To create the source file for this mixed math and text note, create a new document with an editor. Name it `math.tex`, place it in the `work` directory, and type in the following source file—or copy `math.tex` from the `ftp` directory:

```
% Sample file: math.tex
% Typeset with LaTeX format
\documentclass{article}

\begin{document}
In first year Calculus, we   define intervals  such as
$(u, v)$ and $(u, \infty)$.  Such an interval is a
\emph{neighborhood} of  $a$
if  $a$ is in the interval.  Students should
realize that  $\infty$ is only a
symbol, not a number.  This is important since
we soon introduce concepts
 such as $\lim_{x \to \infty} f(x)$.

When we introduce the derivative
\[
   \lim_{x \to a} \frac{f(x) - f(a)}{x - a},
\]
we assume that the function is defined and continuous
in a neighborhood of  $a$.
\end{document}
```

This note introduces the basic techniques of typesetting math with LaTeX:

- There are two kinds of math formulas and environments: *inline* and *displayed*.
- *Inline* math environments open and close with `$`.
- *Displayed* math environments open with `\[` and close with `\]`.
- LaTeX ignores the spaces you insert in math environments with two exceptions: spaces that delimit commands (see section 2.3.1) and spaces in the argument of commands that temporarily revert into text mode. (`\mbox` is such a command; see section 4.5.) Thus spacing in math is important only for the readability of the source file. To summarize:

Rule ■ Spacing in text and math
In text mode, many spaces equal one space, while in math mode, the spaces are ignored.

- The same formula may be typeset differently depending on which math environment it's in. The expression $x \to a$ is typed as a subscript to $\lim$ in the inline formula $\lim_{x \to a} f(x)$, typed as `$\lim_{x \to a} f(x)$`, but it's placed below $\lim$ in the displayed version:

$$\lim_{x \to a} f(x)$$

typed as

```
\[
   \lim_{x \to a} f(x)
\]
```

- A math symbol is invoked by a command. Examples: the command for ∞ is `\infty` and the command for $\to$ is `\to`. The math symbols are organized into tables in Appendix A.

  To access most of the symbols listed in Appendix A by name, use the amssymb package; in other words, the article should start with

```
\documentclass{article}
\usepackage{amssymb}
```

  The amssymb package loads the amsfonts package, which contains the commands for using the AMSFonts (see section 4.14.2).

- Some commands such as `\sqrt` need *arguments* enclosed in { and }. To typeset $\sqrt{5}$, type `$\sqrt{5}$`, where `\sqrt` is the command and `5` is the argument. Some commands need more than one argument. To get

$$\frac{3+x}{5}$$

  type

```
\[
   \frac{3+x}{5}
\]
```

  `\frac` is the command, `3+x` and `5` are the arguments.

There are many mistakes you can make, even in such a simple note. You'll now introduce mistakes in `math.tex`, by inserting and deleting `%` signs to make the mistakes visible to LaTeX one at a time. Recall that lines starting with `%` are ignored by LaTeX. Type the following source file, and save it under the name `mathb.tex` in the `work` directory (or copy over the file `mathb.tex` from the `ftp` directory).

```
% Sample file: mathb.tex
% Typeset with LaTeX format
\documentclass{article}
```

```
\begin{document}
In first year Calculus, we   define intervals  such as
%$(u, v)$ and $(u, \infty)$.  Such an interval is a
 $(u, v)$ and    (u, \infty)$.  Such an interval is a
 {\emph{neighborhood} of $a$
if $a$ is in the interval.  Students should
realize that  $\infty$ is only a
symbol, not a number.  This is important since
we soon introduce concepts
 such as $\lim_{x \to \infty} f(x)$.
%such as $\lim_{x \to \infty f(x)$.

When we introduce the derivative
\[
    \lim_{x \to a} \frac{f(x) - f(a)}{x - a}
   %\lim_{x \to a} \frac{f(x) - f(a)  x - a}
\]
we assume that the function is defined and continuous
in a neighborhood of  $a$.
\end{document}
```

Exercise 1 Note that in line 8, the second `$` is missing. When you typeset the `mathb.tex` file, LaTeX sends the error message:

```
! Missing $ inserted.
<inserted text>
                $
l.8 ..., v)$ and    (u, \infty
                                )$.  Such an interval is a
?
```

Since you omitted `$`, LaTeX reads `(u, \infty)` as text; but the `\infty` command instructs LaTeX to typeset a math symbol, which can only be done in math mode. So LaTeX offers to put a `$` in front of `\infty`. LaTeX suggests a cure, but in this example it comes too late. Math mode should start just prior to `(u`.

Exercise 2 In the `mathb.tex` file, delete `%` at the beginning of line 7 and insert a `%` at the beginning of line 8 (this eliminates the previous error); delete `%` at the beginning of line 15 and insert a `%` at the beginning of line 14 (this introduces a new error: the closing brace of the subscript is missing). Save the changes, and typeset the note. You get the error message:

```
! Missing } inserted.
<inserted text>
                }
```

```
l.15 ...im_{x \to \infty f(x)$
                                          .
?
```

LaTeX is telling you that a closing brace } is missing, but it's not sure where. LaTeX noticed that the subscript started with { and it reached the end of the math formula before finding }. You must look in the formula for a { that is not closed, and close it with }.

Exercise 3 Delete % at the beginning of line 14 and insert a % at the beginning of line 15, which removes the last error, and delete % at the beginning of line 20 and insert a % at the beginning of line 19 (introducing the final error: deleting the closing brace of the first argument of `\frac`). Save and typeset the file. You get the error message:

```
! LaTeX Error: Bad math environment delimiter.

l.21 \]
```

There is a bad math environment delimiter in line 21, namely, `\]`. So the reference to

```
! Bad math environment delimiter.
```

is to the displayed formula. Since the environment delimiter is correct, something must have gone wrong with the displayed formula. This is what happened: LaTeX was trying to typeset

```
\lim_{x \to a} \frac{f(x) - f(a)  x - a}
```

but `\frac` needs two arguments. LaTeX found `f(x) - f(a)  x - a` as the first argument. While looking for the second, it found `\]`, which is obviously an error (it was looking for a `{`).

1.2.3 Building blocks of a formula

A formula is built up from various types of components. We group them as follows:

- Arithmetic
- Subscripts and superscripts
- Accents
- Binomial coefficients
- Congruences
- Delimiters
- Operators
- Ellipses
- Integrals

- Matrices
- Roots
- Sums and products
- Text

Some of the commands in the following examples are defined in the amsmath package; in other words, to typeset these examples with the `article` document class, the article should start with

```
\documentclass{article}
\usepackage{amssymb,amsmath}
```

Arithmetic The arithmetic operations $a + b,\ a - b,\ -a,\ a/b,\ ab$ are typed as expected:

```
$a + b$, $a - b$, $-a$, $a / b$, $a b$
```

If you wish to use $\cdot$ or $\times$ for multiplication, as in $a \cdot b$ or $a \times b$, use `\cdot` or `\times`, respectively. The expressions $a \cdot b$ and $a \times b$ are typed as follows:

```
$a \cdot b$  $a \times b$
```

Displayed fractions, such as

$$\frac{1 + 2x}{x + y + xy}$$

are typed with `\frac`:

```
\[
   \frac{1 + 2x}{x + y + xy}
\]
```

The `\frac` command is seldom used inline.

Subscripts and superscripts Subscripts are typed with _ (underscore) and superscripts with ^ (caret). Remember to enclose the subscripts and superscripts with { and }. To get a_1, type the following characters:

Go into inline math mode:	`$`
type the letter `a`:	`a`
subscript command:	`_`
bracket the subscripted `1`:	`{1}`
exit inline math mode:	`$`

that is, type `$a_{1}$`. Omitting the braces in this example causes no harm; however, to get a_{10}, you *must* type `$a_{10}$`. Indeed, `$a_10$` prints $a_1 0$. Further examples: a_{i_1}, a^2, a^{i_1} are typed as

```
$a_{i_{1}}$, $a^{2}$, $a^{i_{1}}$
```

Accents The four most often used math accents are:

$\bar{a}$	typed as	`$\bar{a}$`
$\hat{a}$	typed as	`$\hat{a}$`
$\tilde{a}$	typed as	`$\tilde{a}$`
$\vec{a}$	typed as	`$\vec{a}$`

Binomial coefficients The amsmath package provides the `\binom` command for binomial coefficients. For example, $\binom{a}{b+c}$ is typed inline as

```
$\binom{a}{b + c}$
```

whereas the displayed version

$$\binom{a}{b + c} \binom{\frac{n^{2} - 1}{2}}{n + 1}$$

is typed as

```
\[
   \binom{a}{b + c} \binom{\frac{n^{2} - 1}{2}}{n + 1}
\]
```

Congruences The two most important forms are:

$a \equiv v \pmod{\theta}$	typed as	`$a \equiv v \pmod{\theta}$`
$a \equiv v \pod{\theta}$	typed as	`$a \equiv v \pod{\theta}$`

The second form requires the amsmath package.

Delimiters These are parenthesis-like symbols that vertically expand to enclose a formula. For example: $(a + b)^{2}$, which is typed as `$(a + b)^{2}$`, and

$$\left(\frac{1 + x}{2 + y^{2}} \right)^{2}$$

which is typed as

```
\[
   \left( \frac{1 + x}{2 + y^{2}} \right)^{2}
\]
```

contain such delimiters. The `\left(` and `\right)` commands tell LATEX to size the parentheses correctly (relative to the size of the symbols inside the parentheses). Two further examples:

$$\left| \frac{a + b}{2} \right|, \quad \left\| A^{2} \right\|$$

would be typed as:

```
\[
  \left| \frac{a + b}{2} \right|,
      \quad \left\| A^{2} \right\|
\]
```

where `\quad` is a spacing command (see section 4.11 and Appendix A).

Operators To typeset the sine function $\sin x$, type: `$\sin x$`. Note that `$sin x$` prints: $sinx$, where the typeface of sin is wrong, as is the spacing.

LATEX calls `\sin` an *operator*; there are a number of operators listed in section 4.7.1 and Appendix A. Some are just like `\sin`; others produce a more complex display:

$$\lim_{x \to 0} f(x) = 0$$

which is typed as

```
\[
   \lim_{x \to 0} f(x) = 0
\]
```

Ellipses The ellipsis (...) in math sometimes needs to be printed as low dots and sometimes as (vertically) centered dots. Print low dots with the `\ldots` command as in $F(x_{1}, x_{2}, \ldots , x_{n})$, typed as

```
$F(x_{1}, x_{2}, \ldots , x_{n})$
```

Print centered dots with the `\cdots` command as in $x_{1} + x_{2} + \cdots + x_{n}$, typed as

```
$x_{1} + x_{2} + \cdots + x_{n}$
```

If you use the amsmath package, there is a good chance that the command `\dots` will print the ellipsis as desired.

Integrals The command for an integral is `\int`; the lower limit is a subscript and the upper limit is a superscript. Example: $\int_{0}^{\pi} \sin x \, dx = 2$ is typed as

```
$\int_{0}^{\pi} \sin x \, dx = 2$
```

`\,` is a spacing command (see section 4.11 and Appendix A).

