get the effects of `\hss` (see Section 20.1 [\mbox & \makebox], page 167).

Here, the first line's `\hss` makes the Z stick out to the right, overwriting the Y. In the second line the Z sticks out to the left, overwriting the X.

```
X\hbox to 0pt{Z\hss}Y
X\hbox to 0pt{\hss Z}Y
```

Without the `\hss` you get something like '`Overfull \hbox (6.11111pt too wide) detected at line 20`'.

19.5 \spacefactor

Synopsis:

```
\spacefactor=integer
```

Influence LaTeX's glue stretch and shrink behavior. Most user-level documents do not use this command.

While LaTeX is laying out the material, it may stretch or shrink the gaps between words. (This space is not a character; it is called the *interword glue*; see Section 19.2 [\hspace], page 155). The `\spacefactor` command (from Plain TeX) allows you to, for instance, have the space after a period stretch more than the space after a word-ending letter.

After LaTeX places each character, or rule or other box, it sets a parameter called the *space factor*. If the next thing in the input is a space then this parameter affects how much stretching or shrinking can happen. A space factor that is larger than the normal value means that the glue can stretch more and shrink less. Normally, the space factor is 1000. This value is in effect following most characters, and any non-character box or math formula. But it is 3000 after a period, exclamation mark, or question mark, it is 2000 after a colon, 1500 after a semicolon, 1250 after a comma, and 0 after a right parenthesis or bracket, or closing double quote or single quote. Finally, it is 999 after a capital letter.

If the space factor f is 1000 then the glue gap will be the font's normal space value (for Computer Modern Roman 10 point this is 3.3333 points). Otherwise, if the space factor f is greater than 2000 then TeX adds the font's extra space value (for Computer Modern Roman 10 point this is 1.11111 points), and then the font's normal stretch value is multiplied by $f/1000$ and the normal shrink value is multiplied by $1000/f$ (for Computer Modern Roman 10 point these are 1.66666 and 1.11111 points).

For example, consider the period ending `A man's best friend is his dog.` After it, TeX puts in a fixed extra space, and also allows the glue to stretch 3 times as much and shrink 1/3 as much, as the glue after `friend`, which does not end in a period.

The rules for space factors are even more complex because they play additional roles. In practice, there are two consequences. First, if a period or other punctuation is followed by a right parenthesis or bracket, or right single or double quote then the spacing effect of that period carries through those characters (that is, the following glue will have increased stretch and shrink). Second, if punctuation comes after a capital letter then its effect is not in place so you get an ordinary space. This second case also affects abbreviations that do not end in a capital letter (see Section 19.5.1 [\@], page 158).

You can only use `\spacefactor` in paragraph mode or LR mode (see Chapter 17 [Modes], page 149). You can see the current value with `\the\spacefactor` or `\showthe\spacefactor`.

(Comment, not really related to `\spacefactor`: if you get errors like '`You can't use '\spacefactor' in vertical mode`', or '`You can't use '\spacefactor' in math mode.`', or '`Improper \spacefactor`' then you have probably tried to redefine an internal command. See Section 2.4.3 [\makeatletter & \makeatother], page 6.)

19.5.1 `\@`

Synopsis:

```
capital-letter\@.
```

Treat a period as sentence-ending, where LaTeX would otherwise think it is part of an abbreviation. LaTeX thinks that a period ends an abbreviation if the period comes after a capital letter, and otherwise thinks the period ends the sentence. By default, in justifying a line LaTeX adjusts the space after a sentence-ending period (or a question mark, exclamation point, comma, or colon) more than it adjusts the space between words (see Section 19.5 [\spacefactor], page 157).

This example shows the two cases to remember.

```
The songs \textit{Red Guitar}, etc.\ are by Loudon Wainwright~III\@.
```

The second period ends the sentence, despite that it is preceded by a capital. We tell LaTeX that it ends the sentence by putting `\@` before it. The first period ends the abbreviation '`etc.`' but not the sentence. The backslash-space, `\ `, produces a mid-sentence space.

So: if you have a capital letter followed by a period that ends the sentence, then put `\@` before the period. This holds even if there is an intervening right parenthesis or bracket, or right single or double quote, because the spacing effect of that period carries through those characters. For example, this

```
Use the \textit{Instructional Practices Guide},
(a book by the MAA)\@.
```

will have correct inter-sentence spacing after the period.

The `\@` command is only for a text mode. If you use it outside of a text mode then you get '`You can't use '\spacefactor' in vertical mode`' (see Chapter 17 [Modes], page 149).

Comment: the converse case is a period ending an abbreviation whose last letter is not a capital letter, and that abbreviation is not the last word in the sentence. For that case follow the period with a backslash-space, (`\ `), or a tie, (`~`), or `\@`. Examples are `Nat.\ Acad.\ Science`, and `Mr.~Bean`, and `(manure, etc.\@) for sale` (note in the last one that the `\@` comes before the closing parenthesis).

19.5.2 `\frenchspacing`

Synopsis, one of:

```
\frenchspacing
\nonfrenchspacing
```

The first declaration causes LaTeX to treat spacing between sentences in the same way as spacing between words in the middle of a sentence. The second causes spacing between sentences to stretch or shrink more (see Section 19.5 [\spacefactor], page 157); this is the default.

Some typographic traditions, including English, prefer to adjust the space between sentences (or spaces following a question mark, exclamation point, comma, or colon) more than

the space between words that are in the middle of a sentence. Declaring `\frenchspacing` (the command is from Plain TEX) switches to the tradition that all spaces are treated equally.

19.5.3 `\normalsfcodes`

Synopsis:

```
\normalsfcodes
```

Reset the LATEX space factor values to the default (see Section 19.5 [\spacefactor], page 157).

19.6 Backslash-space, \

This section refers to the command consisting of two characters, a backslash followed by a space. Synopsis:

```
\
```

Produce a space. By default it produces white space of length 3.33333 pt plus 1.66666 pt minus 1.11111 pt.

A blank is not a space. When you type a blank between words, LATEX produces white space. That's different from an explicit space. This illustrates.

```
\begin{tabular}{l}
Three blanks:   in a row \\
Three spaces:\ \ \ in a row \\
\end{tabular}
```

On the first line LATEX collapses the three blanks to output one whitespace (it would be the same with a single blank or, for instance, with a blank and an tab and a blank, or a blank and a newline and a blank). But the second line asks for three spaces so the white area is wider. Thus, the backslash-space command will create some horizontal space. (But the best way to create horizontal space is with `\hspace`; See Section 19.2 [\hspace], page 155.)

The backslash-space command has two main uses. First, it is often used after control sequences to keep them from gobbling the space that follows, as in `\TeX\ is nice`. (But the approach of using curly parentheses, as in `\TeX{} is nice`, has the advantage of still working if the next character is a period.)

The second common use is that it mark a period as ending an abbreviation instead of ending a sentence, as in `So says Prof.\ Smith` (see Section 19.5.1 [\@], page 158).

Under normal circumstances, `\tab` and `\newline` are equivalent to backslash-space, `\ `.

19.7 ~

Synopsis:

```
before~after
```

The tie character, `~`, produces a space between *before* and *after* at which the line will not be broken. By default the white space has length 3.33333 pt plus 1.66666 pt minus 1.11111 pt (see Chapter 14 [Lengths], page 120).

Here LATEX will not break the line between the final two words.

```
Thanks to Prof.~Lerman.
```

In addition, despite the period, LaTeX does not use the end-of-sentence spacing (see Section 19.5.1 [\@], page 158).

Ties prevent the end of line separation of things where that could cause confusion. But they also reduce LaTeX's options when it breaks lines into paragraphs, so you can use too many. They are also matters of taste, sometimes alarmingly dogmatic taste, among readers. Nevertheless, here are some usage models, many of them from the TeXbook.

- Between an enumerator and its item, such as in references: `Chapter~12`, or `Theorem~\ref{th:Wilsons}`, or `Figure~\ref{fig:KGraph}`. When cases are enumerated inline: `(b)~Show that $f(x)$ is (1)~continuous, and (2)~bounded`.
- Between a number and its unit: `$745.7.8$~watts` (the `siunitx` package has a special facility for this) or `144~eggs`. This includes between a month and a date: `October~12` or `12~Oct`. In general, in any expressions where numbers and abbreviations or symbols are separated by a space: `AD~565`, or `2:50~pm`, or `Boeing~747`, or `268~Plains Road`, or `\$$1.4$~billion`.
- When mathematical phrases are rendered in words: `equals~$n$`, or `less than~$\epsilon$`, or `given~$X$`, or `modulo~$p^e$ for all large~$n$` (but compare `is~$15$` with `is $15$~times the height`). Between mathematical symbols in apposition with nouns: `dimension~$d$` or `function~$f(x)$` (but compare `with length $l$~or more`). When a symbol is a tightly bound object of a preposition: `of~$x$`, or `from $0$ to~$1$`, or `in common with~$m$`.
- Between symbols in series: `$1$,~$2$, or~$3$` or `$1$,~$2$, \ldots,~$n$`.
- Between a person's forenames and between multiple surnames: `Donald~E. Knuth`, or `Luis~I. Trabb~Pardo`, or `Charles~XII` (but you must give TeX places to break the line so you may do `Charles Louis Xavier~Joseph de~la Vall\'ee~Poussin`).
- Before a dash: `pages 12~--14` or `it is~--- it must be said~--- plausible`.

19.8 \thinspace & \negthinspace

Synopsis, one of:

```
\thinspace
\negthinspace
```

Produce an unbreakable and unstretchable space of 1/6 em and -1/6 em. These are the text mode equivalents of `\,` and `\!` (see [Spacing in math mode/\thinspace], page 146). You can use `\,` as a synonym for `\thinspace` in text mode.

The `\negthinspace` command is used in text mode mostly for fiddling with spaces. One common use of `\thinspace` is as the space between nested quotes.

```
Killick replied, ``I heard the Captain say, `Ahoy there.'\thinspace''
```

Another use is that some style guides call for a `\thinspace` between an ellipsis and a sentence ending period (other style guides, though, think the three dots are quite enough already). Still another use is between initials, as in `D.\thinspace E.\ Knuth`.

19.9 \/

Synopsis:

```
before-character\/after-character
```

Insert an *italic correction*, a small space defined by the font designer for each character, to avoid the character colliding with whatever follows. When you use `\/`, LaTeX takes the correction from the font metric file, scales it by any scaling that has been applied to the font, and then inserts that much horizontal space.

Here, were it not for the `\/`, the *before-character* italic f would hit the *after-character* roman H

```
\newcommand{\companylogo}{{\it f}\/H}
```

because the italic letter leans far to the right.

If *after-character* is a period or comma then don't insert an italic correction since those punctuation symbols have a very small height. However, with semicolons or colons as well as with normal letters, the italic correction can help.

When you use commands such as `\textit` or `\itshape` to change fonts, LaTeX will automatically insert any needed italic correction (see Section 4.1 [Font styles], page 18).

Roman characters can also have an italic correction. An example is in the name `pdf\/\TeX`.

There is no concept of italic correction in math mode; spacing is done in a different way.

19.10 `\hrulefill` & `\dotfill`

Synopsis, one of:

```
\hrulefill
\dotfill
```

Produce an infinite horizontal rubber length (see Chapter 14 [Lengths], page 120) that LaTeX fills with a rule (that is, a line) or with dots, instead of white space.

This outputs a line 2 inches long.

```
Name:~\makebox[2in]{\hrulefill}
```

This example, when placed between blank lines, creates a paragraph that is left and right justified and where the middle is filled with evenly spaced dots.

```
\noindent John Aubrey, RN \dotfill{} Melbury Lodge
```

To make the rule or dots go to the line's end use `\null` at the start or end.

To change the rule's thickness, copy the definition and adjust it, as here

```
\renewcommand{\hrulefill}{%
  \leavevmode\leaders\hrule height 1pt\hfill\kern\z@}
```

which changes the default thickness of 0.4 pt to 1 pt. Similarly, adjust the dot spacing as with

```
\renewcommand{\dotfill}{%
  \leavevmode\cleaders\hb@xt@1.00em{\hss .\hss }\hfill\kern\z@}
```

which changes the default length of 0.33 em to 1.00 em.

This example produces a line for a signature.

```
\begin{minipage}{4cm}
  \centering
  \hrulefill\\
```

```
  Signed
\end{minipage}
```

The line is 4 cm long.

19.11 \bigskip & \medskip & \smallskip

Synopsis, one of:

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

Produce an amount of vertical space, large or medium-sized or small. These commands are fragile (see Section 12.9 [\protect], page 113).

Here the skip suggests the passage of time (from *The Golden Ocean* by O'Brian).

```
Mr Saumarez would have something rude to say to him, no doubt: he
was at home again, and it was delightful.

\bigskip
``A hundred and fifty-seven miles and one third, in twenty-four hours,''
said Peter.
```

Each command is associated with a length defined in the document class file.

`\bigskip` The same as `\vspace{\bigskipamount}`, ordinarily about one line space, with stretch and shrink. The default for the `book` and `article` classes is `12pt plus 4pt minus 4pt`.

`\medskip` The same as `\vspace{\medskipamount}`, ordinarily about half of a line space, with stretch and shrink. The default for the `book` and `article` classes is `6pt plus 2pt minus 2pt`.

`\smallskip`
The same as `\vspace{\smallskipamount}`, ordinarily about a quarter of a line space, with stretch and shrink. The default for the `book` and `article` classes is `3pt plus 1pt minus 1pt`.

Because each command is a `\vspace`, if you use on in mid-paragraph then it will insert its vertical space between the line in which you use it and the next line, not necessarily at the place that you use it. So these are best between paragraphs.

The commands `\bigbreak`, `\medbreak`, and `\smallbreak` are similar but also suggest to LaTeX that this is a good place to put a page break (see Section 19.12 [\bigbreak & \medbreak & \smallbreak], page 162.

19.12 \bigbreak & \medbreak & \smallbreak

Synopsis, one of:

```
\bigbreak
\medbreak
\smallbreak
```

Produce a vertical space that is big or medium-sized or small, and suggest to LaTeX that this is a good place to break the page. (The associated penalties are -200, -100, and -50.)

See Section 19.11 [\bigskip & \medskip & \smallskip], page 162, for more. These commands produce the same vertical space but differ in that they also remove a preceding vertical space if it is less than what they would insert (as with `\addvspace`). In addition, they terminate a paragraph where they are used: this example

```
abc\bigbreak def ghi

jkl mno pqr
```

will output three paragraphs, the first ending in '`abc`' and the second starting, after an extra vertical space and a paragraph indent, with '`def`'.

19.13 \strut

Synopsis:

```
\strut
```

Ensure that the current line has height at least `0.7\baselineskip` and depth at least `0.3\baselineskip`. Essentially, LaTeX inserts into the line a rectangle having zero width, `\rule[-0.3\baselineskip]{0pt}{\baselineskip}` (see Section 23.7 [\rule], page 194). The `\baselineskip` changes with the current font and fontsize.

In this example the `\strut` keeps the box inside the frame from having zero height.

```
\setlength{\fboxsep}{0pt}\framebox[2in]{\strut}
```

This example has four lists. In the first there is a much bigger gap between items 2 and 3 than there is between items 1 and 2. The second list fixes that with a `\strut` at the end of its first item's second line.

```
\setlength{\fboxsep}{0pt}
\noindent\begin{minipage}[t]{0.2\linewidth}
\begin{enumerate}
  \item \parbox[t]{15pt}{test \\ test}
  \item test
  \item test
\end{enumerate}
\end{minipage}%
\begin{minipage}[t]{0.2\linewidth}
\begin{enumerate}
  \item \parbox[t]{15pt}{test \\ test\strut}
  \item test
  \item test
\end{enumerate}
\end{minipage}%
\begin{minipage}[t]{0.2\linewidth}
\begin{enumerate}
  \item \fbox{\parbox[t]{15pt}{test \\ test}}
  \item \fbox{test}
  \item \fbox{test}
```

```
\end{enumerate}
\end{minipage}%
\begin{minipage}[t]{0.2\linewidth}
\begin{enumerate}
  \item \fbox{\parbox[t]{15pt}{test \\ test\strut}}
  \item \fbox{test}
  \item \fbox{test}
\end{enumerate}
\end{minipage}%
```

The final two lists use `fbox` to show what's happening. The third list's `\parbox` goes only to the bottom of its second '`test`', which happens not have any characters that descend below the baseline. The fourth list adds the strut that gives the needed extra below-baseline space.

The `\strut` command is often useful in graphics, such as in `TikZ` or `Asymptote`. For instance, you may have a command such as `\graphnode{`*`node-name`*`}` that fits a circle around *node-name*. However, unless you are careful the *node-name*'s '`x`' and '`y`' will produce different-diameter circles because the characters are different sizes. A careful `\graphnode` might insert a `\strut`, then *node-name*, and then draw the circle.

The general approach of using a zero width `\rule` is useful in many circumstances. In this table, the zero-width rule keeps the top of the first integral from hitting the `\hline`. Similarly, the second rule keeps the second integral from hitting the first.

```
\begin{tabular}{rl}
  \textsc{Integral}   &\textsc{Value}           \\
  \hline
  $\int_0^x t\, dt$   &$x^2/2$  \rule{0em}{2.5ex} \\
  $\int_0^x t^2\, dt$ &$x^3/3$  \rule{0em}{2.5ex}
\end{tabular}
```

(Although the line-ending double backslash command has an available optional argument to put in more vertical room, that won't work here. Changing the first double backslash to something like `\\[2.5ex]` will put the room between the header line and the `\hline`, and the integral would still hit the line.)

19.14 \vspace

Synopsis, one of:

```
\vspace{length}
\vspace*{length}
```

Add the vertical space *length*. The *length* can be positive, negative, or zero. It is a rubber length—it may contain a `plus` or `minus` component (see Chapter 14 [Lengths], page 120).

This puts space between the two paragraphs.

```
And I slept.

\vspace{1ex plus 0.5ex}
The new day dawned cold.
```

(See Section 19.11 [\bigskip & \medskip & \smallskip], page 162, for common inter-paragraph spaces.)

The *-version inserts vertical space that non-discardable. More precisely, LaTeX discards vertical space at a page break and the *-version causes the space to stay. This example leaves space between the two questions.

```
Question: Find the integral of \( 5x^4+5 \).

\vspace*{2cm plus 0.5cm}
Question: Find the derivative of \( x^5+5x+9 \).
```

That space will be present even if the page break happens to fall between the questions.

If you use `\vspace` in the middle of a paragraph (i.e., in horizontal mode) then the space is inserted after the line containing the `\vspace` command; it does not start a new paragraph at the `\vspace` command.

In this example the two questions will be evenly spaced vertically on the page, with at least one inch of space below each.

```
\begin{document}
1) Who put the bomp in the bomp bah bomp bah bomp?
\vspace{1in plus 1fill}

2) Who put the ram in the rama lama ding dong?
\vspace{1in plus 1fill}
\end{document}
```

19.15 \vfill

Synopsis:

```
\vfill
```

End the current paragraph and insert a vertical rubber length that is infinite, so it can stretch or shrink as far as needed (see Chapter 14 [Lengths], page 120).

It is often used in the same way as `\vspace{\fill}`, except that `\vfill` ends the current paragraph whereas `\vspace{\fill}` adds the infinite vertical space below its line, irrespective of the paragraph structure. In both cases that space will disappear at a page boundary; to circumvent this see the starred option in Section 19.14 [\vspace], page 164.

In this example the page is filled, so the top and bottom lines contain the text '`Lost Dog!`' and the second '`Lost Dog!`' is exactly halfway between them.

```
\begin{document}
Lost Dog!
\vfill
Lost Dog!  % perfectly in the middle
\vfill
Lost Dog!
\end{document}
```

19.16 \addvspace

Synopsis:

```
\addvspace{vert-length}
```

Add a vertical space of *vert-length*. However, if there are two or more `\addvspace`'s in a sequence then together they only add the space needed to make the natural length equal to the maximum of the *vert-length*'s in that sequence. This command is fragile (see Section 12.9 [\protect], page 113). The *vert-length* is a rubber length (see Chapter 14 [Lengths], page 120).

This example illustrates. The `picture` draws a scale. In a standard LaTeX article the length `\baselineskip` is 12 pt. The two rules here are 22 pt apart: the sum of the `\baselineskip` and the 10 pt from the first `addvspace`.

```
\documentclass{article}
\usepackage{color}
\begin{document}
\setlength{\unitlength}{2pt}%
\noindent\begin{picture}(0,0)%
  \multiput(0,0)(0,-1){25}{{\color{blue}\line(1,0){1}}}
  \multiput(0,0)(0,-5){6}{{\color{red}\line(1,0){2}}}
\end{picture}%
\rule{0.25\linewidth}{0.1pt}%
\par\addvspace{10pt}% \addvspace{20pt}%
\par\noindent\rule{0.25\linewidth}{0.1pt}%
\end{document}
```

Now uncomment the second `\addvspace`. It does not make the gap 20 pt longer; instead the gap is the sum of `\baselineskip` and 20 pt. So `\addvspace` in a sense does the opposite of its name — it makes sure that multiple vertical spaces do not accumulate, but instead that only the largest one is used.

LaTeX uses this command to adjust the vertical space above or below an environment that starts a new paragraph. For instance, a `theorem` environment begins and ends with `\addvspace` so that two consecutive `theorem`'s are separated by one vertical space, not two.

A error '`Something's wrong--perhaps a missing \item`' pointing to an `\addvspace` means that you were not in vertical mode when you hit this command. One way to change that is to precede `\addvspace` with a `\par` command (see Section 15.1 [\par], page 124), as in the above example.

20 Boxes

At its core, LaTeX puts things in boxes and then puts the boxes on a page. So these commands are central.

There are many packages on CTAN that are useful for manipulating boxes. One useful adjunct to the commands here is `adjustbox`.

20.1 \mbox & \makebox

Synopsis, one of:

```
\mbox{text}
\makebox{text}
\makebox[width]{text}
\makebox[width][position]{text}
```

Create a box, a container for material. The *text* is is typeset in LR mode (see Chapter 17 [Modes], page 149) so it is not broken into lines. The `\mbox` command is robust, while `\makebox` is fragile (see Section 12.9 [\protect], page 113).

Because `text` is not broken into lines, you can use `\mbox` to prevent hyphenation. In this example, LaTeX will not hyphenate the table name, '`T-4`'.

```
See Table~\mbox{T-4}
```

The first two command versions, `\mbox` and `\makebox`, are roughly equivalent. They create a box just wide enough to contain the *text*. (They are like plain TeX's `\hbox`.)

In the third version the optional argument *width* specifies the width of the box. Note that the space occupied by the text need not equal the width of the box. For one thing, *text* can be too small; this creates a full-line box

```
\makebox[\linewidth]{Chapter Exam}
```

with '`Chapter Exam`' centered. But *text* can also be too wide for *width*. See the example below of zero-width boxes.

In the *width* argument you can use the following lengths that refer to the dimension of the box that LaTeX gets on typesetting *text*: `\depth`, `\height`, `\width`, `\totalheight` (this is the box's height plus its depth). For example, to make a box with the text stretched to double the natural size you can say this.

```
\makebox[2\width]{Get a stretcher}
```

For the fourth command version the optional argument *position* gives position of the text within the box. It may take the following values:

`c` The *text* is centered (default).

`l` The *text* is flush left.

`r` Flush right.

`s` Stretch the interword space in *text* across the entire *width*. The *text* must contain stretchable space for this to work. For instance, this could head a press release: `\noindent\makebox[\textwidth][s]{\large\hfil IMMEDIATE\hfil RELEASE\hfil}`

A common use of `\makebox` is to make zero-width text boxes. This puts the value of the quiz questions to the left of those questions.

```
\newcommand{\pts}[1]{\makebox[0em][r]{#1 points\hspace*{1em}}}
\pts{10}What is the air-speed velocity of an unladen swallow?

\pts{90}An African or European swallow?
```

The right edge of the output '`10 points `' (note the ending space) will be just before the '`What`' (note the space after '`points`'). You can use `\makebox` similarly when making graphics, such as in `TikZ` or `Asymptote`, where you put the edge of the text at a known location, regardless of the length of that text.

For boxes with frames see Section 20.2 [\fbox & \framebox], page 168. For colors see Section 21.3.3 [Colored boxes], page 176.

There is a related version of `\makebox` that is used within the `picture` environment, where the length is given in terms of `\unitlength` (see Section 8.19.13 [\makebox (picture)], page 73).

If you put a double-backslash into *text* then LaTeX will not give you a new line; for instance `\makebox{abc def \\ ghi}` outputs '`abc defghi`' while `\makebox{abc def \par ghi}` outputs '`abc def ghi`', but neither go to a second line. To get multiple lines see Section 20.3 [\parbox], page 169, and Section 8.18 [minipage], page 65.

20.2 \fbox & \framebox

Synopses, one of:

```
\fbox{text}
\framebox{text}
\framebox[width]{text}
\framebox[width][position]{text}
```

Create a box with an enclosing frame, four lines surrounding the space. These commands are the same as `\mbox` and `\makebox` except for the frame (see Section 20.1 [\mbox & \makebox], page 167). The `\fbox` command is robust, the `\framebox` command is fragile (see Section 12.9 [\protect], page 113).

```
\fbox{Warning! No work shown, no credit given.}
```

LaTeX puts the text into a box that cannot be split or hyphenated. Around that box, separated from it by a small gap, are four lines making a frame.

The first two command invocations, `\fbox{...}` and `\framebox{...}`, are roughly the same. As to the third and fourth invocations, the optional arguments allow you to specify the box width as *width* and the position of the text inside that box as *position*. See Section 20.1 [\mbox & \makebox], page 167, for the full description but here is an example creating an empty box that is 1/4 in wide.

```
\setlength{\fboxsep}{0pt}\framebox[0.25in]{\strut}
```

The `\strut` inserts a vertical height of `\baselineskip` (see Section 19.13 [\strut], page 163).

These parameters determine the frame layout.

`\fboxrule`
: The thickness of the lines around the enclosed box. The default is 0.2 pt. Change it with a command such as `\setlength{\fboxrule}{0.8pt}` (see Section 14.2 [\setlength], page 122).

`\fboxsep`
: The distance from the frame to the enclosed box. The default is 3 pt. Change it with a command such as `\setlength{\fboxsep}{0pt}` (see Section 14.2 [\setlength], page 122). Setting it to 0 pt is useful sometimes: this will put a frame around the picture with no white border.

```
{\setlength{\fboxsep}{0pt}
 \framebox{%
   \includegraphics[width=0.5\textwidth]{prudence.jpg}}}
```

The extra curly braces keep the effect of the `\setlength` local.

As with `\mbox` and `\makebox`, LaTeX will not break lines in *text*. But this example has LaTeX break lines to make a paragraph, and then frame the result.

```
\framebox{%
  \begin{minipage}{0.6\linewidth}
    My dear, here we must run as fast as we can, just to stay in place.
    And if you wish to go anywhere you must run twice as fast as that.
  \end{minipage}}
```

See Section 21.3.3 [Colored boxes], page 176, for colors other than black and white.

The `picture` environment has a version of this command where the units depend on `picture`'s `\unitlength` (see Section 8.19.14 [\framebox (picture)], page 74).

20.3 \parbox

Synopses, one of:

```
\parbox{width}{contents}
\parbox[position]{width}{contents}
\parbox[position][height]{width}{contents}
\parbox[position][height][inner-pos]{width}{contents}
```

Produce a box of text that is *width* wide. Use this command to make a box of small pieces of text, of a single paragraph. This command is fragile (see Section 12.9 [\protect], page 113).

```
\begin{picture}(0,0)
  ...
  \put(1,2){\parbox{1.75in}{\raggedright Because the graph is a line on
                            this semilog paper, the relationship is
                            exponential.}}
\end{picture}
```

The *contents* are processed in a text mode (see Chapter 17 [Modes], page 149) so LaTeX will break lines to make a paragraph. But it won't make multiple paragraphs; for that, use a `minipage` environment (see Section 8.18 [minipage], page 65).

The options for `\parbox` (except for *contents*) are the same as those for `minipage`. For convenience a summary of the options is here but see Section 8.18 [minipage], page 65, for a complete description.

There are two required arguments. The *width* is a rigid length (see Chapter 14 [Lengths], page 120). It sets the width of the box into which LaTeX typesets *contents*. The *contents* is the text that is placed in that box. It should not have any paragraph-making components.

There are three optional arguments, *position*, *height*, and *inner-pos*. The *position* gives the vertical alignment of the `parbox` with respect to the surrounding material. The possible values are `c` or `m` to make the vertical center of the `parbox` lines up with the center of the adjacent line (this is the default), or `t` to match the top line of the `parbox` with the baseline of the surrounding material, or `b` to match the bottom line.

The optional argument *height* overrides the natural height of the box.

The optional argument *inner-pos* controls the placement of *content* inside the `parbox`. Its default is the value of *position*. Its possible values are: `t` to put the *content* at the top of the box, `c` to put it in the vertical center, `b` to put it at the bottom of the box, and `s` to stretch it out vertically (for this, the text must contain vertically stretchable space).

20.4 \raisebox

Synopsis, one of:

```
\raisebox{distance}{text}
\raisebox{distance}[height]{text}
\raisebox{distance}[height][depth]{text}
```

Raise or lower *text*. This command is fragile (see Section 12.9 [\protect], page 113).

This example makes a command for the restriction of a function by lowering the vertical bar symbol.

```
\newcommand\restricted[1]{\raisebox{-.5ex}{$|$}_{#1}}
$f\restricted{A}$
```

The first mandatory argument *distance* specifies how far to raise the second mandatory argument *text*. This is a rigid length (see Chapter 14 [Lengths], page 120). If it is negative then it lowers *text*. The *text* is processed in LR mode so it cannot contain line breaks (see Chapter 17 [Modes], page 149).

The optional arguments *height* and *depth* are dimensions. If they are specified, they override the natural height and depth of the box LaTeX gets by typesetting *text*.

In the arguments *distance*, *height*, and *depth* you can use the following lengths that refer to the dimension of the box that LaTeX gets on typesetting *text*: `\depth`, `\height`, `\width`, `\totalheight` (this is the box's height plus its depth).

This will align two graphics on their top (see Chapter 22 [Graphics], page 177).

```
\usepackage{graphicx} \usepackage{calc}  % in preamble
   ...
\begin{center}
  \raisebox{1ex-\height}{%
    \includegraphics[width=0.4\linewidth]{lion.png}}
  \qquad
  \raisebox{1ex-\height}{%
    \includegraphics[width=0.4\linewidth]{meta.png}}
\end{center}
```

The first `\height` is the height of `lion.png` while the second is the height of `meta.png`.

20.5 \sbox & \savebox

Synopsis, one of:

```
\sbox{box-cmd}{text}
\savebox{box-cmd}{text}
\savebox{box-cmd}[width]{text}
\savebox{box-cmd}[width][pos]{text}
```

Typeset *text* just as with `\makebox` (see Section 20.1 [\mbox & \makebox], page 167) except that LaTeX does not output it but instead saves it in a storage bin named *box-cmd*. The bin name *box-cmd* begins with a backslash, `\`. You must have previously allocated the bin *box-cmd* with `\newsavebox` (see Section 12.5 [\newsavebox], page 108).The `\sbox` command is robust while `\savebox` is fragile (see Section 12.9 [\protect], page 113).

This creates and uses a bin.

```
\newsavebox{\fullname}
\sbox{\fullname}{John Jacob Jingleheimer Schmidt}
  ...
\usebox{\fullname}! His name is my name, too!
Whenever we go out, the people always shout!
There goes \\usebox{\fullname}!  Ya da da da da da da.
```

One advantage of using and reusing a bin over a `\newcommand` is efficiency, that LaTeX need not repeatedly retypeset the contents. See the example below.

The first two command invocations, `\sbox{box-cmd}{text}` and `\savebox{box-cmd}{text}`, are roughly equivalent. As to the third and fourth, the optional arguments allow you to specify the box width as *width*, and the position of the text inside that box as *position*. See Section 20.1 [\mbox & \makebox], page 167, for the full description.