Matrices The amsmath package provides you with a `matrix` environment:

$$\begin{matrix} a+b+c & uv & x-y & 27\\ a+b & u+v & z & 134 \end{matrix}$$

which is typed as follows:

```
\[
   \begin{matrix}
      a + b + c & uv    & x - y & 27\\
      a + b     & u + v & z     & 134
   \end{matrix}
\]
```

The matrix elements are separated by `&`; the rows are separated by `\\`. The basic form gives no parentheses; for parentheses, use the `pmatrix` environment; for brackets, the `bmatrix` environment; for vertical lines (determinants, for example), the `vmatrix` environment; for double vertical lines, the `Vmatrix` environment. For example,

$$\mathbf{A} = \begin{pmatrix} a+b+c & uv\\ a+b & u+v \end{pmatrix} \begin{pmatrix} 30 & 7\\ 3 & 17 \end{pmatrix}$$

is typed as follows:

```
\[
   \mathbf{A} =
   \begin{pmatrix}
      a + b + c & uv\\
      a + b & u + v
   \end{pmatrix}
   \begin{pmatrix}
      30 & 7\\
      3 & 17
   \end{pmatrix}
\]
```

Roots `\sqrt` produces the square root; for instance, $\sqrt{5}$ is typed as

```
$\sqrt{5}$
```

and $\sqrt{a+2b}$ is typed as

```
$\sqrt{a + 2b}$
```

The nth root, $\sqrt[n]{5}$, is done with two arguments:

```
$\sqrt[n]{5}$
```

Note that the first argument is in brackets `[ ]`; it's an *optional argument* (see section 2.3).

Sums and products The command for sum is `\sum` and for product is `\prod`. The examples

$$\sum_{i=1}^{n} x_{i}^{2} \qquad \prod_{i=1}^{n} x_{i}^{2}$$

are typed as

```
\[
   \sum_{i=1}^{n} x_{i}^{2} \qquad \prod_{i=1}^{n} x_{i}^{2}
\]
```

`\qquad` is a spacing command; it separates the two formulas (see section 4.11 and Appendix A).

Sums and products are examples of *large operators*; all of them are listed in section 4.8 and Appendix A. They display in a different style (and size) when used in an inline formula: $\sum_{i=1}^{n} x_{i}^{2} \qquad \prod_{i=1}^{n} x_{i}^{2}$.

Text Place text in a formula with an `\mbox` command. For instance,

$$a = b \mbox{\qquad by assumption}$$

is typed as

```
\[
   a = b \mbox{\qquad by assumption}
\]
```

Note the space command `\qquad` in the argument of `\mbox`. You could also have typed

```
\[
   a = b \qquad \mbox{by assumption}
\]
```

because `\qquad` works in text as well as in math.

If you use the amsmath package, then the `\text` command is available in lieu of the `\mbox` command. It works just like the `\mbox` command except that it automatically changes the size of its argument as required, as in a^{power}, typed as

```
$a^{ \text{power} }$
```

If you do not want to use the large amsmath package, the tiny amstext package also provides the `\text` command (see section 8.5).

1.2.4 Building a formula step-by-step

It is simple to build up complicated formulas from the components described in section 1.2.3. Take the formula

$$\sum_{i=1}^{\left[\frac{n}{2}\right]} \binom{x_{i,i+1}^{i^2}}{\left[\frac{i+3}{3}\right]} \frac{\sqrt{\mu(i)^{\frac{3}{2}}(i^2-1)}}{\sqrt[3]{\rho(i)-2}+\sqrt[3]{\rho(i)-1}}$$

for instance. You should build this up in several steps. Create a new file in the `work` directory. Call it `formula.tex` and type in the lines:

```
% File: formula.tex
% Typeset with LaTeX format
\documentclass{article}
\usepackage{amssymb,amsmath}
\begin{document}
\end{document}
```

and save it. At present, the file has an empty `document` environment.[1] Type each part of the formula as an inline or displayed formula so that you can typeset the document and check for errors.

Step 1 Let's start with $\left[\frac{n}{2}\right]$:

```
$\left[ \frac{n}{2} \right]$
```

Type this into `formula.tex` and test it by typesetting the document.

Step 2 Now you can do the sum:

$$\sum_{i=1}^{\left[\frac{n}{2}\right]}$$

For the superscript, you can cut and paste the formula created in Step 1 (without the dollar signs), to get

```
\[
   \sum_{i = 1}^{ \left[ \frac{n}{2} \right] }
\]
```

[1]The quickest way to create this file is to open `mathb.tex`, save it under the new name `formula.tex`, and delete the lines in the `document` environment. Then add the line `\usepackage{amssymb,amsmath}`

Step 3 Next, do the two formulas in the binomial:

$$x_{i,i+1}^{i^{2}} \qquad \left[\frac{i+3}{3} \right]$$

Type them as separate formulas in `formula.tex`:

```
\[
   x_{i, i + 1}^{i^{2}} \qquad \left[ \frac{i + 3}{3} \right]
\]
```

Step 4 Now it's easy to do the binomial. Type the following formula by cutting and pasting the previous formulas:

```
\[
   \binom{ x_{i,i + 1}^{i^{2}} }{ \left[ \frac{i + 3}{3} \right] }
\]
```

which prints:

$$\binom{ x_{i,i+1}^{i^{2}} }{ \left[\frac{i+3}{3} \right] }$$

Step 5 Next type the formula under the square root $\mu(i)^{\frac{3}{2}}(i^{2}-1)$ as

```
$\mu(i)^{ \frac{3}{2} } (i^{2} - 1)$
```

and then the square root $\sqrt{\mu(i)^{\frac{3}{2}}(i^{2}-1)}$ as

```
$\sqrt{ \mu(i)^{ \frac{3}{2} } (i^{2} - 1) }$
```

Step 6 The two cube roots, $\sqrt[3]{\rho(i)-2}$ and $\sqrt[3]{\rho(i)-1}$, are easy to type:

```
$\sqrt[3]{ \rho(i) - 2 }$  $\sqrt[3]{ \rho(i) - 1 }$
```

Step 7 So now get the fraction:

$$\frac{ \sqrt{ \mu(i)^{\frac{3}{2}} (i^{2}-1) } }{ \sqrt[3]{\rho(i)-2} + \sqrt[3]{\rho(i)-1} }$$

typed, cut, and pasted as

```
\[
   \frac{ \sqrt{ \mu(i)^{ \frac{3}{2}} (i^{2} -1) } }
        { \sqrt[3]{\rho(i) - 2} + \sqrt[3]{\rho(i) - 1} }
\]
```

Step 8 Finally, get the formula

$$\sum_{i = 1}^{ \left[\frac{n}{2} \right] } \binom{ x_{i, i + 1}^{i^{2}} }{ \left[\frac{i + 3}{3} \right] } \frac{ \sqrt{ \mu(i)^{ \frac{3}{2}} (i^{2} - 1) } }{ \sqrt[3]{\rho(i) - 2} + \sqrt[3]{\rho(i) - 1} }$$

by cutting and pasting the pieces together, leaving only one pair of displayed math delimiters:

```
\[
   \sum_{i = 1}^{ \left[ \frac{n}{2} \right] }
      \binom{ x_{i, i + 1}^{i^{2}} }
            { \left[ \frac{i + 3}{3} \right] }
      \frac{ \sqrt{ \mu(i)^{ \frac{3}{2}} (i^{2} - 1) } }
           { \sqrt[3]{\rho(i) - 2} + \sqrt[3]{\rho(i) - 1} }
\]
```

Notice the use of

- spacing to help distinguish the braces (note that some editors help you balance the braces);
- separate lines for the various pieces.

Keep the source file readable. Of course, this is for your benefit, since LATEX does not care. It would also accept

```
\[\sum_{i=1}^{\left[\frac{n}{2}\right]}\binom{x_{i,i+1}^{i^{2}}}
{\left[\frac{i+3}{3}\right]}\frac{\sqrt{\mu(i)^{\frac{3}
{2}}(i^{2}-1)}}{\sqrt[3]{\rho(i)-2}+\sqrt[3]{\rho(i)-1}}\]
```

Problems arise with this haphazard style when you make a mistake. Try to find the error in the next version:

```
\[\sum_{i=1}^{\left[\frac{n}{2}\right]}\binom{x_{i,i+1}^{i^{2}}}
{\left[\frac{i+3}{3}\right]}\frac{\sqrt{\mu(i)^{\frac{3}
{2}}}(i^{2}-1)}}{\sqrt[3]{\rho(i)-2}+\sqrt[3]{\rho(i)-1}}\]
```

(Answer: `\frac{3}{2}` should be followed by `}}` and not by `}}}`.)

1.3 Formula gallery

In this section, I present the formula gallery (`gallery.tex` in the `ftp` directory), a collection of formulas—some simple, some complex—that illustrate the power of LATEX and AMS-LATEX. Most of the commands in these examples have not yet been discussed, but comparing the source formula with the typeset version should answer most of your questions. Occasionally, I'll give you a helping hand with some comments.

Many of these formulas are from text books and research articles. The last six are reproduced from the document `testart.tex` that was distributed by the $\mathcal{AMS}$ with $\mathcal{AMS}$-LaTeX version 1.1. Some of these examples require the amssymb and amsmath packages. So make sure to include the line

```
\usepackage{amssymb,amsmath}
```

following the `documentclass` line of any article using such constructs. The packages (if any) required for each formula shall be indicated.

Formula 1 A set-valued function:

$$x \mapsto \{\, c \in C \mid c \leq x \,\}$$

```
\[
   x \mapsto \{\, c \in C \mid c \leq x \,\}
\]
```

Note that both `|` and `\mid` print $|$. Use $|$ for absolute value signs. In this formula, `\mid` is used because it provides extra spacing (see section 4.6.4). To equalize the spacing around $c \in C$ and $c \leq x$, a thin space was added inside each brace (see section 4.11). The same technique is used in a number of other formulas below.

Formula 2 The `\left|` and `\right|` commands print the vertical bars $|$ whose size adjusts to the size of the formula. The `\mathfrak` command provides access to the *Fraktur math alphabet* (which requires the amsfonts or the eufrak package):

$$\left| \bigcup (\, I_{j} \mid j \in J \,) \right| < \mathfrak{m}$$

typed as

```
\[
   \left| \bigcup (\, I_{j} \mid j \in J \,) \right|
    < \mathfrak{m}
\]
```

Formula 3 Note that you need spacing both before and after the text fragment "$\mbox{for some}$" in the following example. The argument of `\mbox` is typeset in text mode, so a single space is recognized.

$$A = \{\, x \in X \mid x \in X_{i} \mbox{\quad for some } i \in I \,\}$$

```
\[
   A = \{\, x \in X \mid x \in X_{i}
            \mbox{\quad for some } i \in I \,\}
\]
```

Formula 4 Space to show the logical structure:

$$\langle a_{1}, a_{2} \rangle \leq \langle a'_{1}, a'_{2}\rangle \qquad \mbox{iff} \qquad a_{1} < a'_{1} \quad \mbox{or} \quad a_{1} = a'_{1} \mbox{ and } a_{2} \leq a'_{2}$$

```
\[
   \langle a_{1}, a_{2} \rangle \leq \langle a'_{1}, a'_{2}\rangle
    \qquad \mbox{if{f}} \qquad a_{1} < a'_{1} \quad  \mbox{or}
    \quad a_{1} = a'_{1} \mbox{ and } a_{2} \leq a'_{2}
\]
```

Note that in `if{f}` (in the argument of `\mbox`) the second `f` is in braces to avoid the use of the ligature—the merging of the two f's (see section 2.4.5).

Formula 5 Here are some examples of Greek letters:

$$\Gamma_{u'} = \{\, \gamma \mid \gamma < 2\chi,\ B_{\alpha} \nsubseteq u',\ B_{\gamma} \subseteq u' \,\}$$

```
\[
   \Gamma_{u'} = \{\, \gamma \mid \gamma < 2\chi,
    \ B_{\alpha} \nsubseteq u', \ B_{\gamma} \subseteq u' \,\}
\]
```

See Appendix A for a complete listing of Greek letters. The `\nsubseteq` command requires the amssymb package.