In the `\sbox` and `\savebox` commands the *text* is typeset in LR mode so it does not have line breaks (see Chapter 17 [Modes], page 149). If you use these then LaTeX doesn't give you an error but it ignores what you want: if you enter `\sbox{\newbin}{test \\ test}` and `\usebox{\newbin}` then you get '`testtest`', while if you enter `\sbox{\newbin}{test \par test}` and `\usebox{\newbin}` then you get '`test test`', but no error or warning. To fix this use a `\parbox` or `minipage` as here.

```
\savebox{\abin}{%
  \begin{minipage}{\linewidth}
    \begin{enumerate}
      \item First item
      \item Second item
    \end{enumerate}
  \end{minipage}}
  ...
\usebox{\abin}
```

As an example of the efficiency of reusing a bin's contents, this puts the same picture on each page of the document by putting it in the header. LaTeX only typesets it once.

```
\usepackage{graphicx}  % all this in the preamble
\newsavebox{\sealbin}
\savebox{\sealbin}{%
```

```
  \setlength{\unitlength}{1in}%
  \begin{picture}(0,0)%
     \put(1.5,-2.5){%
       \begin{tabular}{c}
          \includegraphics[height=2in]{companylogo.png} \\
          Office of the President
       \end{tabular}}
  \end{picture}%
}
\markright{\usebox{\sealbin}}
\pagestyle{headings}
```

The `picture` environment is good for fine-tuning the placement.

If the bin has not already been defined then you get something like '`Undefined control sequence. <argument> \nobin`'.

20.6 `lrbox`

Synopsis:

```
\begin{lrbox}{box-cmd}
  text
\end{lrbox}
```

The *text* inside the environment is saved in the bin *box-cmd*. The *box-cmd* must begin with a backslash. You must create this bin in advance with `\newsavebox` (see Section 12.5 [\newsavebox], page 108). This is the environment form of the `\sbox` and `\savebox` commands, and is equivalent to them. See Section 20.5 [\sbox & \savebox], page 171, for the full information.

In this example the environment is convenient for entering the `tabular`.

```
\newsavebox{\jhbin}
\begin{lrbox}{\jhbin}
  \begin{tabular}{c}
    \includegraphics[height=1in]{jh.png} \\
    Jim Hef{}feron
  \end{tabular}
\end{lrbox}
  ...
\usebox{\jhbin}
```

20.7 `\usebox`

Synopsis:

```
\usebox{box-cmd}
```

Produce the box most recently saved in the bin *box-cmd* by the commands `\sbox` or `\savebox`, or the `lrbox` environment. See Section 20.5 [\sbox & \savebox], page 171, for more information and examples. (Note that *box-cmd* starts with a backslash.) This command is robust (see Section 12.9 [\protect], page 113).

21 Color

You can add color to text, rules, etc. You can also have color in a box or on an entire page and write text on top of it.

Color support comes as an additional package. So all the commands below will only work if your document preamble contains `\usepackage{color}`, that brings in the standard package.

Many other packages also supplement LaTeX's color abilities. Particularly worth mentioning is `xcolor`, which is widely used and significantly extends the capabilities described here, including adding '`HTML`' and '`Hsb`' color models.

21.1 `color` package options

Synopsis (must be in the document preamble):

```
\usepackage[comma-separated option list]{color}
```

When you load the `color` package there are two kinds of available options.

The first specifies the *printer driver*. LaTeX doesn't contain information about different output systems but instead depends on information stored in a file. Normally you should not specify the driver option in the document, and instead rely on your system's default. One advantage of this is that it makes the document portable across systems. For completeness we include a list of the drivers. The currently relevant ones are: `dvipdfmx`, `dvips`, `dvisvgm`, `luatex`, `pdftex`, `xetex`. The two `xdvi` and `oztex` are essentially aliases for `dvips` (and `xdvi` is monochrome). Ones that should not be used for new systems are: `dvipdf`, `dvipdfm`, `dviwin`, `dvipsone`, `emtex`, `pctexps`, `pctexwin`, `pctexhp`, `pctex32`, `truetex`, `tcidvi`, `vtex` (and `dviwindo` is an alias for `dvipsone`).

The second kind of options, beyond the drivers, are below.

`monochrome`
: Disable the color commands, so that they do not generate errors but do not generate color either.

`dvipsnames`
: Make available a list of 68 color names that are often used, particularly in legacy documents. These color names were originally provided by the `dvips` driver, giving the option name.

`nodvipsnames`
: Do not load that list of color names, saving LaTeX a tiny amount of memory space.

21.2 Color models

A *color model* is a way of representing colors. LaTeX's capabilities depend on the printer driver. However, the `pdftex`, `xetex`, and `luatex` printer drivers are today by far the most commonly used. The models below work for those drivers. All but one of these is also supported by essentially all other printer drivers used today.

Note that color combination can be additive or subtractive. Additive mixes colors of light, so that for instance combining full intensities of red, green, and blue produces white.

Subtractive mixes pigments, such as with inks, so that combining full intensity of cyan, magenta, and yellow makes black.

`cmyk` A comma-separated list with four real numbers between 0 and 1, inclusive. The first number is the intensity of cyan, the second is magenta, and the others are yellow and black. A number value of 0 means minimal intensity, while a 1 is for full intensity. This model is often used in color printing. It is a subtractive model.

`gray` A single real number between 0 and 1, inclusive. The colors are shades of grey. The number 0 produces black while 1 gives white.

`rgb` A comma-separated list with three real numbers between 0 and 1, inclusive. The first number is the intensity of the red component, the second is green, and the third the blue. A number value of 0 means that none of that component is added in, while a 1 means full intensity. This is an additive model.

`RGB` (`pdftex`, `xetex`, `luatex` drivers) A comma-separated list with three integers between 0 and 255, inclusive. This model is a convenience for using `rgb` since outside of LaTeX colors are often described in a red-green-blue model using numbers in this range. The values entered here are converted to the `rgb` model by dividing by 255.

`named` Colors are accessed by name, such as '`PrussianBlue`'. The list of names depends on the driver, but all support the names '`black`', '`blue`', '`cyan`', '`green`', '`magenta`', '`red`', '`white`', and '`yellow`' (See the `dvipsnames` option in Section 21.1 [Color package options], page 173).

21.3 Commands for color

These are the commands available with the `color` package.

21.3.1 Define colors

Synopsis:

```
\definecolor{name}{model}{specification}
```

Give the name *name* to the color. For example, after this

```
\definecolor{silver}{rgb}{0.75,0.75,0.74}
```

you can use that color name with `Hi ho, \textcolor{silver}{Silver}!`.

This example gives the color a more abstract name, so it could change and not be misleading.

```
\definecolor{logocolor}{RGB}{145,92,131}    % RGB needs pdflatex
\newcommand{\logo}{\textcolor{logocolor}{Bob's Big Bagels}}
```

Often a document's colors are defined in the preamble, or in the class or style, rather than in the document body.

21.3.2 Colored text

Synopses:

```
\textcolor{name}{...}
```

```
\textcolor[color model]{color specification}{...}
```

or

```
\color{name}
\color[color model]{specification}
```

The affected text gets the color. This line

```
\textcolor{magenta}{My name is Ozymandias, king of kings:}
Look on my works, ye Mighty, and despair!
```

causes the first half to be in magenta while the rest is in black. You can use a color declared with `\definecolor` in exactly the same way that we just used the builtin color '`magenta`'.

```
\definecolor{MidlifeCrisisRed}{rgb}{1.0,0.11,0.0}
I'm thinking about getting a \textcolor{MidlifeCrisisRed}{sports car}.
```

The two `\textcolor` and `\color` differ in that the first is a command form, enclosing the text to be colored as an argument. Often this form is more convenient, or at least more explicit. The second form is a declaration, as in `The moon is made of {\color{green} green} cheese`, so it is in effect until the end of the current group or environment. This is sometimes useful when writing macros or as below where it colors everything inside the `center` environment, including the vertical and horizontal lines.

```
\begin{center} \color{blue}
  \begin{tabular}{l|r}
    UL &UR \\ \hline
    LL &LR
  \end{tabular}
\end{center}
```

You can use color in equations. A document might have this definition in the preamble

```
\definecolor{highlightcolor}{RGB}{225,15,0}
```

and then contain this equation.

```
\begin{equation}
  \int_a^b \textcolor{highlightcolor}{f'(x)}\,dx=f(b)-f(a)
\end{equation}
```

Typically the colors used in a document are declared in a class or style but sometimes you want a one-off. Those are the second forms in the synopses.

```
Colors of \textcolor[rgb]{0.33,0.14,0.47}{Purple} and
{\color[rgb]{0.72,0.60,0.37} Gold} for the team.
```

The format of *color specification* depends on the color model (see Section 21.2 [Color models], page 173). For instance, while `rgb` takes three numbers, `gray` takes only one.

```
The selection was \textcolor[gray]{0.5}{grayed out}.
```

Colors inside colors do not combine. Thus

```
\textcolor{green}{kind of \textcolor{blue}{blue}}
```

has a final word that is blue, not a combination of blue and green.

21.3.3 Colored boxes

Synopses:

```
\colorbox{name}{...}
\colorbox[model name]{box background color}{...}
```

or

```
\fcolorbox{frame color}{box background color}{...}
\fcolorbox[model name]{frame color}{box background color}{...}
```

Make a box with the stated background color. The `\fcolorbox` command puts a frame around the box. For instance this

```
Name:~\colorbox{cyan}{\makebox[5cm][l]{\strut}}
```

makes a cyan-colored box that is five centimeters long and gets its depth and height from the `\strut` (so the depth is `-.3\baselineskip` and the height is `\baselineskip`). This puts white text on a blue background.

```
\colorbox{blue}{\textcolor{white}{Welcome to the machine.}}
```

The `\fcolorbox` commands use the same parameters as `\fbox` (see Section 20.2 [\fbox & \framebox], page 168), `\fboxrule` and `\fboxsep`, to set the thickness of the rule and the boundary between the box interior and the surrounding rule. LaTeX's defaults are `0.4pt` and `3pt`, respectively.

This example changes the thickness of the border to 0.8 points. Note that it is surrounded by curly braces so that the change ends at the end of the second line.

```
{\setlength{\fboxrule}{0.8pt}
\fcolorbox{black}{red}{Under no circumstances turn this knob.}}
```

21.3.4 Colored pages

Synopses:

```
\pagecolor{name}
\pagecolor[color model]{color specification}
\nopagecolor
```

The first two set the background of the page, and all subsequent pages, to the color. For an explanation of the specification in the second form see Section 21.3.2 [Colored text], page 174. The third returns the background to normal, which is a transparent background. (If that is not supported use `\pagecolor{white}`, although that will make a white background rather than the default transparent background.)

```
 ...
\pagecolor{cyan}
 ...
\nopagecolor
```

22 Graphics

You can use graphics such as PNG or PDF files in your LaTeX document. You need an additional package, which comes standard with LaTeX. This example is the short how-to.

```
\include{graphicx}  % goes in the preamble
  ...
\includegraphics[width=0.5\linewidth]{plot.pdf}
```

To use the commands described here your document preamble must contain either `\usepackage{graphicx}` or `\usepackage{graphics}`. Most of the time, `graphicx` is the better choice.

Graphics come in two main types, raster and vector. LaTeX can use both. In raster graphics the file contains an entry for each location in an array, describing what color it is. An example is a photograph, in JPG format. In vector graphics, the file contains a list of instructions such as '`draw a circle with this radius and that center`'. An example is a line drawing produced by the Asymptote program, in PDF format. Generally vector graphics are more useful because you can rescale their size without pixelation or other problems, and because they often have a smaller size.

There are systems particularly well-suited to make graphics for a LaTeX document. For example, these allow you to use the same fonts as in your document. LaTeX comes with a `picture` environment (see Section 8.19 [picture], page 67) that has simple capabilities. Besides that, there are other ways to include the graphic-making commands in the document. Two such systems are the PSTricks and TikZ packages. There are also systems external to LaTeX, that generate a graphic that you include using the commands of this chapter. Two that use a programming language are Asymptote and MetaPost. One that uses a graphical interface is Xfig. Full description of these systems is outside the scope of this document; see their documentation on CTAN.

22.1 `graphics` package options

Synopsis (must be in the document preamble):

```
\usepackage[comma-separated option list]{graphics}
```

or

```
\usepackage[comma-separated option list]{graphicx}
```

The `graphicx` package has a format for optional arguments to the `\includegraphics` command that is convenient (it is the key-value format), so it is the better choice for new documents. When you load the `graphics` or `graphicx` package with `\usepackage` there are two kinds of available options.

The first is that LaTeX does not contain information about different output systems but instead depends on information stored in a *printer driver* file. Normally you should not specify the driver option in the document, and instead rely on your system's default. One advantage of this is that it makes the document portable across systems.

For completeness here is a list of the drivers. The currently relevant ones are: `dvipdfmx`, `dvips`, `dvisvgm`, `luatex`, `pdftex`, `xetex`. The two `xdvi` and `oztex` are essentially aliases for `dvips` (and `xdvi` is monochrome). Ones that should not be used for new systems are: `dvipdf`, `dvipdfm`, `dviwin`, `dvipsone`, `emtex`, `pctexps`, `pctexwin`, `pctexhp`, `pctex32`,

`truetex`, `tcidvi`, `vtex` (and `dviwindo` is an alias for `dvipsone`). These are stored in files with a `.def` extension, such as `pdftex.def`.

The second kind of options are below.

`demo` Instead of an image file, LaTeX puts in a 150 pt by 100 pt rectangle (unless another size is specified in the `\includegraphics` command).

`draft` For each graphic file, it is not shown but instead the file name is printed in a box of the correct size. In order to determine the size, the file must be present.

`final` (Default) Override any previous `draft` option, so that the document shows the contents of the graphic files.

`hiderotate`
Do not show rotated text. (This allows for the possibility that a previewer does not have the capability to rotate text.)

`hidescale`
Do not show scaled text. (This allows for the possibility that a previewer does not have the capability to scale.)

`hiresbb` In a PS or EPS file the graphic size may be specified in two ways. The `%%BoundingBox` lines describe the graphic size using integer multiples of a PostScript point, that is, integer multiples of 1/72 inch. A later addition to the PostScript language allows decimal multiples, such as 1.23, in `%%HiResBoundingBox` lines. This option has LaTeX to read the size from the latter.

22.2 `graphics` package configuration

These commands configure the way LaTeX searches the file system for the graphic.

The behavior of file system search code is necessarily platform dependent. In this document we cover GNU/Linux, Macintosh, and Windows, as those systems are typically configured. For other situations consult the documentation in `grfguide.pdf`, or the LaTeX source, or your TeX distribution's documentation.

22.2.1 `\graphicspath`

Synopsis:

```
\graphicspath{list of dir names inside curly brackets}
```

Declare a list of directories to search for graphics files. This allows you to later say something like `\includegraphics{lion.png}` instead of having to give its path.

LaTeX always looks for graphic files first in the current directory. The declaration below tells the system to then look in the subdirectory `pix`, and then `../pix`.

```
\usepackage{graphicx}   % or graphics; put in preamble
  ...
\graphicspath{ {pix/} {../pix/} }
```

The `\graphicspath` declaration is optional. If you don't include it then LaTeX's default is to search all of the places that it usually looks for a file (it uses LaTeX's `\input@path`). In particular, in this case one of the places it looks is the current directory.

Enclose each directory name in curly braces; for example, above it says '`{pix}`'. Do this even if there is only one directory. Each directory name must end in a forward slash, `/`. This is true even on Windows, where good practice is to use forward slashes for all the directory separators since it makes the document portable to other platforms. If you have spaces in your directory name then use double quotes, as with `{"my docs/"}`. Getting one of these rules wrong will cause LaTeX to report `Error: File 'filename' not found`.

Basically, the algorithm is that with this example, after looking in the current directory,

```
\graphicspath{ {pix/} {../pix/} }
...
\usepackage{lion.png}
```

for each of the listed directories, LaTeX concatenates it with the file name and searches for the result, checking for `pix/lion.png` and then `../pix/lion.png`. This algorithm means that the `\graphicspath` command does not recursively search subdirectories: if you issue `\graphicspath{{a/}}` and the graphic is in `a/b/lion.png` then LaTeX will not find it. It also means that you can use absolute paths such as `\graphicspath{{/home/jim/logos/}}` or `\graphicspath{{C:/Users/Albert/Pictures/}}`. However, using these means that the document is not portable. (You could preserve portability by adjusting your TeX system settings configuration file parameter `TEXINPUTS`; see the documentation of your system.)

You can use `\graphicspath` anywhere in the document. You can use it more than once. Show its value with `\makeatletter\typeout{\Ginput@path}\makeatother`.

The directories are taken with respect to the base file. That is, suppose that you are working on a document based on `book/book.tex` and it contains `\include{chapters/chap1}`. If in `chap1.tex` you put `\graphicspath{{plots/}}` then LaTeX will not search for graphics in `book/chapters/plots`, but instead in `book/plots`.

22.2.2 \DeclareGraphicsExtensions

Synopses:

```
\DeclareGraphicsExtensions{comma-separated list of file extensions}
```

Declare the filename extensions to try. This allows you to specify the order in which to choose graphic formats when you include graphic files by giving the filename without the extension, as in `\includegraphics{functionplot}`.

In this example, LaTeX will find files in the PNG format before PDF files.

```
\DeclareGraphicsExtensions{.png,PNG,.pdf,.PDF}
  ...
\includegraphics{lion}   % will find lion.png before lion.pdf
```

Because the file name `lion` does not have a period, LaTeX uses the extension list. For each directory in the graphics path (see Section 22.2.1 [\graphicspath], page 178), LaTeX will try the extensions in the order given. If it does not find such a file after trying all the directories and extensions then it reports '`! LaTeX Error: File 'lion' not found`'. Note that you must include the periods at the start of the extensions.

Because GNU/Linux and Macintosh filenames are case sensitive, the list of file extensions is case sensitive on those platforms. The Windows platform is not case sensitive.

You are not required to include `\DeclareGraphicsExtensions` in your document; the printer driver has a sensible default. For example, the most recent `pdftex.def` has this extension list.

```
.png,.pdf,.jpg,.mps,.jpeg,.jbig2,.jb2,.PNG,.PDF,.JPG,.JPEG,.JBIG2,.JB2
```

You can use this command anywhere in the document. You can use it more than once. Show its value with `\makeatletter\typeout{\Gin@extensions}\makeatother`.

22.2.3 \DeclareGraphicsRule

Synopsis:

```
\DeclareGraphicsRule{extension}{type}{size-file extension}{command}
```

Declare how to handle graphic files whose names end in *extension*.

This example declares that all files with names have the form `filename-without-dot.mps` will be treated as output from MetaPost, meaning that the printer driver will use its MetaPost-handling code to input the file.

```
\DeclareGraphicsRule{.mps}{mps}{.mps}{}
```

This

```
\DeclareGraphicsRule{*}{mps}{*}{}
```

tells LaTeX that it should handle as MetaPost output any file with an extension not covered by another rule, so it covers `filename.1`, `filename.2`, etc.

This describes the four arguments.

extension The file extension to which this rule applies. The extension is anything after and including the first dot in the filename. Use the Kleene star, `*`, to denote the default behaviour for all undeclared extensions.

type The type of file involved. This type is a string that must be defined in the printer driver. For instance, files with extensions `.ps`, `.eps`, or `.ps.gz` may all be classed as type `eps`. All files of the same type will be input with the same internal command by the printer driver. For example, the file types that `pdftex` recognizes are: `jpg`, `jbig2`, `mps`, `pdf`, `png`, `tif`.

size-file extension

The extension of the file to be read to determine the size of the graphic, if there is such a file. It may be the same as *extension* but it may be different.

As an example, consider a PostScript graphic. To make it smaller, it might be compressed into a `.ps.gz` file. Compressed files are not easily read by LaTeX so you can put the bounding box information in a separate file. If *size-file extension* is empty then you must specify size information in the arguments of `\includegraphics`.

If the driver file has a procedure for reading size files for `type` then that will be used, otherwise it will use the procedure for reading `.eps` files. (Thus you may specify the size of bitmap files in a file with a PostScript style `%%BoundingBox` line if no other format is available.)

command A command that will be applied to the file. This is very often left blank. This command must start with a single backward quote. Thus, `\DeclareGraphicsRule{.eps.gz}{eps}{.eps.bb}{‘gunzip -c #1}` specifies that any file with the extension `.eps.gz` should be treated as an `eps` file, with the the BoundingBox information stored in the file with extension `.eps.bb`,

and that the command `gunzip -c` will run on your platform to decompresses the file.

Such a command is specific to your platform. In addition, your TEX system must allow you to run external commands; as a security measure modern systems restrict running commands unless you explicitly allow it. See the documentation for your TEX distribution.

22.3 Commands for graphics

These are the commands available with the `graphics` and `graphicx` packages.

22.3.1 \includegraphics

Synopses for `graphics` package:

```
\includegraphics{filename}
\includegraphics[urx,ury]{filename}
\includegraphics[llx,lly][urx,ury]{filename}
\includegraphics*{filename}
\includegraphics*[urx,ury]{filename}
\includegraphics*[llx,lly][urx,ury]{filename}
```

Synopses for `graphicx` package:

```
\includegraphics{filename}
\includegraphics[key-value list]{filename}
\includegraphics*{filename}
\includegraphics*[key-value list]{filename}
```

Include a graphics file. The starred form `\includegraphics*` will clip the graphic to the size specified, while for the unstarred form any part of the graphic that is outside the box of the specified size will over-print the surrounding area.

This

```
\usepackage{graphicx}  % in preamble
  ...
\begin{center}
  \includegraphics{plot.pdf}
\end{center}
```

will incorporate into the document the graphic in `plot.pdf`, centered and at its nominal size. You can also give a path to the file, as with `\includegraphics{graphics/plot.pdf}`. To specify a list of locations to search for the file, see Section 22.2.1 [\graphicspath], page 178.

If your filename includes spaces then put it in double quotes. An example is `\includegraphics{"sister picture.jpg"}`.

The `\includegraphics{filename}` command decides on the type of graphic by splitting *filename* on the first dot. You can use *filename* with no dot, as in `\includegraphics{turing}` and then LATEX tries a sequence of extensions such as `.png` and `.pdf` until it finds a file with that extension (see Section 22.2.2 [\DeclareGraphicsExtensions], page 179).

If your file name contains dots before the extension then you can hide them with curly braces, as in `\includegraphics{{plot.2018.03.12.a}.pdf}`. Or, if you use the `graphicx`

package then you can use the options `type` and `ext`; see below. This and other filename issues are also handled with the package `grffile`.

This example puts a graphic in a figure environment so LaTeX can move it to the next page if fitting it on the current page is awkward (see Section 8.10 [figure], page 54).

```
\begin{figure}
  \centering
  \includegraphics[width=3cm]{lungxray.jpg}
  \caption{The evidence is overwhelming: don't smoke.}  \label{fig:xray}
\end{figure}
```

This places a graphic that will not float, so it is sure to appear at this point in the document even if makes LaTeX stretch the text or resort to blank areas on the page. It will be centered and will have a caption.

```
\usepackage{caption}  % in preamble
  ...
\begin{center}
  \includegraphics{pix/nix.png}
  \captionof{figure}{The spirit of the night} \label{pix:nix} % optional
\end{center}
```

This example puts a box with a graphic side by side with one having text, with the two vertically centered.

```
\newcommand*{\vcenteredhbox}[1]{\begin{tabular}{@{}c@{}}#1\end{tabular}}
  ...
\begin{center}
  \vcenteredhbox{\includegraphics[width=0.4\textwidth]{plot}}
  \hspace{1em}
  \vcenteredhbox{\begin{minipage}{0.4\textwidth}
                   \begin{displaymath}
                     f(x)=x\cdot \sin (1/x)
                   \end{displaymath}
                 \end{minipage}}
\end{center}
```

If you use the `graphics` package then the only options involve the size of the graphic (but see Section 22.3.2 [\rotatebox], page 186, and Section 22.3.3 [\scalebox], page 187). When one optional argument is present then it is `[`*`urx`*`,`*`ury`*`]` and it gives the coordinates of the top right corner of the image, as a pair of TeX dimensions (see Section 14.1 [Units of length], page 121). If the units are omitted they default to `bp`. In this case, the lower left corner of the image is assumed to be at (0,0). If two optional arguments are present then the leading one is `[`*`llx`*`,`*`lly`*`]`, specifying the coordinates of the image's lower left. Thus, `\includegraphics[1in,0.618in]{...}` calls for the graphic to be placed so it is 1 inch wide and 0.618 inches tall and so its origin is at (0,0).

The `graphicx` package gives you many more options. Specify them in a key-value form, as here.

```
\begin{center}
  \includegraphics[width=1in,angle=90]{lion}
  \hspace{2em}
```

```
  \includegraphics[angle=90,width=1in]{lion}
\end{center}
```

The options are read left-to-right. So the first graphic above is made one inch wide and then rotated, while the second is rotated and then made one inch wide. Thus, unless the graphic is perfectly square, the two will end with different widths and heights.

There are many options. The primary ones are listed first.

Note that a graphic is placed by LaTeX into a box, which is traditionally referred to as its bounding box (distinct from the PostScript BoundingBox described below). The graphic's printed area may go beyond this box, or sit inside this box, but when LaTeX makes up a page it puts together boxes and this is the box allocated for the graphic.

`width` The graphic will be shown so its bounding box is this width. An example is `\includegraphics[width=1in]{plot}`. You can use the standard TeX dimensions (see Section 14.1 [Units of length], page 121) and also convenient is `\linewidth`, or in a two-column document, `\columnwidth` (see Section 5.5 [Page layout parameters], page 26). An example is that by using the `calc` package you can make the graphic be 1 cm narrow than the width of the text with `\includegraphics[width=\linewidth-1.0cm]{hefferon.jpg}`.

`height` The graphic will be shown so its bounding box is this height. You can use the standard TeX dimensions (see Section 14.1 [Units of length], page 121), and also convenient are `\pageheight` and `\textheight` (see Section 5.5 [Page layout parameters], page 26). For instance, the command `\includegraphics[height=0.25\textheight]{godel}` will make the graphic a quarter of the height of the text area.

`totalheight`
The graphic will be shown so its bounding box has this height plus depth. This differs from the height if the graphic was rotated. For instance, if it has been rotated by -90 then it will have zero height but a large depth.

`keepaspectratio`
If set to `true`, or just specified as here

```
\includegraphics[...,keepaspectratio,...]{...}
```

and you give as options both `width` and `height` (or `totalheight`), then LaTeX will make the graphic is as large as possible without distortion. That is, LaTeX will ensure that neither is the graphic wider than `width` nor taller than `height` (or `totalheight`).

`scale` Factor by which to scale the graphic. To make a graphic twice its nominal size, enter `\includegraphics[scale=2.0]{...}`. This number may be any value; a number between 1 and 0 will shrink the graphic and a negative number will reflect it.

`angle` Rotate the graphic. The angle is taken in degrees and counterclockwise. The graphic is rotated about its `origin`; see that option. For a complete description of how rotated material is typeset, see Section 22.3.2 [\rotatebox], page 186.

`origin` The point of the graphic about which the rotation happens. Possible values are any string containing one or two of: `l` for left, `r` for right, `b`

for bottom, `c` for center, `t` for top, and `B` for baseline. Thus, entering the command `\includegraphics[angle=180,origin=c]{moon}` will turn the picture upside down about that picture's center, while the command `\includegraphics[angle=180,origin=lB]{LeBateau}` will turn its picture upside down about its left baseline. (The character `c` gives the horizontal center in `bc` or `tc`, but gives the vertical center in `lc` or `rc`.) The default is `lB`.

To rotate about an arbitrary point, see Section 22.3.2 [\rotatebox], page 186.

These are lesser-used options.

`viewport` Pick out a subregion of the graphic to show. Takes four arguments, separated by spaces and given in TEX dimensions, as with `\includegraphics[.., viewport=0in 0in 1in 0.618in]{...}`. The dimensions default to big points, `bp`. They are taken relative to the origin specified by the bounding box. See also the `trim` option.

`trim` Gives parts of the graphic to not show. Takes four arguments, separated by spaces, that are given in TEX dimensions, as with `\includegraphics[.., trim= 0in 0.1in 0.2in 0.3in, ...]{...}`. These give the amounts of the graphic not to show, that is, LATEX will crop the picture by 0 inches on the left, 0.1 inches on the bottom, 0.2 inches on the right, and 0.3 inches on the top. See also the `viewport` option.

`clip` If set to `true`, or just specified as here

```
\includegraphics[...,clip,...]{...}
```

then the graphic is cropped to the bounding box. This is the same as using the starred form of the command, `\includegraphics*[...]{...}`.

`page` Give the page number of a multi-page PDF file. The default is `page=1`.

`pagebox` Specifies which bounding box to use for PDF files from among `mediabox`, `cropbox`, `bleedbox`, `trimbox`, or `artbox`. PDF files do not have the BoundingBox that PostScript files have, but may specify up to four predefined rectangles. The MediaBox gives the boundaries of the physical medium. The CropBox is the region to which the contents of the page are to be clipped when displayed. The BleedBox is the region to which the contents of the page should be clipped in production. The TrimBox is the intended dimensions of the finished page. The ArtBox is the extent of the page's meaningful content. The driver will set the image size based on CropBox if present, otherwise it will not use one of the others, with a driver-defined order of preference. MediaBox is always present.

`interpolate`
Enable or disable interpolation of raster images by the viewer. Can be set with `interpolate=true` or just specified as here.

```
\includegraphics[...,interpolate,...]{...}
```

`quiet` Do not write information to the log. You can set it with `quiet=true` or just specified it with `\includegraphics[...,quite,...]{...}`,

`draft` If you set it with `draft=true` or just specify it with

```
\includegraphics[...,draft,...]{...}
```

then the graphic will not appear in the document, possibly saving color printer ink. Instead, LaTeX will put an empty box of the correct size with the filename printed in it.

These options address the bounding box for Encapsulated PostScript graphic files, which have a size specified with a line `%%BoundingBox` that appears in the file. It has four values, giving the lower x coordinate, lower y coordinate, upper x coordinate, and upper y coordinate. The units are PostScript points, equivalent to TeX's big points, 1/72 inch. For example, if an `.eps` file has the line `%%BoundingBox 10 20 40 80` then its natural size is 30/72 inch wide by 60/72 inch tall.

`bb` Specify the bounding box of the displayed region. The argument is four dimensions separated by spaces, as with `\includegraphics[.., bb= 0in 0in 1in 0.618in]{...}`. Usually `\includegraphics` reads the BoundingBox numbers from the EPS file automatically, so this option is only useful if the bounding box is missing from that file or if you want to change it.

`bbllx, bblly, bburx, bbury`
Set the bounding box. These four are obsolete, but are retained for compatibility with old packages.

`natwidth, natheight`
An alternative for `bb`. Setting

```
\includegraphics[...,natwidth=1in,natheight=0.618in,...]{...}
```

is the same as setting `bb=0 0 1in 0.618in`.

`hiresbb` If set to `true`, or just specified as with

```
\includegraphics[...,hiresbb,...]{...}
```

then LaTeX will look for `%%HiResBoundingBox` lines instead of `%%BoundingBox` lines. (The `BoundingBox` lines use only natural numbers while the `HiResBoundingBox` lines use decimals; both use units equivalent to TeX's big points, 1/72 inch.) To override a prior setting of `true`, you can set it to `false`.

These following options allow a user to override LaTeX's method of choosing the graphic type based on the filename extension. An example is that `\includegraphics[type=png,ext=.xxx,read=.xxx]{lion}` will read the file `lion.xxx` as though it were `lion.png`. For more on these, see Section 22.2.3 [\DeclareGraphicsRule], page 180.

`type` Specify the graphics type.

`ext` Specify the graphics extension. Only use this in conjunction with the option `type`.

`read` Specify the file extension of the read file. Only use this in conjunction with the option `type`.

`command` Specify a command to be applied to this file. Only use this in conjunction with the option `type`. See Section 28.1 [Command line options], page 218, for a discussion of enabling the `\write18` functionality to run external commands.

22.3.2 \rotatebox

Synopsis for `graphics` package:

```
\rotatebox{angle}{material}
```

Synopses for `graphicx` package:

```
\rotatebox{angle}{material}
\rotatebox[key-value list]{angle}{material}
```

Put *material* in a box and rotate it *angle* degrees counterclockwise.