Formula 6 `\mathbb` gives the *Blackboard bold math alphabet* (available only in uppercase):

$$A = B^{2} \times \mathbb{Z}$$

```
\[
   A = B^{2} \times \mathbb{Z}
\]
```

Blackboard bold requires the amsfonts package.

Formula 7 The `\left(` and `\right)` commands tell LaTeX to size the parentheses correctly (relative to the size of the symbols in the parentheses).

$$\left(\bigvee (\, s_{i} \mid i \in I \,) \right)^{c} = \bigwedge (\, s_{i}^{c} \mid i \in I \,)$$

```
\[
   \left( \bigvee (\, s_{i} \mid i \in I \,) \right)^{c} =
    \bigwedge (\, s_{i}^{c} \mid i \in I \,)
\]
```

Notice how the superscript is placed right on top of the subscript in s_{i}^{c}.

Formula 8

$$y \vee \bigvee (\, [B_{\gamma}] \mid \gamma \in \Gamma \,) \equiv z \vee \bigvee (\, [B_{\gamma}] \mid \gamma \in \Gamma \,) \pmod{ \Phi^{x} }$$

```
\[
   y \vee \bigvee (\, [B_{\gamma}] \mid \gamma
    \in \Gamma \,) \equiv z \vee \bigvee (\, [B_{\gamma}]
    \mid \gamma \in \Gamma \,) \pmod{ \Phi^{x} }
\]
```

Formula 9 Use `\nolimits` so that the "limit" of the large operator is displayed as a subscript:

$$f(\mathbf{x}) = \bigvee\nolimits_{\!\mathfrak{m}} \left(\, \bigwedge\nolimits_{\mathfrak{m}} (\, x_{j} \mid j \in I_{i} \,) \mid i < \aleph_{\alpha} \,\right)$$

```
\[
   f(\mathbf{x}) = \bigvee\nolimits_{\!\mathfrak{m}}
    \left(\,
       \bigwedge\nolimits_{\mathfrak{m}}
       (\, x_{j} \mid j \in I_{i} \,) \mid i < \aleph_{\alpha}
    \,\right)
\]
```

The `\mathfrak` command requires the amsfonts or the eufrak package. A negative space (`\!`) was inserted to bring $\mathfrak{m}$ a little closer to $\bigvee$ (see section 4.11).

Formula 10 The `\left.` command gives a blank left delimiter.

$$\left. F(x) \right|_{a}^{b} = F(b) - F(a)$$

```
\[
   \left. F(x) \right|_{a}^{b} = F(b) - F(a)
\]
```

Formula 11

$$u \underset{\alpha}{+} v \overset{1}{\thicksim} w \overset{2}{\thicksim} z$$

```
\[
  u \underset{\alpha}{+} v \overset{1}{\thicksim} w
    \overset{2}{\thicksim} z
\]
```

The `\underset` and `\overset` commands require the amsmath package.

Formula 12 In this formula, `\mbox` would not work properly, so we use `\text`.

$$f(x) \overset{\text{def}}{=} x^{2} - 1$$

```
\[
   f(x) \overset{ \text{def} }{=} x^{2} - 1
\]
```

This formula requires the amsmath package.

Formula 13

$$\overbrace{a + b + \cdots + z}^{n}$$

```
\[
   \overbrace{a + b + \cdots + z}^{n}
\]
```

Formula 14

$$\begin{vmatrix} a + b + c & uv \\ a + b & c + d \end{vmatrix} = 7$$

```
\[
   \begin{vmatrix}
      a + b + c & uv\\
      a + b & c + d
   \end{vmatrix}
   = 7
\]
```

$$\begin{Vmatrix} a + b + c & uv \\ a + b & c + d \end{Vmatrix} = 7$$

```
\[
   \begin{Vmatrix}
      a + b + c & uv\\
      a + b & c + d
   \end{Vmatrix}
   = 7
\]
```

The `vmatrix` and `Vmatrix` environments require the amsmath package.

Formula 15 The `\mathbf{N}` command makes a bold $\mathbf{N}$. (`\textbf{N}` would use a different font, namely, **N**.)

$$\sum_{j \in \mathbf{N}} b_{ij} \hat{y}_{j} = \sum_{j \in \mathbf{N}} b^{(\lambda)}_{ij} \hat{y}_{j} + (b_{ii} - \lambda_{i}) \hat{y}_{i} \hat{y}$$

```
\[
   \sum_{j \in \mathbf{N}} b_{ij} \hat{y}_{j} =
   \sum_{j \in \mathbf{N}} b^{(\lambda)}_{ij} \hat{y}_{j} +
   (b_{ii} - \lambda_{i}) \hat{y}_{i} \hat{y}
\]
```

Formula 16 To produce the formula:

$$\biggl(\prod^n_{\, j = 1} \hat x_{j} \biggr) H_{c} = \frac{1}{2} \hat{k}_{ij} \det \widehat{ \mathbf{K} }(i|i)$$

try

```
\[
   \left( \prod^n_{\, j = 1} \hat x_{j} \right) H_{c} =
    \frac{1}{2} \hat k_{ij} \det \hat{ \mathbf{K} }(i|i)
\]
```

However, this produces:

$$\left(\prod^n_{\, j = 1} \hat x_{j} \right) H_{c} = \frac{1}{2} \hat k_{ij} \det \hat{ \mathbf{K} }(i|i)$$

Correct the overly large parentheses by using the `\biggl` and `\biggr` commands in place of `\left(` and `\right)`, respectively (see section 4.6.2). Adjust the small hat over K by using `\widehat`:

```
\[
   \biggl( \prod^n_{\, j = 1} \hat x_{j} \biggr) H_{c} =
    \frac{1}{2} \hat{k}_{ij} \det \widehat{ \mathbf{K} }(i|i)
\]
```

Formula 17 In this formula, use `\overline{I}` to get $\overline{I}$ (the variant `\bar{I}`, which prints $\bar{I}$, is less pleasing to me):

$$\det \mathbf{K} (t = 1, t_{1}, \dots, t_{n}) = \sum_{I \in \mathbf{n} }(-1)^{|I|} \prod_{i \in I} t_{i} \prod_{j \in I} (D_{j} + \lambda_{j} t_{j}) \det \mathbf{A}^{(\lambda)} (\overline{I} | \overline{I}) = 0$$

```
\[
  \det \mathbf{K} (t = 1, t_{1}, \dots, t_{n}) =
   \sum_{I \in \mathbf{n} }(-1)^{|I|}
   \prod_{i \in I} t_{i}
   \prod_{j \in I} (D_{j} + \lambda_{j} t_{j})
   \det \mathbf{A}^{(\lambda)} (\overline{I} | \overline{I}) = 0
\]
```

Formula 18 Note that `\|` provides the $\|$ math symbol in this formula:

$$\lim_{(v, v') \to (0, 0)} \frac{H(z + v) - H(z + v') - BH(z)(v - v')}{\| v - v' \|} = 0$$

```
\[
  \lim_{(v, v') \to (0, 0)}
   \frac{H(z + v) - H(z + v') - BH(z)(v - v')}
        {\| v - v' \|} = 0
\]
```

Formula 19 This formula uses the calligraphic math alphabet:

$$\int_{\mathcal{D}} | \overline{\partial u} |^{2} \Phi_{0}(z) e^{\alpha |z|^2} \geq c_{4} \alpha \int_{\mathcal{D}} |u|^{2} \Phi_{0} e^{\alpha |z|^{2}} + c_{5} \delta^{-2} \int_{A} |u|^{2} \Phi_{0} e^{\alpha |z|^{2}}$$

```
\[
  \int_{\mathcal{D}} | \overline{\partial u} |^{2}
   \Phi_{0}(z) e^{\alpha |z|^2} \geq
   c_{4} \alpha \int_{\mathcal{D}} |u|^{2} \Phi_{0}
   e^{\alpha |z|^{2}} + c_{5} \delta^{-2} \int_{A}
   |u|^{2} \Phi_{0} e^{\alpha |z|^{2}}
\]
```

Formula 20 The `\hdotsfor` command places dots spanning multiple columns in a matrix.

The `\dfrac` command is the displayed variant of `\frac` (see section 4.4.1).

$$\mathbf{A} = \begin{pmatrix} \dfrac{\varphi \cdot X_{n, 1}}{\varphi_{1} \times \varepsilon_{1}} & (x + \varepsilon_{2})^{2} & \cdots & (x + \varepsilon_{n - 1})^{n - 1} & (x + \varepsilon_{n})^{n} \\ \dfrac{\varphi \cdot X_{n, 1}}{\varphi_{2} \times \varepsilon_{1}} & \dfrac{\varphi \cdot X_{n, 2}}{\varphi_{2} \times \varepsilon_{2}} & \cdots & (x + \varepsilon_{n - 1})^{n - 1} & (x + \varepsilon_{n})^{n} \\ \hdotsfor{5} \\ \dfrac{\varphi \cdot X_{n, 1}}{\varphi_{n} \times \varepsilon_{1}} & \dfrac{\varphi \cdot X_{n, 2}}{\varphi_{n} \times \varepsilon_{2}} & \cdots & \dfrac{\varphi \cdot X_{n, n - 1}}{\varphi_{n} \times \varepsilon_{n - 1}} & \dfrac{\varphi \cdot X_{n, n}}{\varphi_{n} \times \varepsilon_{n}} \end{pmatrix} + \mathbf{I}_{n}$$

```
\[
  \mathbf{A} =
  \begin{pmatrix}
```

```
      \dfrac{\varphi \cdot X_{n, 1}}
            {\varphi_{1} \times \varepsilon_{1}}
      & (x + \varepsilon_{2})^{2} & \cdots
      & (x + \varepsilon_{n - 1})^{n - 1}
      & (x + \varepsilon_{n})^{n}\\
      \dfrac{\varphi \cdot X_{n, 1}}
            {\varphi_{2} \times \varepsilon_{1}}
      & \dfrac{\varphi \cdot X_{n, 2}}
              {\varphi_{2} \times \varepsilon_{2}}
      & \cdots & (x + \varepsilon_{n - 1})^{n - 1}
      & (x + \varepsilon_{n})^{n}\\
      \hdotsfor{5}\\
      \dfrac{\varphi \cdot X_{n, 1}}
            {\varphi_{n} \times \varepsilon_{1}}
      & \dfrac{\varphi \cdot X_{n, 2}}
              {\varphi_{n} \times \varepsilon_{2}}
      & \cdots & \dfrac{\varphi \cdot X_{n, n - 1}}
                       {\varphi_{n} \times \varepsilon_{n - 1}}
      & \dfrac{\varphi\cdot X_{n, n}}
              {\varphi_{n} \times \varepsilon_{n}}
   \end{pmatrix}
    + \mathbf{I}_{n}
\]
```

This formula requires the amsmath and the amssymb packages. I'll show in section 9.1.2 how to write this formula so that it's short and more readable.

1.4 Typing equations and aligned formulas

1.4.1 Equations

The `equation` environment creates a displayed math formula and automatically generates a number. The equation

$$\int_{0}^{\pi} \sin x \, dx = 2 \tag{1}$$

is typed as

```
\begin{equation} \label{E:firstInt}
   \int_{0}^{\pi} \sin x \, dx = 2
\end{equation}
```

Of course, the number generated depends on how many equations precede the given one.

To refer to this formula without having to remember a (changeable) number, assign a *name* to the equation in the argument of a `\label` command; I'll call the name of the equation a *label*. In this section, let's call the first equation "`firstInt`" (first integral). I use the convention that the label of an equation starts with "`E:`".

The number of this formula is referenced with the `\ref` command. For example, to get the reference "see (1)", type

```
see~(\ref{E:firstInt})
```

Alternatively, with the amsmath package, you can use the `\eqref` command. For instance,

```
see~\eqref{E:firstInt}
```

also produces "see (1)".

An advantage of this cross-referencing system is that if a new equation is introduced, or the existing equations are rearranged, the numbering will automatically be adjusted to reflect these changes.

Rule ■ Typeset twice
For renumbering to work, you have to typeset the source file twice.

See sections 6.3.2 and E.2.4. LaTeX will send a warning if you forget.

At the end of the typesetting, LaTeX stores the labels in the aux file (see section 1.11.3). For every label, it stores the number the label is associated with and also the page number on which the label occurs in the typeset version.

An equation will be numbered whether or not there is a `\label` command attached to it. Of course, if there is no `\label` command, the number generated by LaTeX for the equation can't be referenced automatically.

The system described here is called *symbolic referencing*. The argument of `\label` is the "symbol" for the number, and `\ref` provides the referencing. LaTeX uses the same mechanism for all numberings it automatically generates: numbering of section titles, equations, theorems, lemmas, and bibliographic references—except that for bibliographic references the commands are `\bibitem` and `\cite`, respectively (see section 1.7.4).

With the amsmath package, equations can also be *tagged* by attaching a name to the formula with the `\tag` command; the tag replaces the number.

Example:

$$\int_0^\pi \sin x\,dx = 2 \tag{Int}$$

is typed as

```
\begin{equation}
   \int_{0}^{\pi} \sin x \, dx = 2 \tag{Int}
\end{equation}
```

Tags (of the type discussed here) are **absolute**; this equation is always referred to as (Int). Equation numbers, on the other hand, are **relative**; they change as equations are added, deleted, or rearranged.

1.4.2 Aligned formulas

LaTeX, with the help of the amsmath package, has many ways to typeset multiline formulas. Right now, you'll be introduced to three constructs: *simple align*, *annotated align*, and *cases*; see Chapter 5 for a discussion of many others.

The `align` math environment is used for simple and annotated align. *Each line* in this environment is an equation, which LaTeX automatically numbers.

Simple align

Simple align is used to align two or more formulas. To obtain the formulas

$$\begin{align} r^{2} &= s^{2} + t^{2} \tag{2}\\ 2u + 1 &= v + w^{\alpha} \tag{3}\\ x &= \frac{y + z}{\sqrt{s + 2u}} \tag{4} \end{align}$$

type (using \\ as a line separator)

```
\begin{align}
   r^{2}  &= s^{2} + t^{2}                 \label{E:eqn1}\\
   2u + 1 &= v + w^{\alpha}                \label{E:eqn2}\\
   x      &= \frac{y + z}{\sqrt{s + 2u}}  \label{E:eqn3}
\end{align}
```

(These equations are numbered (2), (3), and (4) because they are preceded by one numbered equation earlier in this section.)

The `align` environment can also be used to break a long formula into two. Since numbering both lines is undesirable, you may prevent the numbering of the second line with the `\notag` command.

$$\begin{align} h(x) &= \int \left(\frac{f(x) + g(x)}{1 + f^{2}(x)} + \frac{1 + f(x)g(x)}{\sqrt{1 - \sin x}} \right) \, dx \tag{5}\\ &= \int \frac{1 + f(x)}{1 + g(x)} \, dx - 2 \tan^{-1}(x - 2) \notag \end{align}$$

This formula may be typed as

```
\begin{align} \label{E:longInt}
   h(x) &= \int
    \left(
          \frac{ f(x) + g(x) }
               { 1+ f^{2}(x) }
          + \frac{ 1+ f(x)g(x) }
                 { \sqrt{1 - \sin x} }
    \right) \, dx\\
        &= \int \frac{ 1 + f(x) }
                     { 1 + g(x) }
         \, dx - 2 \tan^{-1}(x-2) \notag
\end{align}
```

See the `split` subsidiary math environment in section 5.5.2 for a better way to split a long formula into (two or more) aligned parts, and on how to center the formula number (5) between the two lines.

The rules are easy for simple align:

Rule ■ Simple align

- Separate the lines with `\\`.
- In each line, indicate the alignment point with `&`.
- Place a `\notag` in each line that you do not wish numbered.
- Place a `\label` in each numbered line you may want to reference with `\ref` or `\eqref`.

Annotated align

Annotated align will align the formulas and the annotation (explanatory text) separately:

$$
\begin{align}
x &= x \wedge (y \vee z) & &\text{(by distributivity)} \tag{6}\\
&= (x \wedge y) \vee (x \wedge z) & &\text{(by condition (M))} \notag\\
&= y \vee z. \notag
\end{align}
$$

This is typed as:

```
\begin{align} \label{E:DoAlign}
   x &= x \wedge (y \vee z)
                    & &\text{(by distributivity)}\\
     &= (x \wedge y) \vee (x \wedge z)
                    & &\text{(by condition (M))} \notag\\
     &= y \vee z. \notag
\end{align}
```

The rules for annotated align are similar to the rules of simple align. In each line, in addition to the alignment point (marked by `&`), there is also a mark for the start of the annotation: `& &`.

The `align` environment does much more than simple and annotated aligns (see section 5.4).

Cases

The `cases` construct is a *subsidiary math environment*; it must be used in a displayed math environment or in an `equation` environment (see section 5.5). Here is a typical example:

$$f(x)=\begin{cases}-x^{2}, & \text{if $x < 0$;}\\ \alpha + x, & \text{if $0 \leq x \leq 1$;}\\ x^{2}, & \text{otherwise.}\end{cases}$$

which may be typed as follows:

```
\[
   f(x)=
   \begin{cases}
      -x^{2},         &\text{if $x < 0$;}\\
      \alpha + x,     &\text{if $0 \leq x \leq 1$;}\\
      x^{2},          &\text{otherwise.}
   \end{cases}
\]
```

The rules for `cases` are simple:

Rule ■ `cases`

- Separate the lines with `\\`.
- In each line, indicate the alignment point for the annotation with `&`.

1.5 The anatomy of an article

The `sampart.tex` sample article (typeset on pages 361–363) uses the $\mathcal{AMS}$ article document class, `amsart`. In this introductory chapter, I want to start off with the popular `article` document class of LaTeX, which is easier to use. So we'll use a simplified and shortened sample article, `intrart.tex` (in the `ftp` directory). Type it in as we discuss the parts of an article.

The *preamble* of an article is the initial part of the source file up to the line

```
\begin{document}
```

See Figure 1.1. The preamble contains instructions for the entire article, for instance, the

```
\documentclass
```

command.

Here is the preamble of the introductory sample article:

```
% Introductory sample article: intrart.tex
% Typeset with LaTeX format

\documentclass{article}
\usepackage{amssymb,amsmath}
\newtheorem{theorem}{Theorem}
\newtheorem{definition}{Definition}
\newtheorem{notation}{Notation}
```

The preamble names the document class, `article`, and then names the LaTeX enhancements, or packages, used by the article. This article loads two packages:

The amssymb package provides the names of all the math symbols in Appendix A and the amsmath package provides many of the math constructs used.

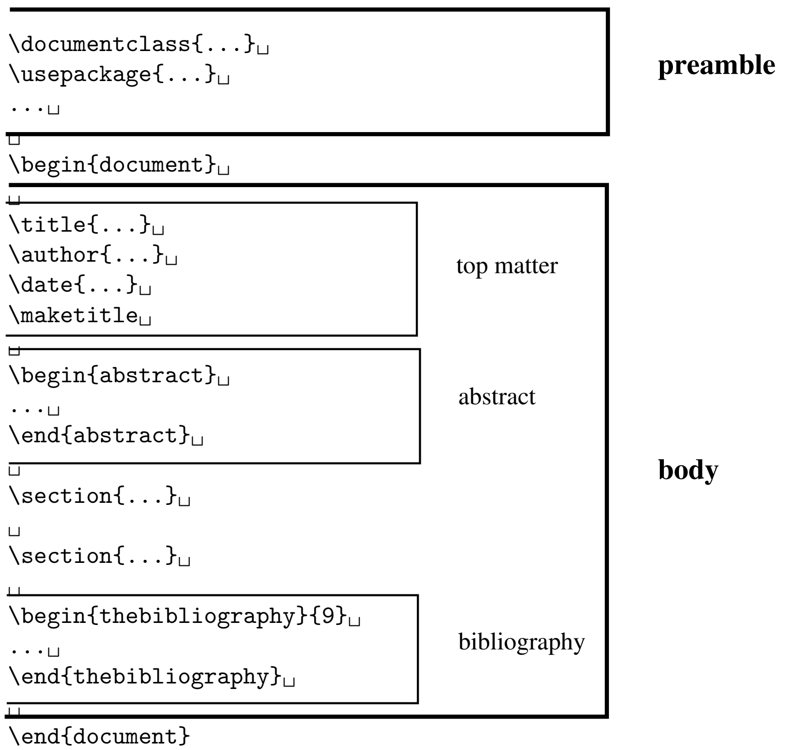

Figure 1.1: A schematic view of an article

A *proclamation* is a theorem, definition, corollary, note, and so on. In the preamble, three proclamations are defined. For instance,

```
\newtheorem{theorem}{Theorem}
```

defines the `theorem` environment, which you can use in the body of your article (see section 1.7.3). LATEX will automatically number and visually format the theorems.

The article proper, called the *body* of the article, is contained in the `document` environment, that is, between the lines

```
\begin{document}
```

and

```
\end{document}
```

as illustrated in Figure 1.1. The body of the article is also logically split up into several parts; we'll discuss these in detail in section 6.1.

The body of the article starts with the *top matter*, which contains the "title page" information. It follows the line:

```
\begin{document}
```

and concludes with the line

```
\maketitle
```

Here is the top matter of the introductory sample article:

```
\title{A construction of complete-simple\\
       distributive lattices}
\author{George~A. Menuhin\thanks{Research supported
   by the NSF under grant number~23466.}\\
   Computer Science Department\\
   University of Winnebago\\
   Winnebago, Minnesota 23714\\
   \texttt{menuhin@ccw.uwinnebago.edu}}
\date{March 15, 1995}
\maketitle
```

The body continues with an (optional) abstract, contained in an `abstract` environment:

```
\begin{abstract}
   In this note we prove that there exist \emph{complete-simple
   distributive lattices}, that is, complete distributive
   lattices in which there are only two complete congruences.
\end{abstract}
```