This example rotates the table column heads forty five degrees.

```
\begin{tabular}{ll}
  \rotatebox{45}{Character} &\rotatebox{45}{NATO phonetic}   \\
  A                         &AL-FAH  \\
  B                         &BRAH-VOH
\end{tabular}
```

The *material* can be anything that goes in a box, including a graphic.

```
\rotatebox[origin=c]{45}{\includegraphics[width=1in]{lion}}
```

To place the rotated material, the first step is that LaTeX sets *material* in a box, with a reference point on the left baseline. The second step is the rotation, by default about the reference point. The third step is that LaTeX computes a box to bound the rotated material. Fourth, LaTeX moves this box horizontally so that the left edge of this new bounding box coincides with the left edge of the box from the first step (they need not coincide vertically). This new bounding box, in its new position, is what LaTeX uses as the box when typesetting this material.

If you use the `graphics` package then the rotation is about the reference point of the box. If you use the `graphicx` package then then these are the options that can go in the *key-value list*, but note that you can get the same effect without needing this package, except for the `x` and `y` options (see Section 22.3.1 [\includegraphics], page 181).

`origin` The point of the *material*'s box about which the rotation happens. Possible value is any string containing one or two of: `l` for left, `r` for right, `b` for bottom, `c` for center, `t` for top, and `B` for baseline. Thus, the first line here

```
\includegraphics[angle=180,origin=c]{moon}
\includegraphics[angle=180,origin=lB]{LeBateau}
```

will turn the picture upside down from the center while the second will turn its picture upside down about its left baseline. (The character `c` gives the horizontal center in `bc` or `tc` but gives the vertical center in `lc` or `rc`.) The default is `lB`.

`x, y` Specify an arbitrary point of rotation with `\rotatebox[x=`*TeX dimension*`,y=`*TeX dimension*`]{...}` (see Section 14.1 [Units of length], page 121). These give the offset from the box's reference point.

`units` This key allows you to change the default of degrees counterclockwise. Setting `units=-360` changes the direction to degrees clockwise and setting `units=6.283185` changes to radians counterclockwise.

22.3.3 \scalebox

Synopses:

```
\scalebox{horizontal factor}{material}
\scalebox{horizontal factor}[vertical factor]{material}
\reflectbox{material}
```

Scale the *material*.

This example halves the size, both horizontally and vertically, of the first text and doubles the size of the second.

```
\scalebox{0.5}{DRINK ME} and \scalebox{2.0}{Eat Me}
```

If you do not specify the optional *vertical factor* then it defaults to the same value as the *horizontal factor*.

You can use this command to resize a graphic, as here.

```
\scalebox{0.5}{\includegraphics{lion}}
```

If you use the `graphicx` package then you can accomplish the same thing with optional arguments to `\includegraphics` (see Section 22.3.1 [\includegraphics], page 181).

The `\reflectbox` command abbreviates `\scalebox{-1}[1]{material}`. Thus, `Able was I\reflectbox{Able was I}` will show the phrase '`Able was I`' immediately followed by its mirror reflection.

22.3.4 \resizebox

Synopses:

```
\resizebox{horizontal length}{vertical length}{material}
\resizebox*{horizontal length}{vertical length}{material}
```

Given a size, such as `3cm`, transform *material* to make it that size. If either *horizontal length* or *vertical length* is an exclamation point `!` then the other argument is used to determine a scale factor for both directions.

This example makes the graphic be a half inch wide and scales it vertically by the same factor to keep it from being distorted.

```
\resizebox{0.5in}{!}{\includegraphics{lion}}
```

The unstarred form `\resizebox` takes *vertical length* to be the box's height while the starred form `\resizebox*` takes it to be height+depth. For instance, make the text have a height+depth of a quarter inch with `\resizebox*{!}{0.25in}{\parbox{1in}{This box has both height and depth.}}`.

You can use `\depth`, `\height`, `\totalheight`, and `\width` to refer to the original size of the box. Thus, make the text two inches wide but keep the original height with `\resizebox{2in}{\height}{Two inches}`.

23 Special insertions

LaTeX provides commands for inserting characters that have a special meaning do not correspond to simple characters you can type.

23.1 Reserved characters

LaTeX sets aside the following characters for special purposes. For example, the percent sign `%` is for comments. They are called *reserved characters* or *special characters*.

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

If you want a reserved character to be printed as itself, in the text body font, for all but the final three characters in that list simply put a backslash `\` in front of the character. Thus, typing `\$1.23` will produce `$1.23` in your output.

As to the last three characters, to get a tilde in the text body font use `\~{}` (omitting the curly braces would result in the next character receiving a tilde accent). Similarly, to get a get a text body font circumflex use `\^{}`. To get a backslash in the font of the text body, enter `\textbackslash{}`.

To produce the reserved characters in a typewriter font use `\verb!!` as below (the double backslash `\\` is only there to split the lines).

```
\begin{center}
  \# \$ \% \& \{ \} \_ \~{} \^{} \textbackslash \\
  \verb!# $ % & { } _ ~ ^ \!
\end{center}
```

23.2 Upper and lower case

Synopsis:

```
\uppercase{text}
\lowercase{text}
\MakeUppercase{text}
\MakeLowercase{text}
```

Change the case of characters. The TeX primitives commands `\uppercase` and `\lowercase` only work for American characters. The LaTeX commands `\MakeUppercase` and `\MakeLowercase` commands also change characters accessed by commands such as `\ae` or `\aa`. The commands `\MakeUppercase` and `\MakeLowercase` are robust but they have moving arguments (see Section 12.9 [\protect], page 113).

These commands do not change the case of letters used in the name of a command within *text*. But they do change the case of every other Latin letter inside the argument *text*. Thus, `\MakeUppercase{Let $y=f(x)$}` produces '`LET Y=F(X)`'. Another example is that the name of an environment will be changed, so that `\MakeUppercase{\begin{tabular} ... \end{tabular}}` will produce an error because the first half is changed to `\begin{TABULAR}`.

LaTeX uses the same fixed table for changing case throughout a document, The table used is designed for the font encoding T1; this works well with the standard TeX fonts for all Latin alphabets but will cause problems when using other alphabets.

To change the case of text that results from a macro inside *text* you need to do expansion. Here the `\Schoolname` produces '`COLLEGE OF MATHEMATICS`'.

```
\newcommand{\schoolname}{College of Mathematics}
\newcommand{\Schoolname}{\expandafter\MakeUppercase
                         \expandafter{\schoolname}}
```

The `textcase` package brings some of the missing feature of the standard LaTeX commands `\MakeUppercase` and `\MakeLowerCase`.

To uppercase only the first letter of words, you can use the package `mfirstuc`.

23.3 Symbols by font position

You can access any character of the current font using its number with the `\symbol` command. For example, the visible space character used in the `\verb*` command has the code decimal 32, so it can be typed as `\symbol{32}`.

You can also specify numbers in octal (base 8) by using a `'` prefix, or hexadecimal (base 16) with a `"` prefix, so the previous example could also be written as `\symbol{'40}` or `\symbol{"20}`.

23.4 Text symbols

LaTeX provides commands to generate a number of non-letter symbols in running text. Some of these, especially the more obscure ones, are not available in OT1. Unless you are using XeLaTeX or LuaLaTeX then you may need to load the `textcomp` package.

`\copyright`
`\textcopyright`
: © The copyright symbol.

`\dag`
: † The dagger symbol (in text).

`\ddag`
: ‡ The double dagger symbol (in text).

`\LaTeX`
: The LaTeX logo.

`\LaTeXe`
: The LaTeX2e logo.

`\guillemotleft` («)
`\guillemotright` (»)
`\guilsinglleft` (‹)
`\guilsinglright` (›)
: «, », ‹, › Double and single angle quotation marks, commonly used in French.

`\ldots`
`\dots`
`\textellipsis`
: . . . An ellipsis (three dots at the baseline): `\ldots` and `\dots` also work in math mode.

`\lq`
: ‘ Left (opening) quote.

`\P`
`\textparagraph`
: ¶ Paragraph sign (pilcrow).

`\pounds`
`\textsterling`
: £ English pounds sterling.

`\quotedblbase` („)
`\quotesinglbase` (‚)
: „ and ‚ Double and single quotation marks on the baseline.

`\rq` ' Right (closing) quote.

`\S`
`\textsection`
: § Section sign.

`\TeX` The TEX logo.

`\textasciicircum`
: ^ ASCII circumflex.

`\textasciitilde`
: ~ ASCII tilde.

`\textasteriskcentered`
: * Centered asterisk.

`\textbackslash`
: \ Backslash.

`\textbar` | Vertical bar.

`\textbardbl`
: || Double vertical bar.

`\textbigcircle`
: Big circle symbol.

`\textbraceleft`
: { Left brace.

`\textbraceright`
: } Right brace.

`\textbullet`
: • Bullet.

`\textcircled{`*letter*`}`
: Circle around *letter*.

`\textcompwordmark`
`\textcapitalcompwordmark`
`\textascendercompwordmark`
: Used to separate letters that would normally ligature. For example, `f\textcompwordmark i` produces 'fi' without a ligature. This is most useful in non-English languages. The `\textcapitalcompwordmark` form has the cap height of the font while the `\textascendercompwordmark` form has the ascender height.

`\textdagger`
: † Dagger.

`\textdaggerdbl`
: ‡ Double dagger.

`\textdollar` (or `\$`)
: $ Dollar sign.

`\textemdash` (or `---`)
: — Em-dash (used for punctuation, as in `The playoffs --- if you are fortunate enough to make the playoffs --- is more like a sprint.`).

`\textendash` (or `--`)
: – En-dash (used for ranges, as in `See pages 12--14`).

`\texteuro`
: The Euro symbol: €. For an alternative glyph design, try the `eurosym` package; also, most fonts nowadays come with their own Euro symbol (Unicode U+20AC).

`\textexclamdown` (or `!‘`)
: ¡ Upside down exclamation point.

`\textgreater`
: > Greater than symbol.

`\textless`
: < Less than symbol.

`\textleftarrow`
: Left arrow.

`\textordfeminine`
`\textordmasculine`
: ª, º Feminine and masculine ordinal symbols.

`\textperiodcentered`
: · Centered period.

`\textquestiondown` (or `?‘`)
: ¿ Upside down question mark.

`\textquotedblleft` (or ‘‘)
: “ Double left quote.

`\textquotedblright` (or ’’)
: ” Double right quote.

`\textquoteleft` (or ‘)
: ‘ Single left quote.

`\textquoteright` (or ’)
: ’ Single right quote.

`\textquotesingle`
: Straight single quote. (From TS1 encoding.)

`\textquotestraightbase`
`\textquotestraightdblbase`
: Single and double straight quotes on the baseline.

`\textregistered`
: ® Registered symbol.

`\textrightarrow`
: Right arrow.

`\textthreequartersemdash`
: "Three-quarters" em-dash, between en-dash and em-dash.

`\texttrademark`
: TM Trademark symbol.

`\texttwelveudash`
: "Two-thirds" em-dash, between en-dash and em-dash.

`\textunderscore`
: _ Underscore.

`\textvisiblespace`
: Visible space symbol.

23.5 Accents

LaTeX has wide support for many of the world's scripts and languages, through the `babel` package and related support if you are using pdfLaTeX, or `polyglossia` if you are using XeLaTeX or LuaLaTeX. This section does not cover that support. It only lists the core LaTeX commands for creating accented characters. The `\capital...` commands shown here produce alternative forms for use with capital letters. These are not available with OT1.

Below, to make them easier to find, the accents are all illustrated with lowercase '`o`'.

Note that `\i` produces a dotless i, and `\j` produces a dotless j. These are often used in place of their dotted counterparts when they are accented.

`\"`
`\capitaldieresis`
: ö Umlaut (dieresis).

`\'`
`\capitalacute`
: ó Acute accent.

`\.`
: ȯ Dot accent.

`\=`
`\capitalmacron`
: ō Macron (overbar) accent.

`\^`
`\capitalcircumflex`
: ô Circumflex (hat) accent.

`\‘`
`\capitalgrave`
: ò Grave accent.

`\~`
`\capitaltilde`
: ñ Tilde accent.

`\b`
: o̲ Bar accent underneath.

  Related to this, `\underbar{`*text*`}` produces a bar under *text*. The argument is always processed in LR mode (see Chapter 17 [Modes], page 149). The bar is always a fixed position under the baseline, thus crossing through descenders. See also `\underline` in Section 16.7 [Math miscellany], page 146.

`\c`
`\capitalcedilla`
: ç Cedilla accent underneath.

`\d`
`\capitaldotaccent`
: ọ Dot accent underneath.

`\H`
`\capitalhungarumlaut`
: ő Long Hungarian umlaut accent.

`\k`
`\capitalogonek`
: ǫ Ogonek. Not available in the OT1 encoding.

`\r`
`\capitalring`
: ů Ring accent.

`\t`
`\capitaltie`
`\newtie`
`\capitalnewtie`
: o͡o Tie-after accent. The `\newtie` form is centered in its box.

`\u`
`\capitalbreve`
: ŏ Breve accent.

`\v`
`\capitalcaron`
: ǒ Háček (check, caron) accent.

23.6 Additional Latin letters

Here are the basic LaTeX commands for inserting letters beyond A–Z that extend the Latin alphabet, used primarily in languages other than English.

`\aa`
`\AA`
: å and Å.

`\ae`
`\AE` æ and Æ.

`\dh`
`\DH` Icelandic letter eth: ð and Ð. Not available with OT1 encoding, you need the `fontenc` package to select an alternate font encoding, such as T1.

`\dj`
`\DJ` Crossed d and D, a.k.a. capital and small letter d with stroke. Not available with OT1 encoding, you need the `fontenc` package to select an alternate font encoding, such as T1.

`\ij`
`\IJ` ij and IJ (except somewhat closer together than appears here).

`\l`
`\L` ł and Ł.

`\ng`
`\NG` Lappish letter eng, also used in phonetics.

`\o`
`\O` ø and Ø.

`\oe`
`\OE` œ and Œ.

`\ss`
`\SS` ß and SS.

`\th`
`\TH` Icelandic letter thorn: þ and Þ. Not available with OT1 encoding, you need the `fontenc` package to select an alternate font encoding, such as T1.

23.7 `\rule`

Synopsis, one of:

```
\rule{width}{thickness}
\rule[raise]{width}{thickness}
```

Produce a *rule*, a filled-in rectangle.

This produces a rectangular blob, sometimes called a Halmos symbol, often used to mark the end of a proof.

```
\newcommand{\qedsymbol}{\rule{0.4em}{2ex}}
```

The `amsthm` package includes this command, with a somewhat different-looking symbol.

The mandatory arguments give the horizontal *width* and vertical *thickness* of the rectangle. They are rigid lengths (see Chapter 14 [Lengths], page 120). The optional argument *raise* is also a rigid length, and tells LaTeX how much to raise the rule above the baseline, or lower it if the length is negative.

This produces a line, a rectangle that is wide but not tall.

```
\noindent\rule{\textwidth}{0.4pt}
```

The line is the width of the page and 0.4 points tall. This line thickness is common in LaTeX.

A rule that has zero width, or zero thickness, will not show up in the output, but can cause LaTeX to change the output around it. See Section 19.13 [\strut], page 163, for examples.

23.8 \today

Synopsis:

```
\today
```

Produce today's date in the format '*month* *dd*, *yyyy*'. An example of a date in that format is '`July 4, 1976`'.

Multilingual packages such as `babel` or `polyglossia`, or classes such as `lettre`, will localize `\today`. For example, the following will output '`4 juillet 1976`':

```
\year=1976 \month=7 \day=4
\documentclass{minimal}
\usepackage[french]{babel}
\begin{document}
\today
\end{document}
```

`\today` uses the counters `\day`, `\month`, and `\year` (see Section 13.8 [\day & \month & \year], page 119).

A number of package on CTAN work with dates. One is `datetime` package which can produce a wide variety of date formats, including ISO standards.

The date is not updated as the LaTeX process runs, so in principle the date could be incorrect by the time the program finishes.

24 Splitting the input

LaTeX lets you split a large document into several smaller ones. This can simplify editing or allow multiple authors to work on the document. It can also speed processing.

Regardless of how many separate files you use, there is always one *root file*, on which LaTeX compilation starts. This shows such a file with five included files.

```
\documentclass{book}
\includeonly{  % comment out lines below to omit compiling
  pref,
  chap1,
  chap2,
  append,
  bib
  }
\begin{document}
\frontmatter
\include{pref}
\mainmatter
\include{chap1}
\include{chap2}
\appendix
\include{append}
\backmatter
\include{bib}
\end{document}
```

This will bring in material from `pref.tex`, `chap1.tex`, `chap2.tex`, `append.tex`, and `bib.tex`. If you compile this file, and then comment out all of the lines inside `\includeonly{...}` except for `chap1,` and compile again, then LaTeX will only process the material in the first chapter. Thus, your output will appear more quickly and be shorter to print. However, the advantage of the `\includeonly` command is that LaTeX will retain the page numbers and all of the cross reference information from the other parts of the document so these will appear in your output correctly.

See Section A.4 [Larger book template], page 223, for another example of `\includeonly`.

24.1 \endinput

Synopsis:

```
\endinput
```

When you `\include{filename}`, inside `filename.tex` the material after `\endinput` will not be included. This command is optional; if `filename.tex` has no `\endinput` then LaTeX will read all of the file.

For example, suppose that a document's root file has `\input{chap1}` and this is `chap1.tex`.

```
\chapter{One}
This material will appear in the document.
```

```
\endinput
This will not appear.
```

This can be useful for putting documentation or comments at the end of a file, or for avoiding junk characters that can be added during mailing. It is also useful for debugging: one strategy to localize errors is to put `\endinput` halfway through the included file and see if the error disappears. Now, knowing which half contains the error, moving `\endinput` to halfway through that area further narrows down the location. This process rapidly finds the offending line.

After reading `\endinput`, LaTeX continues to read to the end of the line, so something can follow this command and be read nonetheless. This allows you, for instance, to close an `\if...` with a `\fi`.

24.2 \include & \includeonly

Synopsis:

```
\includeonly{  % in document preamble
  ...
  filename,
  ...
  }
  ...
\include{filename}  % in document body
```

Bring material from the external file *filename*`.tex` into a LaTeX document.

The `\include` command does three things: it executes `\clearpage` (see Section 10.1 [\clearpage & \cleardoublepage], page 97), then it inputs the material from *filename*`.tex` into the document, and then it does another `\clearpage`. This command can only appear in the document body. The `\includeonly` command controls which files will be read by LaTeX under subsequent `\include` commands. Its list of filenames is comma-separated, and it can only appear in the preamble.

This example root document, `constitution.tex`, brings in three files, `preamble.tex`, `articles.tex`, and `amendments.tex`.

```
\documentclass{book}
\includeonly{
  preamble,
  articles,
  amendments
  }
\begin{document}
\include{preamble}
\include{articles}
\include{amendments}
\end{document}
```

The file `preamble.tex` contains no special code; you have just excerpted the chapter from `consitution.tex` and put it in a separate file just for editing convenience.

```
\chapter{Preamble}
```

```
We the People of the United States,
in Order to form a more perfect Union, ...
```

Running LaTeX on `constitution.tex` makes the material from the three files appear in the document but also generates the auxiliary files `preamble.aux`, `articles.aux`, and `amendments.tex`. These contain information such as page numbers and cross-references (see Chapter 7 [Cross references], page 43). If you now comment out `\includeonly`'s lines with `preamble` and `amendments` and run LaTeX again then the resulting document shows only the material from `articles.tex`, not the material from `preamble.tex` or `amendments.tex`. Nonetheless, all of the auxiliary information from the omitted files is still there, including the starting page number of the chapter.

If the document preamble does not have `\includeonly` then LaTeX will include all the files you call for with `\include` commands.

The `\include` command makes a new page. To avoid that, see Section 24.3 [\input], page 199, (which, however, does not retain the auxiliary information).

See Section A.4 [Larger book template], page 223, for another example using `\include` and `\includeonly`. That example also uses `\input` for some material that will not necessarily start on a new page.

File names can involve paths.

```
\documentclass{book}
\includeonly{
  chapters/chap1,
  }
\begin{document}
\include{chapters/chap1}
\end{document}
```

To make your document portable across distributions and platforms you should avoid spaces in the file names. The tradition is to instead use dashes or underscores. Nevertheless, for the name '`amo amas amat`', this works under TeX Live on GNU/Linux:

```
\documentclass{book}
\includeonly{
  "amo\space amas\space amat"
  }
\begin{document}
\include{"amo\space amas\space amat"}
\end{document}
```

and this works under MiKTeX on Windows:

```
\documentclass{book}
\includeonly{
  {"amo amas amat"}
  }
\begin{document}
\include{{"amo amas amat"}}
\end{document}
```

You cannot use `\include` inside a file that is being included or you get '`LaTeX Error: \include cannot be nested.`' The `\include` command cannot appear in the document preamble; you will get '`LaTeX Error: Missing \begin{document}`'.

If a file that you `\include` does not exist, for instance if you `\include{athiesm}` but you meant `\include{atheism}`, then LaTeX does not give you an error but will warn you '`No file athiesm.tex.`' (It will also create `athiesm.aux`.)

If you `\include` the root file in itself then you first get '`LaTeX Error: Can be used only in preamble.`' Later runs get '`TeX capacity exceeded, sorry [text input levels=15]`'. To fix this, you must remove the inclusion `\include{root}` but also delete the file *`root`*`.aux` and rerun LaTeX.

24.3 `\input`

Synopsis:

```
\input{filename}
```

LaTeX processes the file as if its contents were inserted in the current file. For a more sophisticated inclusion mechanism see Section 24.2 [\include & \includeonly], page 197.

If *filename* does not end in '`.tex`' then LaTeX first tries the filename with that extension; this is the usual case. If *filename* ends with '`.tex`' then LaTeX looks for the filename as it is.

For example, this

```
\input{macros}
```

will cause LaTeX to first look for `macros.tex`. If it finds that file then it processes its contents as thought they had been copy-pasted in. If there is no file of the name `macros.tex` then LaTeX tries the name `macros`, without an extension. (This may vary by distribution.)

To make your document portable across distributions and platforms you should avoid spaces in the file names. The tradition is to instead use dashes or underscores. Nevertheless, for the name '`amo amas amat`', this works under TeX Live on GNU/Linux:

```
\input{"amo\space amas\space amat"}
```

and this works under MiKTeX on Windows:

```
\input{{"amo amas amat"}}
```

25 Front/back matter

25.1 Table of contents etc.

Synopsis, one of:

```
\tableofcontents
\listoffigures
\listoftables
```

Produce a table of contents, or list of figures, or list of tables. Put the command in the input file where you want the table or list to go. You do not type the entries; for example, typically the table of contents entries are automatically generated from the sectioning commands `\chapter`, etc.

This example illustrates the first command, `\tableofcontents`. LaTeX will produce a table of contents on the book's first page.

```
\documentclass{book}
% \setcounter{tocdepth}{1}
\begin{document}
\tableofcontents\newpage
  ...
\chapter{...}
  ...
\section{...}
  ...
\subsection{...}
  ...
\end{document}
```

Uncommenting the second line would cause that table to contain chapter and section listings but not subsection listings, because the `\section` command has level 1. See Chapter 6 [Sectioning], page 32, for level numbers of the sectioning units. For more on the `tocdepth` see [Sectioning/tocdepth], page 33.

Another example of the use of `\tableofcontents` is in Section A.4 [Larger book template], page 223.

If you want a page break after the table of contents, write a `\newpage` command after the `\tableofcontents` command, as above.

To make the table of contents LaTeX stores the information in an auxiliary file named *`root-file`*`.toc` (see Chapter 24 [Splitting the input], page 196). For example, this LaTeX file `test.tex`

```
\documentclass{article}
\begin{document}
\tableofcontents\newpage
\section{First section}
\subsection{First subsection}
  ...
```

writes the following line to `test.toc`.

```
\contentsline {section}{\numberline {1}First section}{2}
\contentsline {subsection}{\numberline {1.1}First subsection}{2}
```

The `section` or `subsection` is the sectioning unit. The hook `\numberline` lets you to change how the information appears in the table of contents. Of its two arguments, `1` or `1.1` is the sectioning unit number and `First section` or `First subsection` is the title. Finally, `2` is the page number on which the sectioning units start.

One consequence of this auxiliary file storage strategy is that to get the contents page correct you must run LaTeX twice, once to store the information and once to get it. In particular, the first time that you run LaTeX on a new document, the table of contents page will be empty except for its '`Contents`' header. Just run it again.

The commands `\listoffigures` and `\listoftables` produce a list of figures and a list of tables. They work the same way as the contents commands; for instance, these work with information stored in `.lof` and `.lot` files.

To change the header for the table of contents page do something like the first line here.

```
\renewcommand{\contentsname}{Table of contents}
\renewcommand{\listfigurename}{Plots}
\renewcommand{\listtablename}{Tables}
```

Similarly, the other two lines will do the other two. Internationalization packages such as `babel` or `polyglossia` will change the headers depending on the chosen base language.

CTAN has many packages for the table of contents and lists of figures and tables. One convenient one for adjusting some aspects of the default, such as spacing, is `tocloft`. And, `tocbibbind` will automatically add the bibliography, index, etc. to the table of contents.

25.1.1 `\addcontentsline`

Synopsis:

```
\addcontentsline{ext}{unit}{text}
```

Add an entry to the file specified by *ext*. Usually *ext* is one of `toc` for the table of contents, `lof` for the list of figures, or `lot` for the list of tables.

The following will result in an '`Appendices`' line in the table of contents.

```
\addcontentsline{toc}{section}{\protect\textbf{Appendices}}
```

It will appear at the same indentation level as the sections, will be in boldface, and will be assigned the page number associated with the point where it appears in the input file.

The `\addcontentsline` command writes information to the file *root-name.ext*. It writes that information as the text of the command `\contentsline{`*unit*`}{`*text*`}{`*num*`}`, where *num* is the current value of counter *unit*. The most common case is the table of contents and there *num* is the page number of the first page of *unit*.

This command is invoked by the sectioning commands `\chapter`, etc., and also by `\caption` inside a float environment. But it is also used by authors. For example, in a book to have the preface unnumbered, you may use the starred `\chapter*`. But that does not put in table of contents information, so you can enter it manually, as here.

```
\chapter*{Preface}
\addcontentsline{toc}{chapter}{\protect\numberline{}Preface}
```

In the `.toc` file LaTeX will put the line `\contentsline {chapter}{\numberline {}Preface}{3}`; note the page number '3'.

All of the arguments for `\addcontentsline` are required.

ext Typically one of the strings `toc` for the table of contents, `lof` for the list of figures, or `lot` for the list of tables. The filename extension of the information file.

unit A string that depends on the value of the *ext* argument:

- `toc` For the table of contents, this is the name of a sectional unit: `part`, `chapter`, `section`, `subsection`, etc.
- `lof` For the list of figures: `figure`.
- `lot` For the list of tables: `table`.

text The text of the entry. You must `\protect` any commands that are fragile (see Section 12.9 [\protect], page 113).

The `\addcontentsline` command has an interaction with `\include` (see Section 24.2 [\include & \includeonly], page 197). If you use them at the same level, as with `\addcontentsline{...}{...}{...}\include{...}` then lines in the table of contents can come out in the wrong order. The solution is to move `\addcontentsline` into the file being included.

If you use a *unit* that LaTeX does not recognize, as here

```
\addcontentsline{toc}{setcion}{\protect\textbf{Appendices}}
```

then you don't get an error but the formatting in the table of contents will not make sense.

25.1.2 \addtocontents

Synopsis:

```
\addtocontents{ext}{text}
```

Add *text*, which may be text or formatting commands, directly to the auxiliary file with extension *ext*. This is most commonly used for the table of contents so that is the discussion here, but this also applies to the list of figures and list of tables.

This will put some vertical space in the table of contents after the '`Contents`' header.

```
\tableofcontents\newpage
\addtocontents{toc}{\protect\vspace*{3ex}}
```

The `\addtocontents` command has two arguments. Both are required.

ext Typically one of: `toc` for the table of contents, `lof` for the list of figures, or `lot` for the list of tables. The extension of the file holding the information.

text The text, and possibly commands, to be written.

The sectioning commands such as `\chapter` use the `\addcontentsline` command to store information. This command creates lines in the `.toc` auxiliary file containing the `\contentsline` command (see Section 25.1.1 [\addcontentsline], page 201). In contrast, the command `\addtocontents` puts material directly in that file.

The `\addtocontents` command has an interaction with `\include` (see Section 24.2 [\include & \includeonly], page 197). If you use them at the same level, as with `\addtocontents{...}{...}\include{...}` then lines in the table of contents can come out in the wrong order. The solution is to move `\addtocontents` into the file being included.

25.1.3 `\nofiles`

Synopsis:

```
\nofiles
```

Prevent LaTeX from writing any auxiliary files. The only output will be the `.log` and `.pdf` (or `.dvi`) files. This command must go in the preamble.

Because of the `\nofiles` command this example will not produce a `.toc` file.

```
\documentclass{book}
\nofiles
\begin{document}
\tableofcontents\newpage
\chapter{...}
  ...
```

LaTeX will not erase any existing auxiliary files, so if you insert the `\nofiles` command after you have run the file and gotten a `.toc` then the table of contents page will continue to show the old information.

25.2 Indexes

This document has an index.

```
\documentclass{article}
\usepackage{makeidx} \makeindex
  ...
\begin{document}
  ...
Recall Wilson's Theorem: \index{Wilson's Theorem}
a number \( n>1 \) is prime if and only if the factorial of \( n-1 \)
is congruent to \( -1 \) modulo~\( n \).
  ...
\printindex
  ...
```

The `\usepackage{makeidx}` and `\makeindex` in the preamble bring in the relevant commands.

Producing an index is a three stage process. First, in the document body you declare index entries with the `\index` command (see Section 25.2.1 [\index], page 204). When you run LaTeX, the `\index` writes its information to an auxiliary file *`root-name`*`.idx`. Next, to alphabetize and to do other manipulations you run an external command, typically `makeindex` or `xindy` (see Section 25.2.2 [makeindex], page 205). These output a file *`root-name`*`.ind`. Finally, you bring the information back into your document and typeset it with the `\printindex` command (see Section 25.2.3 [\printindex], page 208).

There are many packages that apply to indexing commands. The `showidx` package causes each index entries to be shown in the margin on the page where the entry appears. This can help in preparing the index. The `multind` package supports multiple indexes. See also the TEX FAQ entry on this topic, `http://www.tex.ac.uk/cgi-bin/texfaq2html?label=multind`.

25.2.1 \index

Synopsis:

```
\index{index-entry-string}
```

Declare an entry in the index. This command is fragile (see Section 12.9 [\protect], page 113).

For example, as described in Section 25.2 [Indexes], page 203, one way to get an index from what's below is to compile the document with `pdflatex test`, then process the index entries with `makeindex test`, and then compile again with `pdflatex test`.

```
W~Ackermann (1896--1962).\index{Ackermann}
  ...
Ackermann function\index{Ackermann!function}
  ...
rate of growth\index{Ackermann!function!growth rate}
```

All three index entries will get a page number, such as '`Ackermann, 22`'. LaTeX will format the second as a subitem of the first, on the line below it and indented, and the third as a subitem of the second. Three levels deep is as far as you can nest subentries. (If you add `\index{Ackermann!function!growth rate!comparison}` then `makeindex` says '`Scanning input file test.idx....done (4 entries accepted, 1 rejected)`' and nothing appears in the index).

If you enter a second `\index` with the same *index-entry-string* then you will get a single index entry with two page numbers (unless they happen to fall on the same page). Thus, adding `as for Ackermann.\index{Ackermann}` later in the same document as above will give an index entry like '`Ackermann, 22, 151`'. Also, you can enter the index entries in any order, so for instance `\index{Ackermann!function}` could come before `\index{Ackermann}`.

Get a page range in the output, like '`Hilbert, 23--27`', as here.

```
W~Ackermann (1896--1962).\index{Ackermann}
  ...
D~Hilbert (1862--1943)\index{Ackermann!Hilbert\(}
  ...
disapproved of his marriage.\index{Ackermann!Hilbert\)}
```

If the beginning and ending of the page range are equal then the system just gives a single page entry, not a range.