And here is the rest of the body of the introductory sample article:

```
\section{Introduction} \label{S:intro}
In this note we prove the following result:

\begin{theorem}
   There exists an infinite complete distributive lattice $K$
   with only the two trivial complete congruence relations.
\end{theorem}

\section{The $\Pi^{*}$ construction} \label{S:P*}
The following construction is crucial in our proof of our Theorem:

\begin{definition} \label{D:P*}
   Let $D_{i}$, $i \in I$, be complete distributive
   lattices satisfying condition~\textup{(J)}.  Their
   $\Pi^{*}$ product is defined as follows:
   \[
      \Pi^{*} ( D_{i} \mid i \in I ) =
       \Pi ( D_{i}^{-} \mid i \in I ) + 1;
   \]
   that is, $\Pi^{*} ( D_{i} \mid i \in I )$ is
   $\Pi ( D_{i}^{-} \mid i \in I )$ with a new unit element.
\end{definition}

\begin{notation}
   If $i \in I$ and $d \in D_{i}^{-}$, then
   \[
      \langle \dots, 0, \dots, \overset{i}{d}, \dots, 0,
       \dots \rangle
   \]
   is the element of $\Pi^{*} ( D_{i} \mid i \in I )$ whose
   $i$th component is $d$ and all the other components
   are $0$.
\end{notation}

See also Ernest~T. Moynahan~\cite{eM57a}.


Next we verify the following result:

\begin{theorem} \label{T:P*}
   Let $D_{i}$, $i \in I$, be complete distributive
   lattices satisfying condition~\textup{(J)}.  Let $\Theta$
   be a complete congruence relation on
```

```
   $\Pi^{*} ( D_{i} \mid i \in I )$.
   If there exists an $i \in I$ and a $d \in D_{i}$ with
   $d < 1_{i}$ such that for all $d \leq c < 1_{i}$,
   \begin{equation} \label{E:cong1}
      \langle \dots, 0, \dots,\overset{i}{d},
      \dots, 0, \dots \rangle \equiv \langle \dots, 0, \dots,
      \overset{i}{c}, \dots, 0, \dots \rangle \pmod{\Theta},
   \end{equation}
   then $\Theta = \iota$.
\end{theorem}

\emph{Proof.} Since
\begin{equation} \label{E:cong2}
   \langle \dots, 0, \dots, \overset{i}{d}, \dots, 0,
      \dots \rangle \equiv \langle \dots, 0, \dots,
      \overset{i}{c}, \dots, 0, \dots \rangle \pmod{\Theta},
\end{equation}
and $\Theta$ is a complete congruence relation, it follows
from condition~(C) that
\begin{align} \label{E:cong}
   & \langle \dots, \overset{i}{d}, \dots, 0,
    \dots \rangle \equiv\\
   &\qquad \qquad \quad \bigvee ( \langle \dots, 0, \dots,
   \overset{i}{c}, \dots, 0, \dots \rangle \mid d \leq c < 1 )
   \equiv 1 \pmod{\Theta}. \notag
\end{align}

Let $j \in I$, $j \neq i$, and let $a \in D_{j}^{-}$.
Meeting both sides of the congruence \eqref{E:cong2} with
$\langle \dots, 0, \dots, \overset{j}{a}, \dots, 0,
\dots \rangle$, we obtain

\begin{align} \label{E:comp}
   0 = & \langle \dots, 0, \dots, \overset{i}{d}, \dots, 0, \dots
      \rangle \wedge \langle \dots, 0, \dots, \overset{j}{a},
      \dots, 0, \dots \rangle \equiv\\
       &\langle \dots, 0, \dots, \overset{j}{a}, \dots, 0, \dots
      \rangle \pmod{\Theta}, \notag
\end{align}
Using the completeness of $\Theta$ and \eqref{E:comp},
we get:
\[
```

```
   0 \equiv \bigvee ( \langle \dots, 0, \dots, \overset{j}{a},
   \dots, 0,\dots\rangle \mid a \in D_{j}^{-} ) = 1 \pmod{\Theta},
\]
hence $\Theta = \iota$.

\begin{thebibliography}{9}
   \bibitem{sF90}
      Soo-Key Foo, \emph{Lattice constructions}, Ph.D. thesis,
      University of Winnebago, Winnebago MN, December 1990.
   \bibitem{gM68}
      George~A. Menuhin, \emph{Universal Algebra}, D.~van Nostrand,
      Princeton-Toronto-London-Mel\-bourne, 1968.
   \bibitem{eM57}
      Ernest~T. Moynahan, \emph{On a problem of M.~H. Stone}, Acta
      Math. Acad. Sci. Hungar. \textbf{8} (1957), 455--460.
   \bibitem{eM57a}
      Ernest~T. Moynahan, \emph{Ideals and congruence relations in
      lattices. II}, Magyar Tud. Akad. Mat. Fiz. Oszt. K\"{o}zl.
      \textbf{9} (1957), 417--434.
\end{thebibliography}
```

At the end of the body, the *bibliography* is typed between the lines

```
\begin{thebibliography}{9}
\end{thebibliography}
```

The argument "`9`" of the `thebibliography` environment tells LaTeX to make room for single digit numbering, since in this article there are fewer than 10 articles. In the typeset article, the bibliography is entitled "References".

Observe that we refer to condition (J) in the definition as `\textup{(J)}`. We do this so that if the text of the definition is emphasized (as it is), then `(J)` should still be typeset as (J) and not as *(J)*; see section 2.6.4 for the `\textup` command.

1.5.1 The typeset article

Here is the typeset introductory sample article (note that the equation numbers are on the right, the default in the `article` document class; elsewhere in this book you find the $\mathcal{AMS}$ default, equations on the left—see sections 7.1.2 and 8.4 on how to change the default).

A construction of complete-simple distributive lattices

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March 15, 1995

Abstract

In this note we prove that there exist *complete-simple distributive lattices*, that is, complete distributive lattices in which there are only two complete congruences.

1 Introduction

In this note we prove the following result:

Theorem 1 *There exists an infinite complete distributive lattice K with only the two trivial complete congruence relations.*

2 The Π^* construction

The following construction is crucial in our proof of our Theorem:

Definition 1 *Let D_i, $i \in I$, be complete distributive lattices satisfying condition* (J)*. Their Π^* product is defined as follows:*

$$\Pi^*(D_i \mid i \in I) = \Pi(D_i^- \mid i \in I) + 1;$$

that is, $\Pi^*(D_i \mid i \in I)$ is $\Pi(D_i^- \mid i \in I)$ with a new unit element.

Notation 1 *If $i \in I$ and $d \in D_i^-$, then*

$$\langle \ldots, 0, \ldots, \overset{i}{d}, \ldots, 0, \ldots \rangle$$

is the element of $\Pi^*(D_i \mid i \in I)$ whose ith component is d and all the other components are 0.

*Research supported by the NSF under grant number 23466.

See also Ernest T. Moynahan [4].

Next we verify the following result:

Theorem 2 *Let D_i, $i \in I$, be complete distributive lattices satisfying condition* (J). *Let Θ be a complete congruence relation on $\Pi^*(D_i \mid i \in I)$. If there exists an $i \in I$ and a $d \in D_i$ with $d < 1_i$ such that for all $d \le c < 1_i$,*

$$\langle \dots, 0, \dots, \overset{i}{d}, \dots, 0, \dots \rangle \equiv \langle \dots, 0, \dots, \overset{i}{c}, \dots, 0, \dots \rangle \pmod{\Theta}, \tag{1}$$

then $\Theta = \iota$.

Proof. Since

$$\langle \dots, 0, \dots, \overset{i}{d}, \dots, 0, \dots \rangle \equiv \langle \dots, 0, \dots, \overset{i}{c}, \dots, 0, \dots \rangle \pmod{\Theta}, \tag{2}$$

and Θ is a complete congruence relation, it follows from condition (C) that

$$\begin{aligned} &\langle \dots, \overset{i}{d}, \dots, 0, \dots \rangle \equiv \\ &\qquad \bigvee (\langle \dots, 0, \dots, \overset{i}{c}, \dots, 0, \dots \rangle \mid d \le c < 1) \equiv 1 \pmod{\Theta}. \end{aligned} \tag{3}$$

Let $j \in I$, $j \ne i$, and let $a \in D_j^-$. Meeting both sides of the congruence (2) with $\langle \dots, 0, \dots, \overset{j}{a}, \dots, 0, \dots \rangle$, we obtain

$$\begin{aligned} 0 = &\langle \dots, 0, \dots, \overset{i}{d}, \dots, 0, \dots \rangle \wedge \langle \dots, 0, \dots, \overset{j}{a}, \dots, 0, \dots \rangle \equiv \\ &\langle \dots, 0, \dots, \overset{j}{a}, \dots, 0, \dots \rangle \pmod{\Theta}, \end{aligned} \tag{4}$$

Using the completeness of Θ and (4), we get:

$$0 \equiv \bigvee (\langle \dots, 0, \dots, \overset{j}{a}, \dots, 0, \dots \rangle \mid a \in D_j^-) = 1 \pmod{\Theta},$$

hence $\Theta = \iota$.

References

[1] Soo-Key Foo, *Lattice Constructions*, Ph.D. thesis, University of Winnebago, Winnebago, MN, December 1990.

[2] George A. Menuhin, *Universal Algebra*, D. van Nostrand, Princeton-Toronto-London-Melbourne, 1968.

[3] Ernest T. Moynahan, *On a problem of M. H. Stone*, Acta Math. Acad. Sci. Hungar. **8** (1957), 455–460.

[4] Ernest T. Moynahan, *Ideals and congruence relations in lattices. II*, Magyar Tud. Akad. Mat. Fiz. Oszt. Közl. **9** (1957), 417–434.

1.6 Article templates

Before you start writing your first article, I suggest you create two article templates for your own use.

There are two templates for articles written in the `article` document class in this book: `article.tpl` for articles with one author and `article2.tpl` for articles with two authors.[2] You can find these in the `ftp` directory (see page 4). So copy `article.tpl` into the `work` directory or type it in as follows:

```
% Sample file: article.tpl
% Typeset with LaTeX format

\documentclass{article}
\usepackage{amsmath,amssymb}

\newtheorem{theorem}{Theorem}
\newtheorem{lemma}{Lemma}
\newtheorem{proposition}{Proposition}
\newtheorem{definition}{Definition}
\newtheorem{corollary}{Corollary}
\newtheorem{notation}{Notation}

\begin{document}
\title{%
   titleline1\\
   titleline2}
\author{name\thanks{support}\\
   addressline1\\
   addressline2\\
   addressline3}
\date{date}
\maketitle

\begin{abstract}
   abstract
\end{abstract}

\begin{thebibliography}{99}

\end{thebibliography}
\end{document}
```

[2] In section 8.3, we discuss a template file, `amsart.tpl`, for the $\mathcal{A}\mathcal{M}\mathcal{S}$ document class `amsart`.

Now copy article2.tpl into the work directory, or type it in. It is identical to article.tpl except for the argument of the \author command:

```
\author{name1\thanks{support1}\\
   address1line1\\
   address1line2\\
   address1line3
   \and
   name2\thanks{support2}\\
   address2line1\\
   address2line2\\
   address2line3}
```

Note the \and command; it separates the two authors.

Now let's customize the template files. Open article.tpl and save it under a name of your choosing; I saved it under the name ggart.tpl (in the ftp directory—see page 4). In this personalized template file, I edit the top matter:

```
\title{titleline1\\
       titleline2}
\author{G. Gr\"{a}tzer\thanks{Research supported by the
                              NSERC of Canada.}\\
   University of Manitoba\\
   Department of Mathematics\\
   Winnipeg, Man. R3T 2N2\\
   Canada}
\date{date}
```

I did not edit the \title lines because they change from article to article. There is also a personalized ggart2.tpl for two authors.

1.7 Your first article

Your first article will be typeset using the article document class. To start, open the personalized article template created in section 1.6, and save it under the name of your first article. The name must be **one word** (no spaces) ending with .tex.

1.7.1 Editing the top matter

Edit the top matter to contain the article information (title, date, and so on). Here are some simple rules to follow:

Rule ■ Top matter for the `article` document class

1. If the title is only one line long, then there is no `\\` in the argument of the `\title` command; otherwise, separate the lines of the title with `\\`. There is no `\\` at the end of the last line.
2. Separate the lines of the address with `\\`. There is no `\\` at the end of the last line.
3. `\thanks` places a footnote at the bottom of the first page. If it is not needed, delete it.
4. Multiple authors are separated by `\and`. There is only one `\author` command, and it contains all the information (name, address, support) about all the authors.
5. The `\title` command is the only compulsory command. The others are optional.
6. If there is no `\date` command, the current date will be shown. If you do not want a date, type the form `\date{}`; if you want a specific date, say February 21, 1995, write
`\date{February 21, 1995}`

1.7.2 Sectioning

An article, as a rule, is divided into sections. To start the section entitled "Introduction", type

```
\section{Introduction} \label{S:intro}
```

`Introduction` is the title of the section, `S:intro` is the label. I use the convention that "`S:`" starts the label for a section. The number of the section is automatically assigned by LaTeX, and you can refer to this section number by `\ref{S:intro}`, as in

```
In section~\ref{S:intro}, we introduce ...
```

(the tilde ˜ is an unbreakable space, it keeps the word "section" and the section number together—see section 2.4.3).

For instance, the section title of this section was typed as follows:

```
\section{Typing your first article} \label{S:FirstArticle}
```

A reference to this section is made by typing

```
\ref{S:FirstArticle}
```

Sections have subsections, and subsections have subsubsections, followed by paragraphs and subparagraphs. The corresponding commands are

```
\subsection    \subsubsection   \paragraph   \subparagraph
```

1.7.3 Invoking proclamations

In the preamble of `article.tpl`, you typed the theorem, lemma, proposition, definition, corollary, and notation proclamations. Each of these proclamations defines an environment. For example, type a theorem in a `theorem` environment; the body of the theorem (that is, the part of the source file that produces the theorem) is between the two lines:

```
\begin{theorem} \label{T:xxx}
```

and

```
\end{theorem}
```

where `T:xxx` is the label for the theorem. Of course, `xxx` should be somewhat descriptive of the contents of the theorem. The theorem number is automatically assigned by LaTeX, and it can be referenced by `\ref{T:xxx}` as in

```
it follows from Theorem~\ref{T:xxx}
```

(the tilde ˜ keeps the word "Theorem" and the theorem number together—see section 2.4.3). I use the convention that the label for a theorem starts with "`T:`".

1.7.4 Inserting references

Finally, we discuss the bibliography. Below are typical entries for the most often used types of references: an article in a journal, a book, an article in a conference proceedings, an article (chapter) in a book, a Ph.D. thesis, and a technical report (see `inbibl.tpl` in the `ftp` directory).

```
\bibitem{eM57}
   Ernest~T. Moynahan, \emph{On a problem of M.~H. Stone},
    Acta Math. Acad. Sci. Hungar. \textbf{8} (1957), 455--460.

\bibitem{gM68}
   George~A. Menuhin, \emph{Universal Algebra}, D.~van Nostrand,
    Princeton-Toronto-London-Melbourne, 1968.

\bibitem{pK69}
```

```
   Peter~A. Konig, \emph{Composition of functions}, Proceedings
     of the Conference on Universal Algebra (Kingston, 1969).

\bibitem{hA70}
   Henry~H. Albert, \emph{Free torsoids}, Current Trends in
     Lattice Theory, D.~van Nostrand, 1970.

\bibitem{sF90}
   Soo-Key Foo, \emph{Lattice constructions}, Ph.D. thesis,
    University of Winnebago, 1990.

\bibitem{gF86}
   Grant~H. Foster, \emph{Computational complexity in lattice
    theory}, Tech. report, Carnegie Mellon University, 1986.
```

I use the convention that the label for the `\bibitem` consists of the initials of the author and the year of publication: a publication by Andrew B. Reich in 1987 would have the label `aR87` (the second publication would be `aR87a`). For joint publications, the label consists of the initials of the authors and the year of publication; for instance, a publication by John Bradford and Andrew B. Reich in 1987 would have the label `BR87`. Of course, you can use any label you choose (subject to the rule in section 6.4.2).

Suppose you want to include as the fifth item in the bibliography the following article:

John Bradford and Andrew B. Reich, *Duplexes in posets*, Proc. Amer. Math. Soc. **112** (1987), 115–125.

Modeling it after Moynahan's article, type it as:

```
\bibitem{BR87}
   John~Bradford and Andrew~B. Reich, \emph{Duplexes in posets},
    Proc. Amer. Math. Soc. \textbf{112} (1987), 115--125.
```

A reference to this article is made with `\cite{BR87}`, for instance:

this result was first published in [5]

typed as

```
this result was first published in~\cite{BR87}
```

Note that you have to arrange the references in the `thebibliography` environment in the order you wish to see them. LaTeX only takes care of the numbering and the citations in the text.

Tip The `thebibliography` environment properly handles periods. You do not have to mark periods for abbreviations (in the form `.\ ` —as discussed in section 2.2.2) in the name of a journal, so

```
Acta Math. Acad. Sci. Hungar.
```

is correct.

1.8 LaTeX error messages

You'll probably make a number of mistakes in your first article. The mistakes come in various forms:

- Typographical errors, which LaTeX will blindly typeset. View the typeset version, find the errors, and correct the source file.
- Errors in mathematical formulas or in the formatting of the text.
- Errors in your instructions—commands and environments—to LaTeX.

Let's look at some examples by introducing a number of errors in the source file of the `intrart.tex` introductory sample article and see what error messages occur.

Example 1 Go to line 21 (you do not have to count lines, since most editors have a "go to line" command) and remove the closing brace so it reads:

```
\begin{abstract
```

Upon typesetting `intrart.tex`, LaTeX informs you of a mistake:

```
Runaway argument?
{abstract
! Paragraph ended before \end was complete.
<to be read again>
                   \par
l.26
```

Line 26 of the file is the line after `\end{abstract}`. From the error message, you can tell that something is wrong with the `abstract` environment.

Example 2 Now correct line 21, go to line 25, change it from

```
\end{abstract}
```

to

```
\end{abstrac}
```

and typeset again. LaTeX will inform you:

```
! LaTeX Error: \begin{abstract} on input line 21
ended by \end{abstrac}.

l.25 \end{abstrac}
```

Pressing return, LaTeX will recover from this error.

Example 3 Instead of correcting the error in line 25, comment it out:

```
% \end{abstrac}
```

and introduce an additional error in line 67. This line presently reads:

```
   lattices satisfying condition~\textup{(J)}.  Let $\Theta$
```

Change `\Theta` to `\Teta`:

```
   lattices satisfying condition~\textup{(J)}.  Let $\Teta$
```

Typesetting the article now, the message is:

```
! Undefined control sequence.
l.67 ...xtup{(J)}.  Let $\Teta
                                $
```

and pressing return gives the message:

```
! LaTeX Error: \begin{abstract} on input line 21 ended
by \end{document}.

l.131 \end{document}
```

These two mistakes are easy to identify. `\Teta` is a typo for `\Theta`. Observe how LaTeX tries to match

```
\begin{abstract}
```

with

```
\end{document}
```

Undo the two changes (lines 25 and 67).

Example 4 In line 73, change

```
      \langle \dots, 0, \dots,\overset{i}{d},
```

to

```
      \langle \dots, 0, \dots,\overset{i}{d,
```

This results in the message:

```
Runaway argument?
\def \\{\@amsmath@err {\Invalid@@ \\}\@eha } \label {E\ETC.
! Paragraph ended before \equation was complete.
<to be read again>
                   \par
l.79
```

Line 79 is the blank line following `\end{theorem}`. LaTeX skipped over the defective construct `\overset` and the incomplete `equation` environment, indicating the error past the end of the `theorem` environment. The error message indicates that the error may have been caused by the new paragraph (`\par`). Of course, there can be no new paragraph in either the second argument of `\overset` or the displayed formula. The solution does not come easily except by isolating the last paragraph and investigating it.

Error messages from LaTeX are not always as helpful as one would like, but there is always some information to be gleaned from them. As a rule, the error message should at least inform you of the line number (or paragraph or formula) where the error was caught. Try to identify the structure that caused the error: a command, an environment, or so forth. Keep in mind that it could be quite far from the line where LaTeX indicated the error. Try reading the section of this book that describes that command or environment; it should help in correcting the error.

The next best defense is to isolate your problem. Create a `current.tex` file that is the same as the present article, except that there is only one paragraph in the `document` environment. When this paragraph is typeset correctly, cut and paste it into your source file. If there is only one paragraph in the document, the error is easier to find. If the error is of the type as in the last example, split the paragraph into smaller paragraphs. See also section 2.5 on how to use the `comment` environment for finding errors.

1.9 Logical and visual design

This book attempts to show how to typeset an article, **not** how to write it. Nevertheless, it seems appropriate to point out some approaches to article design.

The typeset version of our `intrart.tex` introductory sample article (pp. 39–40) looks impressive. (For another example of a typeset article, see `sampart.tex` on pp. 361–363.) To produce an article like this, you have to realize that there are two aspects of article design: the *visual* and the *logical*. Let's borrow an example from the sample article to illustrate this: a theorem. You tell LaTeX to typeset a theorem and number it. Here is how you type the theorem:

```
\begin{theorem} \label{T:P*}
```

```
   Let $D_{i}$, $i \in I$, be complete distributive
   lattices satisfying condition~\textup{(2)}.  Let $\Theta$
   be a complete congruence relation on
   $\Pi^{*} ( D_{i} \mid i \in I )$.
   If there exists an $i \in I$ and a $d \in D_{i}$ with
   $d < 1_{i}$ such that for all $d \leq c < 1_{i}$,
   \begin{equation} \label{E:cong1}
      \langle \dots, 0, \dots,\overset{i}{d},
      \dots, 0, \dots \rangle \equiv \langle \dots, 0, \dots,
      \overset{i}{c}, \dots, 0, \dots \rangle \pmod{\Theta},
   \end{equation}
   then $\Theta = \iota$.
\end{theorem}
```

You find the typeset form on page 40.

The logical design is the theorem itself, which is placed in the `theorem` environment. For the visual design, LaTeX makes literally hundreds of decisions: the vertical space before and after the theorem; the bold **Theorem** heading and its numbering; the vertical space before and after the equation, and its numbering; the spacing of all the math symbols (inline and displayed formulas are spaced differently); the text of the theorem to be emphasized; and so on.

The decisions were made by professional designers, whose expertise is hidden in TeX itself, in LaTeX, in the document class, and in the packages. Could you have typeset this theorem yourself? Probably not. Aesthetic decisions are difficult for lay people to make. But even if you could have guessed the correct spacing, you would have faced the problem of consistency (guaranteeing that the next theorem will look the same), and just as importantly, you would have spent a great deal of time and energy on the *visual design* of the theorem, as opposed to the *logical design*. The idea is to concentrate on the logical design and let LaTeX take care of the visual design.

This approach has the advantage that by changing the document class (or its options; see sections 7.1.2 and 8.4), the visual design can be changed. If you code the visual design into the article ("hard coding" it, as a programmer would say), it's very difficult to change.

LaTeX uses four major tools to separate the logical and visual designs of an article:

Commands Information is given to LaTeX as arguments of commands; it's up to LaTeX to process the information. For instance, the title page information (especially in the `amsart` document class) is given in this form; the organization of the title page is completely up to the document class and its options.

A more subtle example is the use of a command for distinguishing a term or notation. For instance, you may want to use an `\env` command for environment names. You may define `\env` as follows (`\newcommand` is explained in section 9.1.1):

```
\newcommand{\env}[1]{\texttt{#1}}
```

which typesets all environment names in typewriter style (see section 2.6.2). Logically, you have decided that an environment name should be marked up. Visually, you may change the decision any time. By changing the definition to

```
\newcommand{\env}[1]{\textbf{#1}}
```

all environment names will be typeset in bold (see section 2.6.7).