If you index subentries but not a main entry, as with `\index{Jones!program}` and `\index{Jones!results}`, then the output is the item '`Jones`' with no comma or page number, followed by two subitems, like '`program, 50`' and '`results, 51`'.

Generate a index entry that says '`See`' by using a vertical bar character: `\index{Ackermann!function|see{P\'eter's function}}`. You can instead get '`See`

also' with seealso. (The text 'See' is defined by \seename, and 'See also' by \alsoname. You can redefine these either by using an internationalization package such as babel or polyglossia, or directly as with \renewcommand{\alsoname}[1]{Also see #1}.)

The 'See' feature is part of a more general functionality. After the vertical bar you can put the name of a one-input command, as in \index{group|textit} (note the missing backslash on the \textit command) and the system will apply that command to the page number, here giving something like \textit{7}. You can define your own one-input commands, such as \newcommand{\definedpage}[1]{{\color{blue}#1}} and then \index{Ackermann!function|definedpage} will give a blue page number (see Chapter 21 [Color], page 173). Another, less practical, example is this,

```
\newcommand\indexownpage[1]{#1, \thepage}
  ... Epimenides.\index{self-reference|indexownpage}
```

which creates an entry citing the page number of its own index listing.

The two functions just described combine, as here

```
\index{Ackermann!function|(definedpage}
  ...
\index{Ackermann!function|)}
```

which outputs an index entry like 'function, 23--27' where the page number range is in blue.

Consider an index entry such as 'α-ring'. Entering it as α-ring will cause it to be alphabetized according to the dollar sign. You can instead enter it using an at-sign, as \index{alpha-ring@α-ring}. If you specify an entry with an at-sign separating two strings, *pos*@*text*, then *pos* gives the alphabetical position of the entry while *text* produces the text of the entry. Another example is that \index{Saint Michael's College@SMC} produces an index entry 'SMC' alphabetized into a different location than its spelling would naturally give it.

To put a !, or @, or | character in an index entry, preceding it with a double quote, ". (The double quote gets deleted before alphabetization.)

A number of packages on CTAN have additional functionality beyond that provided by makeidx. One is index, which allows for multiple indices and contains a command \index*{*index-entry-string*} that prints the *index-entry-string* as well as indexing it.

The \index command writes the indexing information to the file *root-name*.idx file. Specifically, it writes text of the command \indexentry{*index-entry-string*}{*page-num*}, where where *page-num* is the value of the \thepage counter. On occasion, when the \printindex command is confused, you have to delete this file to start with a fresh slate.

If you omit the closing brace of an \index command then you get a message like this.

```
Runaway argument?  {Ackermann!function
!  Paragraph ended before \@wrindex was complete.
```

25.2.2 makeindex

Synopsis, one of:

```
makeindex filename
makeindex -s style-file filename
```

```
makeindex options filename0 ...
```

Sort, and otherwise process, the index information in the auxiliary file *filename*. This is a command line program. It takes one or more raw index files, *`filename`*`.idx` files, and produces the actual index file, the *`filename`*`.ind` file that is input by `\printindex` (see Section 25.2.3 [\printindex], page 208).

The first form of the command suffices for many uses. The second allows you to format the index by using an *index style file*, a `.isty` file. The third form is the most general; see the full documentation on CTAN.

This is a simple `.isty` file.

```
% book.isty
%   $ makeindex -s book.isty -p odd book.idx
% creates the index as book.ind, starting on an odd page.
preamble
"\\pagestyle{empty}
\\small
\\begin{theindex}
\\thispagestyle{empty}"

postamble
"\n
\\end{theindex}"
```

The description here covers only some of the index formatting possibilities in *style-file*. For a full list see the documentation on CTAN.

A style file consists of a list of pairs: *specifier* and *attribute*. These can appear in the file in any order. All of the *attributes* are strings, except where noted. Strings are surrounded with double quotes, `"`, and the maximum length of a string is 144 characters. The `\n` is for a newline and `\t` is for a tab. Backslashes are escaped with another backslash, `\\`. If a line begins with a percent sign, `%`, then it is a comment.

`preamble` Preamble of the output file. Defines the context in which the index is formatted. Default: `"\\begin{theindex}\n"`.

`postamble`
Postamble of the output file. Default: `"\n\n\\end{theindex}\n"`.

`group_skip`
Traditionally index items are broken into groups, typically a group for entries starting with '`a`', etc. This specifier gives what is inserted when a new group begins. Default: `"\n\n \\indexspace\n"` (`\indexspace` is a rubber length with default value `10pt plus5pt minus3pt`).

`lethead_flag`
An integer. It governs what is inserted for a new group or letter. If it is 0 (which is the default) then other than `group_skip` nothing will be inserted before the group. If it is is positive then at a new letter the `lethead_prefix` and `lethead_suffix` will be inserted, with that letter in uppercase between them. If it is negative then what will be inserted is the letter in lowercase. The default is 0.

`lethead_prefix`
: If a new group begins with a different letter then this is the prefix inserted before the new letter header. Default: `""`

`lethead_suffix`
: If a group begins with a different letter then this is the suffix inserted after the new letter header. Default: `""`.

`item_0` What is put between two level 0 items. Default: `"\n \\item "`.

`item_1` Put between two level 1 items. Default: `"\n \\subitem "`.

`item_2` put between two level 2 items. Default: `"\n \\subsubitem "`.

`item_01` What is put between a level 0 item and a level 1 item. Default: `"\n \\subitem "`.

`item_x1` What is put between a level 0 item and a level 1 item in the case that the level 0 item doesn't have any page numbers (as in `\index{aaa|see{bbb}}`). Default: `"\n \\subitem "`.

`item_12` What is put between a level 1 item and a level 2 item. Default: `"\n \\subsubitem "`.

`item_x2` What is put between a level 1 item and a level 2 item, if the level 1 item doesn't have page numbers. Default: `"\n \\subsubitem "`.

`delim_0` Delimiter put between a level 0 key and its first page number. Default: a comma followed by a blank, `", "`.

`delim_1` Delimiter put between a level 1 key and its first page number. Default: a comma followed by a blank, `", "`.

`delim_2` Delimiter between a level 2 key and its first page number. Default: a comma followed by a blank, `", "`.

`delim_n` Delimiter between two page numbers for the same key (at any level). Default: a comma followed by a blank, `", "`.

`delim_r` What is put between the starting and ending page numbers of a range. Default: `"--"`.

`line_max` An integer. Maximum length of an index entry's line in the output, beyond which the line wraps. Default: `72`.

`indent_space`
: What is inserted at the start of a wrapped line. Default: `"\t\t"`.

`indent_length`
: A number. The length of the wrapped line indentation. The default `indent_space` is two tabs and each tab is eight spaces so the default here is `16`.

`page_precedence`
: A document may have pages numbered in different ways. For example, a book may have front matter pages numbered in lowercase roman while main matter pages are in arabic. This string specifies the order in which they will appear in

the index. The `makeindex` command supports five different types of numerals: lowercase roman `r`, and numeric or arabic `n`, and lowercase alphabetic `a`, and uppercase roman `R`, and uppercase alphabetic `A`. Default: `"rnaRA"`.

There are a number of other programs that do the job `makeindex` does. One is `xindy`, which does internationalization and can process indexes for documents marked up using LaTeX and a number of other languages. It is is highly configurable, both in markup terms and in terms of the collating order of the text. See the documentation on CTAN.

25.2.3 `\printindex`

Synopsis:

```
\printindex
```

Place the index into the output.

To get an index you must first include `\usepackage{makeidx}\makeindex` in the document preamble and compile the document, then run the system command `makeindex`, and then compile the document again. See Section 25.2 [Indexes], page 203, for further discussion and an example of the use of `\printindex`.

25.3 Glossaries

Synopsis:

```
\usepackage{glossaries} \makeglossaries
  ...
\newglossaryentry{label}{settings}
  ...
\gls{label}.
  ...
\printglossaries
```

The `glossaries` package allows you to make glossaries, including multiple glossaries, as well as lists of acronyms.

To get the output from this example, compile the document (for instance with `pdflatex filename`), then run the command line command `makeglossaries filename`, and then compile the document again.

```
\documentclass{...}
\usepackage{glossaries} \makeglossaries
\newglossaryentry{tm}{%
  name={Turing machine},
  description={A model of a machine that computes.  The model is simple
               but can compute anything any existing device can compute.
               It is the standard model used in Computer Science.},
  }
\begin{document}
Everything begins with the definition of a \gls{tm}.
  ...
\printglossaries
\end{document}
```

That gives two things. In the main text it outputs '`... definition of a Turing machine`'. In addition, in a separate sectional unit headed '`Glossary`' there appears a description list. In boldface it says '`Turing machine`' and the rest of the item says in normal type '`A model of a machine ... Computer Science`'.

The command `\makeglossary` opens the file that will contain the entry information, *root-file*`.glo`. Put the `\printglossaries` command where you want the glossaries to appear in your document.

The `glossaries` package is very powerful. For instance, besides the commands `\newglossaryentry` and `\gls`, there are similar commands for a list of acronyms. See the package documentations on CTAN.

25.3.1 \newglossaryentry

Synopsis, one of:

```
\newglossaryentry{label}
{
  name={name},
  description={description},
  other options, ...
}
```

or

```
\longnewglossaryentry{label}
{
  name={name},
  other options ...,
}
{description}
```

Declare a new entry for a glossary. The *label* must be unique for the document. The settings associated with the label are pairs: *key*`=`*value*.

This puts the blackboard bold symbol for the real numbers in the glossary.

```
\newglossaryentry{R}
{
  name={\ensuremath{\mathbb{R}}},
  description={the real numbers},
}
```

Use the second command form if the *description* spans more than one paragraph.

For a full list of *key*s see the package documentation on CTAN but here are a few.

`name` (Required.) The word, phrase, or symbol that you are defining.

`description`
(Required.) The description that will appear in the glossary. If this has more than one paragraph then you must use the second command form given in the synopsis.

`plural` The plural form of *name*. Refer to the plural form using `\glspl` or `\Glspl` (see Section 25.3.2 [\gls], page 210).

`sort` How to place this entry in the list of entries that the glossary holds.

`symbol` A symbol, such as a mathematical symbol, besides the name.

25.3.2 \gls

Synopsis, one of:

```
\gls{label}
\glspl{label}
\Gls{label}
\Glspl{label}
```

Refer to a glossary entry. The entries are declared with `\newglossaryentry` (see Section 25.3.1 [\newglossaryentry], page 209).

This

```
\newglossaryentry{N}{%
  name={the natural numbers},
  description={The numbers $0$, $1$, $2$, $\ldots$\@},
  symbol={\ensuremath{\mathbb{N}}},
  }
  ...
Consider \gls{N}.
```

gives the output '`Consider the natural numbers`'.

The second command form `\glspl{label}` produces the plural of *name* (by default it tries adding an '`s`'). The third form capitalizes the first letter of *name*, as does the fourth form, which also takes the plural.

26 Letters

Synopsis:

```
\documentclass{letter}
\address{senders address}   % return address
\signature{sender name}
\begin{document}
\begin{letter}{recipient address}
\opening{salutation}
  letter body
\closing{closing text}
\end{letter}
   ...
\end{document}
```

Produce one or more letters.

Each letter is in a separate `letter` environment, whose argument *recipient address* often contains multiple lines separated with a double backslash, (`\\`). For example, you might have:

```
\begin{letter}{Ninon de l'Enclos \\
               l'h\^otel Sagonne}
  ...
\end{letter}
```

The start of the `letter` environment resets the page number to 1, and the footnote number to 1 also.

The *sender address* and *sender name* are common to all of the letters, whether there is one or more, so these are best put in the preamble. As with the recipient address, often *sender address* contains multiple lines separated by a double backslash (`\\`). LaTeX will put the *sender name* under the closing, after a vertical space for the traditional hand-written signature.

Each `letter` environment body begins with a required `\opening` command such as `\opening{Dear Madam or Sir:}`. The *letter body* text is ordinary LaTeX so it can contain everything from enumerated lists to displayed math, except that commands such as `\chapter` that make no sense in a letter are turned off. Each `letter` environment body typically ends with a `\closing` command such as `\closing{Yours,}`.

Additional material may come after the `\closing`. You can say who is receiving a copy of the letter with a command like `\cc{the Boss \\ the Boss's Boss}`. There's a similar `\encl` command for a list of enclosures. And, you can add a postscript with `\ps`.

LaTeX's default is to indent the sender name and the closing above it by a length of `\longindentation`. By default this is `0.5\textwidth`. To make them flush left, put `\setlength{\longindentation}{0em}` in your preamble.

To set a fixed date use something like `\renewcommand{\today}{1958-Oct-12}`. If put in your preamble then it will apply to all the letters.

This example shows only one `letter` environment. The three lines marked as optional are typically omitted.

```
\documentclass{letter}
```

```
\address{Sender's street \\ Sender's town}
\signature{Sender's name \\ Sender's title}
% optional: \location{Mailbox 13}
% optional: \telephone{(102) 555-0101}
\begin{document}
\begin{letter}{Recipient's name \\ Recipient's address}
\opening{Sir:}
% optional: \thispagestyle{firstpage}
I am not interested in entering a business arrangement with you.
\closing{Your most humble, etc.,}
\end{letter}
\end{document}
```

These commands are used with the `letter` class.

26.1 \address

Synopsis:

```
\address{senders address}
```

Specify the return address, as it appears on the letter and on the envelope. Separate multiple lines in *senders address* with a double backslash, `\\`.

Because it can apply to multiple letters this declaration is often put in the preamble. However, it can go anywhere, including inside an individual `letter` environment.

This command is optional: if you do not use it then the letter is formatted with some blank space on top, for copying onto pre-printed letterhead paper. If you do use the `\address` declaration then it is formatted as a personal letter.

Here is an example.

```
\address{Stephen Maturin \\
         The Grapes of the Savoy}
```

26.2 \cc

Synopsis:

```
\cc{name0 \\
     ... }
```

Produce a list of names to which copies of the letter were sent. This command is optional. If it appears then typically it comes after `\closing`. Put the names on different lines by separating them with a double backslash, `\\`, as in:

```
\cc{President \\
    Vice President}
```

26.3 \closing

Synopsis:

```
\closing{text}
```

Produce the letter's closing. This is optional, but usual. It appears at the end of a letter, above a handwritten signature. For example:

```
\closing{Regards,}
```

26.4 \encl

Synopsis:

```
\encl{first enclosed object \\
      ... }
```

Produce a list of things included with the letter. This command is optional; when it is used, it typically is put after `\closing`. Separate multiple lines with a double backslash, `\\`.

```
\encl{License \\
      Passport}
```

26.5 \location

Synopsis:

```
\location{text}
```

The *text* appears centered at the bottom of the page. It only appears if the page style is `firstpage`.

26.6 \makelabels

Synopsis:

```
\makelabels   % in preamble
```

Optional, for a document that contains `letter` environments. If you just put `\makelabels` in the preamble then at the end of the document you will get a sheet with labels for all the recipients, one for each letter environment, that you can copy to a sheet of peel-off address labels.

Customize the labels by redefining the commands `\startlabels`, `\mlabel`, and `\returnaddress` (and perhaps `\name`) in the preamble. The command `\startlabels` sets the width, height, number of columns, etc., of the page onto which the labels are printed. The command `\mlabel{`*`return address`*`}{`*`recipient address`*`}` produces the two labels (or one, if you choose to ignore the *return address*) for each letter environment. The first argument, *return address*, is the value returned by the macro `\returnaddress`. The second argument, *recipient address*, is the value passed in the argument to the `letter` environment. By default `\mlabel` ignores the first argument, the *return address*, causing the default behavior described in the prior paragraph.

This illustrates customization. Its output includes a page with two columns having two labels each.

```
\documentclass{letter}
\renewcommand*{\returnaddress}{Fred McGuilicuddy \\
                               Oshkosh, Mineola 12305}
\newcommand*\originalMlabel{}
```

```
\let\originalMlabel\mlabel
\def\mlabel#1#2{\originalMlabel{}{#1}\originalMlabel{}{#2}}
\makelabels
  ...
\begin{document}
\begin{letter}{A Einstein \\
               112 Mercer Street \\
               Princeton, New Jersey, USA 08540}
  ...
\end{letter}
\begin{letter}{K G\"odel \\
               145 Linden Lane \\
               Princeton, New Jersey, USA 08540}
  ...
\end{letter}
\end{document}
```

The first column contains the return address twice. The second column contains the address for each recipient.