The following more mathematical example is taken from `sampart2.tex` (see Appendix D and the `ftp` directory). This article defines the construct $D^{\langle 2 \rangle}$ with the command

```
\newcommand{\Ds}{D^{\langle 2 \rangle}}
```

If a referee (or coauthor) suggests a different notation, changing this *one line* will carry out the change throughout the whole article.

Environments Important logical structures are placed in environments. For instance, you can give a list as an environment by saying that this is a list and these are the items (see section 3.1). Again, exactly how the list is typeset is up to LaTeX; you can even switch from one list type to another by just changing the name of the environment.

Proclamations These define numbered environments. If the amsthm package is used, you can further specify which one of three styles to use for typesetting; at any time you can change the style or the numbering scheme in the preamble (see the typeset `sampart.tex` on pages 361–363 for examples of proclamations printed in the three styles).

Cross-referencing Since theorems and sections are logical units, they can be freely moved around. This gives tremendous freedom in reorganizing the source file to improve the logical design.

You write articles to communicate. The closer you get to a separation of logical and visual design, the more you are able to concentrate on communicating your ideas. Of course, you can never quite reach this ideal. For instance, a "line too wide" warning (see sections 1.1.3 and 2.7.1) is a problem of visual design. When the journal changes the document class, unless the new document class retains the same fonts and line width, new "line too wide" problems arise. However, LaTeX is successful well over 95% of the time in solving visual design problems without your intervention. This is getting fairly close to the ideal.

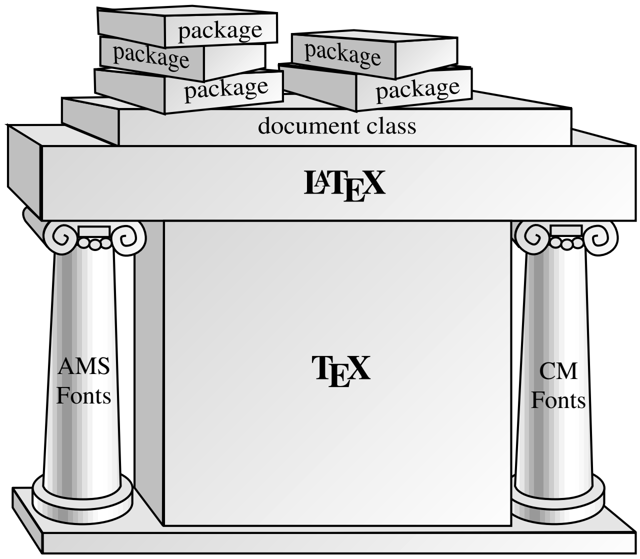

Figure 1.2: The structure of LaTeX

1.10 A brief overview

Having finished the short course, maybe it's time to pause and get a brief overview of how LaTeX works. As I pointed out in the Introduction, at the core of LaTeX is a *programming language* called TeX, providing many typesetting instructions. Along with TeX comes a set of fonts called *Computer Modern* (CM). The CM fonts and the TeX programming language form the foundation of a typical TeX system.

TeX is expandable, that is, additional commands can be defined in terms of more basic ones. One of the best known expansions of TeX is LaTeX; it introduces the idea of a *logical unit* that you read about in section 1.9.

Visual layout in LaTeX is determined by the *document class*; for example, you now have some familiarity with the `article` document class. Expansions of LaTeX are called *packages*; you have already come across the amssymb and amsmath packages.

The structure of LaTeX is illustrated in Figure 1.2. This figure suggests that, in order to work with a LaTeX document, you first have to install TeX and the CM fonts, then LaTeX, and finally specify the document class and the necessary packages. The AMSFonts font set is useful but it's not absolutely necessary.

Figure 1.2 illustrates my view of TEX and LATEX: it is the foundation on which many useful packages—extensions of LATEX—are built. It is essential that you understand the packages that make your work easier. An important example of this is the central focus of this book: typesetting math in LATEX. When typesetting math, invoke the amsmath package. In Part I, you invoke the amsmath package directly; in later parts of this book, I point out when a described feature needs the amsmath (or some other) package. The $\mathcal{AMS}$ document classes automatically load the amsmath and amsfonts packages.

1.11 Using LATEX

Figure 1.3 illustrates the steps taken to produce a typeset document. As illustrated in Figure 1.3, you open the source file or create a new one using an editor; call the source file `myart.tex`. Once the document is ready, typeset it with TEX using the `LaTeX` format. This step produces three files:

- `myart.dvi`, the typeset article in machine readable format;
- `myart.aux`, the auxiliary file; it is used by LATEX for internal "book keeping", including cross-referencing;
- `myart.log`, the log file; LATEX records the typesetting session in the log file, including the warnings and the errors.

Use a video driver to display the typeset article, `myart.dvi`, on the monitor, and a printer driver to print the typeset article, `myart.dvi` on a printer.

It should be emphasized that of the four programs used, only one (TEX) is the same for all computers and all implementations. If you use TEX in an "integrated environment", then all four programs appear as one.

1.11.1 $\mathcal{AMS}$-LATEX revisited

Now that you understand the structure of LATEX, we can again discuss $\mathcal{AMS}$-LATEX, a set of enhancements to LATEX by the $\mathcal{AMS}$. As outlined in the Introduction, the $\mathcal{AMS}$ enhancements to LATEX fall into three groups: the $\mathcal{AMS}$ math enhancements, the document classes, and the AMSFonts. Each consists of several packages.

An $\mathcal{AMS}$ document class automatically invokes the following $\mathcal{AMS}$ packages (see section 8.5 for a more detailed discussion and for the package interdependency diagram, Figure 8.3):

- amsmath, the main $\mathcal{AMS}$ math package;
- amsthm, proclamations with style and the `proof` environment;
- amsopn, operator names;
- amstext, the `\text` command;
- amsfonts, commands for math alphabets;
- amsbsy, bold symbol commands.

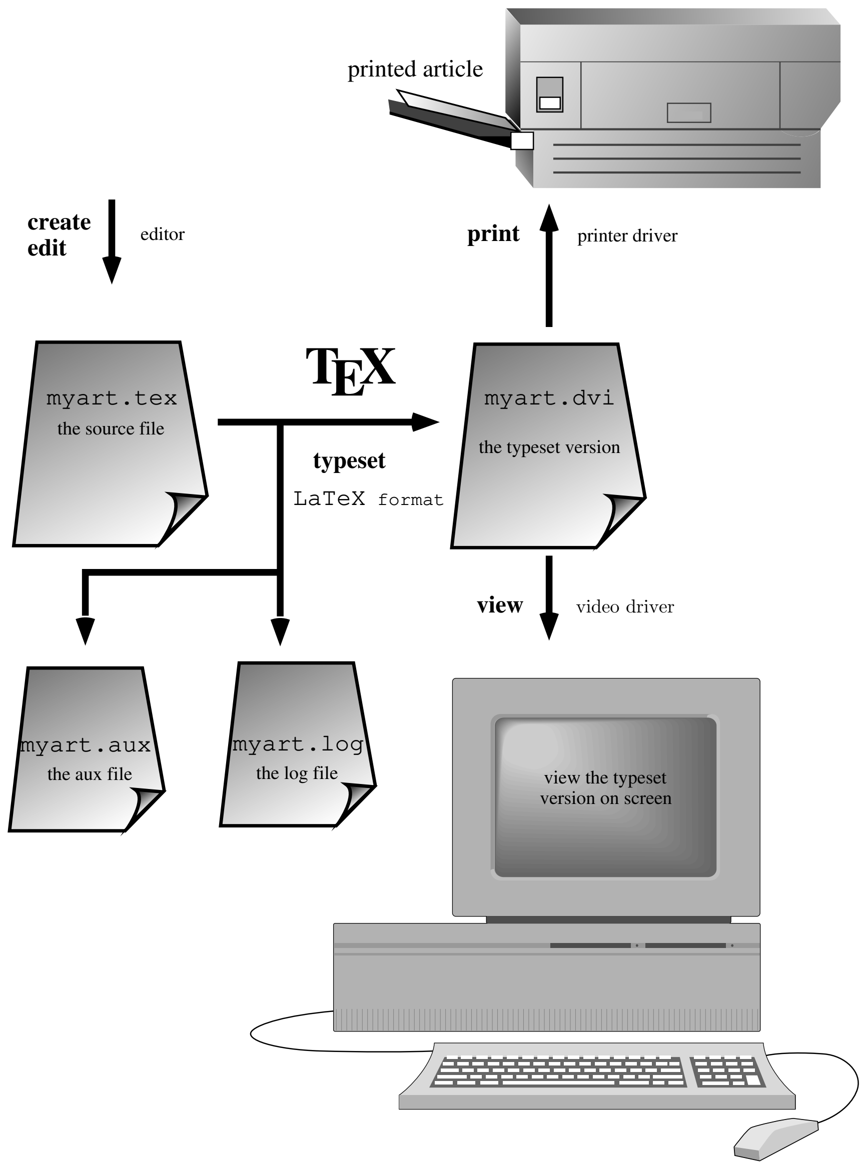

Figure 1.3: Using LATEX

They do not automatically input the amssymb package, which provides the math symbol names. You can additionally input this and other $\mathcal{AMS}$-LaTeX or LaTeX packages as needed.

When we discuss a feature of LaTeX that requires a package, I point this out in the text. I do not always point out, however, the interdependencies of the document classes and of the packages. For instance, the `\text` command (section 2.9) is provided by the amstext package, which is loaded automatically by the amsmath package, which in turn is loaded automatically by each of the $\mathcal{AMS}$-LaTeX document classes. These interdependencies are discussed in section 8.5.

1.11.2 Interactive LaTeX

As a rule, LaTeX typesets an article non-interactively. Occasionally, you may want to use LaTeX interactively, that is, give LaTeX an instruction and ask it to carry it out. If LaTeX can't carry out your instructions, it displays a prompt:

- The `**` prompt means that LaTeX wants to know the name of a source file to typeset. Probably, you misspelled a name, or you are in the wrong directory.
- The `?` prompt asks "What should I do about the error I found?" Press return to continue; most of the time LaTeX recovers from the error, and completes the typesetting. If LaTeX can't recover from the error at the `?` prompt, press `X` to exit. Typing `H` instead may yield useful advice.
- The `*` signifies interactive mode: LaTeX is waiting for an instruction. To get to such a prompt, comment out the line

  ```
  \end{document}
  ```

  (by inserting `%` as the first character of the line) in the source file and typeset. Interactive instructions (such as `\show`—see section 9.1.6) may be given at the `*` prompt. Typing

  ```
  \end{document}
  ```

  at the `*` prompt exits LaTeX.

1.11.3 Files

A number of files are created when a document called, say, `myart.tex` is typeset. When the typesetting takes place, a number of messages appear on the monitor. These are stored in the *log file*, `myart.log`. The typeset document is written in the `myart.dvi` file. LaTeX also writes one or more auxiliary files, as necessary. The most important one is `myart.aux`, the `aux` file (see section E.2.4).

1.11.4 Versions

All components of LaTeX interact. Since all of them have many versions, make sure they are up-to-date and compatible. While writing this book, I used LaTeX 2_ε (LaTeX version 2e), issued on December 1, 1994. You can check the version numbers and dates by reading the first few lines of the files in an editor or by checking the dates shown on the file list discussed below.

LaTeX is updated every six months; in-between updates, the `ltpatch.ltx` document is posted periodically on the CTAN (see Appendix G). Get this file and place it in your TeX input directory. When you rebuild your formats, `ltpatch.ltx` will patch LaTeX.