The package `envlab` makes formatting the labels easier, with standard sizes already provided. The preamble lines `\usepackage[personalenvelope]{envlab}` and `\makelabels` are all that you need to print envelopes.

26.7 \name

Synopsis:

```
\name{name}
```

Optional. Sender's name, used for printing on the envelope together with the return address.

26.8 \opening

Synopsis:

```
\opening{salutation}
```

Required. Follows the `\begin{letter}{...}`. The argument *salutation* is mandatory. For instance:

```
\opening{Dear John:}
```

26.9 \ps

Synopsis:

```
\ps{text}
```

Add a postscript. This command is optional and usually is used after `\closing`.

```
\ps{P.S. After you have read this letter, burn it. Or eat it.}
```

26.10 \signature

Synopsis:

```
\signature{first line \\
          ... }
```

The sender's name. This command is optional, although its inclusion is usual.

The argument text appears at the end of the letter, after the closing. LaTeX leaves some vertical space for a handwritten signature. Separate multiple lines with a double backslash, \\. For example:

```
\signature{J Fred Muggs \\
          White House}
```

LaTeX's default for the vertical space from the \closing text down to the \signature text is 6\medskipamount, which is six times \medskipamount (where \medskipamount is equal to a \parskip, which in turn is defined by default here to 0.7 em).

This command is usually in the preamble, to apply to all the letters in the document. To have it apply to one letter only, put it inside a letter environment and before the \closing.

You can include a graphic in the signature as here.

```
\signature{\vspace{-6\medskipamount}\includegraphics{sig.png}\\
           My name}
```

For this you must put \usepackage{graphicx} in the preamble (see Chapter 22 [Graphics], page 177).

26.11 \telephone

Synopsis:

```
\telephone{number}
```

The sender's telephone number. This is typically in the preamble, where it applies to all letters. This only appears if the firstpage pagestyle is selected. If so, it appears on the lower right of the page.

27 Terminal input/output

27.1 \typein

Synopsis, one of:

```
\typein{prompt-msg}
\typein[cmd]{prompt-msg}
```

Print *prompt-msg* on the terminal and cause LaTeX to stop and wait for you to type a line of input. This line of input ends when you hit the return key.

For example, this

```
As long as I live I shall never forget \typein{Enter student name:}
```

coupled with this command line interaction

```
Enter student name:

\@typein=Aphra Behn
```

gives the output '`... never forget Aphra Behn`'.

The first command version, `\typein{prompt-msg}`, causes the input you typed to be processed as if it had been included in the input file in place of the `\typein` command.

In the second command version the optional argument *cmd* argument must be a command name — it must begin with a backslash, `\`. This command name is then defined or redefined to be the input that you typed. For example, this

```
\typein[\student]{Enter student name:}
\typeout{Recommendation for \student .}
```

gives this output on the command line,

```
Enter student name:

\student=John Dee
Recommendation for John Dee.
```

where the user has entered '`John Dee.`'

27.2 \typeout

Synopsis:

```
\typeout{msg}
```

Print `msg` on the terminal and in the `log` file.

This

```
\newcommand{\student}{John Dee}
\typeout{Recommendation for \student .}
```

outputs '`Recommendation for John Dee`'. Like what happens here with `\student`, commands that are defined with `\newcommand` or `\renewcommand` (among others) are replaced by their definitions before being printed.

LaTeX's usual rules for treating multiple spaces as a single space and ignoring spaces after a command name apply to `msg`. As above, use the command `\space` to get a single space,

independent of surrounding spaces. Use `^^J` to get a newline. Get a percent character with `\csname @percentchar\endcsname`.

This command can be useful for simple debugging, as here:

```
\newlength{\jhlength}
\setlength{\jhlength}{5pt}
\typeout{The length is \the\jhlength.}
```

produces on the command line '`The length is 5.0pt`'.

28 Command line

Synopsis (from a terminal command line):

```
pdflatex options argument
```

Run LaTeX on *argument*. In place of `pdflatex` you can also use `xelatex`, or `lualatex`, or `dviluatex`, or `latex`.

For example, this will run LaTeX on the file `thesis.tex`, creating the output `thesis.pdf`.

```
pdflatex thesis
```

Note that `.tex` is the default file extension.

pdfTeX is a development of the original TeX program, as are XeTeX and LuaTeX (see Section 2.3 [TeX engines], page 4). They are completely backward compatible. But the original program had a custom output format, DVI, while the newer ones can output directly to PDF. This allows them to take advantage of the extra features in PDF such as hyperlinks, support for modern image formats such as JPG and PNG, and ubiquitous viewing programs. In short, if you run `pdflatex` or `xelatex` or `lualatex` then you will by default get PDF and have access to all its modern features. If you run `latex`, or `dvilualatex`, then you will get DVI. The description here assumes pdfLaTeX.

See Section 28.1 [Command line options], page 218, for a selection of the most useful command line options. As to *argument*, the usual case is that it does not begin with a backslash, so the system takes it to be the name of a file and it compiles that file. If *argument* begins with a backslash then the system will interpret it as a line of LaTeX input, which can be used for special effects (see Section 28.2 [Command line input], page 220).

If you gave no arguments or options then `pdflatex` prompts for input from the terminal. You can escape from this by entering `<control>-D`.

If LaTeX finds an error in your document then by default it stops and asks you about it. See Section 28.3 [Recovering from errors], page 220, for an outline of what to do.

28.1 Command line options

These are the command-line options relevant to ordinary document authoring. For a full list, try running '`latex --help`' from the command line.

With many implementations you can specify command line options by prefixing them with '`-`' or '`--`'. This is the case for both TeX Live (and MacTeX) and MiKTeX. We will use both conventions interchangeably.

`-version` Show the current version, like '`pdfTeX 3.14159265-2.6-1.40.16 (TeX Live 2015/Debian)`' along with a small amount of additional information, and exit.

`-help` Give a brief usage message that is useful as a prompt and exit.

`-interaction=`*mode*

TeX compiles a document in one of four interaction modes: `batchmode`, `nonstopmode`, `scrollmode`, `errorstopmode`. In *errorstop mode* (the default), TeX stops at each error and asks for user intervention. In *batch mode* it prints nothing on the terminal, errors are scrolled as if the user hit `<return>` at every error, and missing files cause the job to abort. In *nonstop mode*, diagnostic message appear on the terminal but as in batch mode there is no

user interaction. In *scroll mode*, TEX only stops for missing files or keyboard input.

For instance, starting LATEX with this command line

```
pdflatex -interaction=batchmode filename
```

eliminates most terminal output.

`-jobname=`*`string`*
: Set the value of TEX's `jobname` to the string. The log file and output file will then be named *`string`*`.log` and *`string`*`.pdf`.

  When you run `pdflatex` *`options argument`*, if *argument* does not start with a backslash then TEX considers it the name of a file to input. Otherwise it waits for the first `\input` instruction and the name of the input file will be the job name. This is used to name the log file the output file. This option overrides that process and directly specifies the name. See Section 28.2 [Command line input], page 220, for an example of its use.

`-output-directory=`*`directory`*
: Write files in the directory *directory*. It must already exist.

`shell-escape`
`no-shell-escape`
`enable-write18`
`disable-write18`
: Enable or disable `\write18{`*`shell command`*`}`. The first two options are for with TEX Live or MacTEX while the second two are for MiKTEX.

  Sometimes you want to run external system commands from inside a LATEX file. For instance the package `sagetex` allows you to have the mathematics software system *Sage* do calculations or draw graphs and then incorporate that output in your document. For this TEX provides the `\write18` command.

  But with this functionality enabled, security issues could happen if you compiled a LATEX file from the Internet. By default `\write18` is disabled. (More precisely, by default TEX Live, MacTEX, and MiKTEX only allow the execution of a limited number of TEX-related programs, which they distribute.)

  If you invoke LATEX with the option `no-shell-escape`, and in your document you call `\write18{ls -l}`, then you do not get an error but the log file says '`runsystem(ls -l)...disabled`'.

`-halt-on-error`
: Stop processing at the first error.

`-file-line-error`
`-no-file-line-error`
: Enable or disable *`filename`*`:`*`lineno`*`:`*`error`*-style error messages. These are only available with TEX Live or MacTEX.

28.2 Command line input

As part of the command line invocation `pdflatex` *`options argument`* you can specify arbitrary LaTeX input by starting *argument* with a backslash. This allows you to do some special effects.

For example, this file (which uses the `hyperref` package for hyperlinks) can produce two kinds of output, one for paper and one for a PDF.

```
\ifdefined\paperversion        % in preamble
\newcommand{\urlcolor}{black}
\else
\newcommand{\urlcolor}{blue}
\fi
\usepackage[colorlinks=true,urlcolor=\urlcolor]{hyperref}
  ...
\href{https://www.ctan.org}{CTAN}  % in body
  ...
```

Compiling this document `book.tex` with the command line `pdflatex test` will give the '`CTAN`' link in blue. But compiling it with `pdflatex "\def\paperversion{}\input test.tex"` has the link in black. (Note the use of double quotes to prevent interpretation of the symbols by the command line shell; your system may do this differently.)

In a similar way, from the single file `main.tex` you can compile two different versions.

```
pdflatex -jobname=students "\def\student{}\input{main}"
pdflatex -jobname=teachers "\def\teachers{}\input{main}"
```

The `jobname` option is there because otherwise both files would be called `main.pdf` and the second would overwrite the first.

A final example. This loads the package `graphicx` with the option `draft`

```
pdflatex -jobname=aa "\RequirePackage[draft]{graphicx}\input{aa.tex}"
```

so the graphic files are read for their size information but not incorporated into the PDF. (The `jobname` option is needed because otherwise the output file would be `graphicx.pdf`, as `\RequirePackage` does an `\input` of its own.)

28.3 Recovering from errors

If LaTeX finds an error in your document then it gives you an error message and prompts you with a question mark, `?`. For instance, running LaTeX on this file

```
\newcommand{\NP}{\ensuremath{\textbf{NP}}}
The \PN{} problem is a million dollar one.
```

causes it show this, and wait for input.

```
! Undefined control sequence.
l.5 The \PN
           {} problem is a million dollar one.
?
```

The simplest thing is to enter '`x`' and `<return>` and fix the typo. You could instead enter '`?`' and `<return>` to see other options.

There are two other error scenarios. The first is that you forgot to include the `\end{document}` or misspelled it. In this case LaTeX gives you a '`*`' prompt. You can get back to the command line by typing `\stop` and `<return>`.

The last scenario is that you mistyped the file name. For instance, instead of `pdflatex test` you might type `pdflatex tste`.

```
! I can't find file 'tste'.
<*> tste

(Press Enter to retry, or Control-D to exit)
Please type another input file name:
```

The simplest thing is to enter `<Contol>` and '`d`' (holding them down at the same time), and just fix the command line.

Appendix A Document templates

Although not reference material, perhaps these document templates will be useful. Additional template resources are listed at `http://tug.org/interest.html#latextemplates`.

A.1 `beamer` template

The `beamer` class creates presentation slides. It has a vast array of features, but here is a basic template:

```
\documentclass{beamer}

\title{Beamer Class template}
\author{Alex Author}
\date{July 31, 2007}

\begin{document}

\maketitle

% without [fragile], any {verbatim} code gets mysterious errors.
\begin{frame}[fragile]
 \frametitle{First Slide}

\begin{verbatim}
  This is \verbatim!
\end{verbatim}

\end{frame}

\end{document}
```

One web resource for this: `http://robjhyndman.com/hyndsight/beamer/`.

A.2 `article` template

```
\documentclass{article}
\title{Article Class Template}
\author{Alex Author}

\begin{document}
\maketitle

\section{First section}
Some text.

\subsection{First section, first subsection}
Additional text.
```

```
\section{Second section}
Some more text.
\end{document}
```

A.3 book template

This is a straightforward template for a book. See See Section A.4 [Larger book template], page 223, for a more elaborate one.

```
\documentclass{book}
\title{Book Class Template}
\author{Alex Author}

\begin{document}
\maketitle

\chapter{First}
Some text.

\chapter{Second}
Some other text.

\section{A subtopic}
The end.
\end{document}
```

A.4 Larger book template

This is a more elaborate template for a book. It has `\frontmatter`, `\mainmatter`, and `\backmatter` to control the typography of the three main areas of a book (see Section 6.7 [\frontmatter & \mainmatter & \backmatter], page 39). The book has a bibliography and an index.

Notable is that it uses `\include` and `\includeonly` (see Chapter 24 [Splitting the input], page 196). While you are working on a chapter you can comment out all the other chapter entries from the argument to `\includeonly`. That will speed up compilation without losing any information such as cross-references. (Material that does not need to come on a new page is brought in with `\input` instead of `\include`. You don't get the cross-reference benefit this way.)

```
\documentclass[titlepage]{book}
\usepackage{makeidx}\makeindex

\title{Book Class Template}
\author{Alex Author}

\includeonly{%
  frontcover,
  preface,
  chap1,
```

```
  ...
  }
\begin{document}
\frontmatter
\include{frontcover}
  % maybe comment out while drafting:
\maketitle \input{dedication} \input{copyright}
\tableofcontents
\include{preface}
\mainmatter
\include{chap1}
...
\appendix
\include{appena}
...
\backmatter
\bibliographystyle{apalike}
\addcontentsline{toc}{chapter}{Bibliography}
\bibliography
\addcontentsline{toc}{chapter}{Index}
\printindex
\include{backcover}
\end{document}
```

A.5 tugboat template

TUGboat is the journal of the TEX Users Group, http://tug.org/TUGboat.

```
\documentclass{ltugboat}

\usepackage{graphicx}
\usepackage{ifpdf}
\ifpdf
\usepackage[breaklinks,hidelinks]{hyperref}
\else
\usepackage{url}
\fi

%%% Start of metadata %%%

\title{Example \TUB\ article}

% repeat info for each author.
\author{First Last}
\address{Street Address \\ Town, Postal \\ Country}
\netaddress{user (at) example dot org}
\personalURL{http://example.org/~user/}
```

```
%%% End of metadata %%%

\begin{document}

\maketitle

\begin{abstract}
This is an example article for \TUB{}.
Please write an abstract.
\end{abstract}

\section{Introduction}

This is an example article for \TUB, linked from
\url{http://tug.org/TUGboat/location.html}.

We recommend the \texttt{graphicx} package for image inclusions, and the
\texttt{hyperref} package if active urls are desired (in the \acro{PDF}
output).  Nowadays \TUB\ is produced using \acro{PDF} files exclusively.

The \texttt{ltugboat} class provides these abbreviations (and many more):
% verbatim blocks are often better in \small
\begin{verbatim}[\small]
\AllTeX \AMS \AmS \AmSLaTeX \AmSTeX \aw \AW
\BibTeX \CTAN \DTD \HTML
\ISBN \ISSN \LaTeXe
\mf \MFB
\plain \POBox \PS
\SGML \TANGLE \TB \TP
\TUB \TUG \tug
\UNIX \XeT \WEB \WEAVE

\, \bull \Dash \dash \hyph

\acro{FRED} -> {\small[er] fred}  % please use!
\cs{fred}   -> \fred
\meta{fred} -> <fred>
\nth{n}     -> 1st, 2nd, ...
\sfrac{3/4} -> 3/4
\booktitle{Book of Fred}
\end{verbatim}

For references to other \TUB\ issue, please use the format
\textsl{volno:issno}, e.g., ``\TUB\ 32:1'' for our \nth{100} issue.

This file is just a template.  The \TUB\ style documentation is the
\texttt{ltubguid} document at \url{http://ctan.org/pkg/tugboat}.  (For
```

```
\CTAN\ references, where sensible we recommend that form of url, using
\texttt{/pkg/}; or, if you need to refer to a specific file location,
\texttt{http://mirror.ctan.org/\textsl{path}}.)

Email \verb|tugboat@tug.org| if problems or questions.

\bibliographystyle{plain}  % we recommend the plain bibliography style
\nocite{book-minimal}      % just making the bibliography non-empty
\bibliography{xampl}       % xampl.bib comes with BibTeX

\makesignature
\end{document}
```

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