When you typeset a LaTeX document, LaTeX introduces itself in the log file with a line such as

```
LaTeX2e <1994/12/01> patch level 3
```

giving you the release date and patch level. If you use a new feature of LaTeX that was introduced recently, place in the preamble of your document the command

```
\NeedsTeXFormat{LaTeX2e}[1994/12/01]
```

where the date is the release date of the version you must use.

As of this writing, $\mathcal{AMS}$-LaTeX is at version 1.2 and the AMSFonts font set is at version 2.2. See Appendix G on how to get updated versions of $\mathcal{AMS}$-LaTeX and the AMSFonts.

BibTeX is at version 0.99 (version 1.0 is expected soon). In this book, I use the `amsplain.bst` bibliographic style file (version 1.2a).

If you include the `\listfiles` command in the preamble of your document, the log file will contain a detailed listing of all the files used in the typesetting of your document.

Here are a few lines from such a listing:

```
*File List*
book.cls      1994/12/09 v1.2x Standard LaTeX document class
leqno.clo     1994/12/09 v1.2x Standard LaTeX option
bk10.clo      1994/12/09 v1.2x Standard LaTeX file (size option)
amsmath.sty   1995/02/23 v1.2b AMS math features
Ueus57.fd     1994/10/17 v2.2d AMS font definitions
latexsym.sty  1994/09/25 v2.1f Standard LaTeX package
xspace.sty    1994/11/15 v1.03 Space after command names (DPC)
Ulasy.fd      1994/09/25 v2.1f LaTeX symbol font definitions
***********
```

1.12 What's next?

Having read thus far, you probably know enough about LaTeX to write your first article. The best way to learn LaTeX is by experimentation. Later, you may want to read Parts II–V.

If you look at the source files of the sample articles, your first impression may be how very verbose LaTeX is. In actual practice, LaTeX is fairly easy to type. There are two basic tools to make typing LaTeX more efficient.

Firstly, you should have a good editor. For instance, you should be able to train your editor so that a single keystroke produces the text:

```
\begin{theorem} \label{T:}

\end{theorem}
```

with the cursor in the position following ":" (where you type the label).

Secondly, customizing LaTeX will make repetitious structures such as

```
\begin{equation}
   \langle \dots, 0, \dots, \overset{i}{d}, \dots, 0,
    \dots \rangle \equiv \langle
    \dots, 0, \dots, \overset{i}{c}, \dots, 0, \dots
    \rangle \pmod{\Theta},
\end{equation}
```

which prints

$$\langle \dots, 0, \dots, \overset{i}{d}, \dots, 0, \dots \rangle \equiv \langle \dots, 0, \dots, \overset{i}{c}, \dots, 0, \dots \rangle \pmod{\Theta}, \tag{3.1}$$

(see page 369) become much shorter and (with practice) more readable. Utilizing the user-defined commands `\con` (for congruence), `\vct` (for vector), and `\gQ` (for Greek theta), in `sampart2.tex` (in the `ftp` directory and in Appendix C), this formula becomes

```
\begin{equation}
   \con \vct{i}{d}=\vct{i}{c}(\gQ),
\end{equation}
```

which is about as long as the typeset formula itself.

The topic of user-defined commands is taken up in Part IV.

Finally, custom formats (section 9.7) substantially speed up the typesetting of an average document.

APPENDIX

A

Math symbol tables

A.1 Hebrew letters

Type:	Print:	Type:	Print:
`\aleph`	$\aleph$	`\beth`	$\beth$
`\daleth`	$\daleth$	`\gimel`	$\gimel$

All symbols but `\aleph` need the amssymb package.

A.2 Greek characters

Type:	Print:	Type:	Print:	Type:	Print:
`\alpha`	α	`\beta`	β	`\gamma`	γ
`\digamma`	$\digamma$	`\delta`	δ	`\epsilon`	ϵ
`\varepsilon`	ε	`\zeta`	ζ	`\eta`	η
`\theta`	θ	`\vartheta`	ϑ	`\iota`	ι
`\kappa`	κ	`\varkappa`	$\varkappa$	`\lambda`	λ
`\mu`	μ	`\nu`	ν	`\xi`	ξ
`\pi`	π	`\varpi`	ϖ	`\rho`	ρ
`\varrho`	ϱ	`\sigma`	σ	`\varsigma`	ς
`\tau`	τ	`\upsilon`	υ	`\phi`	ϕ
`\varphi`	φ	`\chi`	χ	`\psi`	ψ
`\omega`	ω				

`\digamma` and `\varkappa` require the amssymb package.

Type:	Print:	Type:	Print:
`\Gamma`	Γ	`\varGamma`	$\varGamma$
`\Delta`	Δ	`\varDelta`	$\varDelta$
`\Theta`	Θ	`\varTheta`	$\varTheta$
`\Lambda`	Λ	`\varLambda`	$\varLambda$
`\Xi`	Ξ	`\varXi`	$\varXi$
`\Pi`	Π	`\varPi`	$\varPi$
`\Sigma`	Σ	`\varSigma`	$\varSigma$
`\Upsilon`	Υ	`\varUpsilon`	$\varUpsilon$
`\Phi`	Φ	`\varPhi`	$\varPhi$
`\Psi`	Ψ	`\varPsi`	$\varPsi$
`\Omega`	Ω	`\varOmega`	$\varOmega$

All symbols whose name begins with `var` need the amsmath package.

A.3 LaTeX binary relations

Type:	Print:	Type:	Print:
`\in`	$\in$	`\ni`	$\ni$
`\leq`	$\leq$	`\geq`	$\geq$
`\ll`	$\ll$	`\gg`	$\gg$
`\prec`	$\prec$	`\succ`	$\succ$
`\preceq`	$\preceq$	`\succeq`	$\succeq$
`\sim`	$\sim$	`\cong`	$\cong$
`\simeq`	$\simeq$	`\approx`	$\approx$
`\equiv`	$\equiv$	`\doteq`	$\doteq$
`\subset`	$\subset$	`\supset`	$\supset$
`\subseteq`	$\subseteq$	`\supseteq`	$\supseteq$
`\sqsubseteq`	$\sqsubseteq$	`\sqsupseteq`	$\sqsupseteq$
`\smile`	$\smile$	`\frown`	$\frown$
`\perp`	$\perp$	`\models`	$\models$
`\mid`	$\mid$	`\parallel`	$\parallel$
`\vdash`	$\vdash$	`\dashv`	$\dashv$
`\propto`	$\propto$	`\asymp`	$\asymp$
`\bowtie`	$\bowtie$		
`\sqsubset`	$\sqsubset$	`\sqsupset`	$\sqsupset$
`\Join`	$\Join$		

The latter three symbols need the latexsym package.

A.4 $\mathcal{AMS}$ binary relations

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

All symbols require the amssymb package.

A.5 $\mathcal{AMS}$ negated binary relations

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

All symbols but `\ne` require the amssymb package.

A.6 Binary operations

Type:	Print:	Type:	Print:
`\pm`	$\pm$	`\mp`	$\mp$
`\times`	$\times$	`\cdot`	$\cdot$
`\circ`	$\circ$	`\bigcirc`	$\bigcirc$
`\div`	$\div$	`\diamond`	$\diamond$
`\ast`	$\ast$	`\star`	$\star$
`\cap`	$\cap$	`\cup`	$\cup$
`\sqcap`	$\sqcap$	`\sqcup`	$\sqcup$
`\wedge`	$\wedge$	`\vee`	$\vee$
`\triangleleft`	$\triangleleft$	`\triangleright`	$\triangleright$
`\bigtriangleup`	$\bigtriangleup$	`\bigtriangledown`	$\bigtriangledown$
`\oplus`	$\oplus$	`\ominus`	$\ominus$
`\otimes`	$\otimes$	`\oslash`	$\oslash$
`\odot`	$\odot$	`\bullet`	$\bullet$
`\dagger`	$\dagger$	`\ddagger`	$\ddagger$
`\setminus`	$\setminus$	`\uplus`	$\uplus$
`\wr`	$\wr$	`\amalg`	$\amalg$
`\lhd`	$\lhd$	`\rhd`	$\rhd$
`\unlhd`	$\unlhd$	`\unrhd`	$\unrhd$
`\dotplus`	$\centerdot$	`\centerdot`	$\leftthreetimes$
`\ltimes`	$\rtimes$	`\rtimes`	$\smallsetminus$
`\leftthreetimes`	$\rightthreetimes$	`\rightthreetimes`	$\circleddash$
`\circleddash`	$\barwedge$	`\smallsetminus`	$\divideontimes$
`\barwedge`	$\doublebarwedge$	`\doublebarwedge`	$\curlywedge$
`\curlywedge`	$\curlyvee$	`\curlyvee`	$\veebar$
`\veebar`	$\intercal$	`\intercal`	$\Cap$
`\Cap`	$\Cup$	`\Cup`	$\circledast$
`\circledast`	$\circledcirc$	`\circledcirc`	$\boxminus$
`\boxminus`	$\boxtimes$	`\boxtimes`	$\boxdot$
`\boxdot`	$\boxplus$	`\boxplus`	$\rightleftharpoons$
`\divideontimes`	$\nleftarrow$		
`\And`	$\&$		

This table is divided into four parts. The first part contains the binary operations in LaTeX. The second part requires the latexsym package. The third part contains the $\mathcal{AMS}$ additions; they require the amssymb package. The symbol `\And` requires the amsmath package.

A.7 Arrows

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

Type:	Print:	Type:	Print:
`\leftleftarrows`	$\rightrightarrows$	`\rightrightarrows`	$\leftrightarrows$
`\leftrightarrows`	$\rightleftarrows$	`\rightleftarrows`	$\Lleftarrow$
`\Lleftarrow`	$\Rrightarrow$	`\Rrightarrow`	$\twoheadleftarrow$
`\twoheadleftarrow`	$\twoheadrightarrow$	`\twoheadrightarrow`	$\leftarrowtail$
`\leftarrowtail`	$\rightarrowtail$	`\rightarrowtail`	$\looparrowleft$
`\looparrowleft`	$\looparrowright$	`\looparrowright`	$\upuparrows$
`\upuparrows`	$\downdownarrows$	`\downdownarrows`	$\upharpoonleft$
`\upharpoonleft`	$\upharpoonright$	`\upharpoonright`	$\downharpoonleft$
`\downharpoonleft`	$\downharpoonright$	`\downharpoonright`	$\leftrightsquigarrow$
`\leftrightsquigarrow`	$\rightsquigarrow$	`\rightsquigarrow`	$\multimap$
`\multimap`	$\angle$		

Type:	Print:	Type:	Print:
`\nleftarrow`	$\nrightarrow$	`\nrightarrow`	$\nleftarrow$
`\nLeftarrow`	$\nRightarrow$	`\nRightarrow`	$\nleftrightarrow$
`\nleftrightarrow`	$\nLeftrightarrow$	`\nLeftrightarrow`	$\hbar$

This table is divided into three parts. The top part contains the symbols provided by LaTeX; the last command, `\leadsto`, requires the latexsym package. The middle table contains the $\mathcal{AMS}$ arrows; they all require the amssymb package. The bottom table lists the negated arrow symbols; they also require amssymb.

A.8 Miscellaneous symbols

Type:	Print:	Type:	Print:
\hbar	$\hbar$	\ell	ℓ
\imath	$\imath$	\jmath	$\jmath$
\wp	$\wp$	\Re	$\Re$
\Im	$\Im$	\partial	∂
\infty	∞	\prime	$\prime$
\emptyset	$\emptyset$	\backslash	$\backslash$
\forall	$\forall$	\exists	$\exists$
\smallint	$\smallint$	\triangle	$\triangle$
\surd	$\surd$	\Vert	$\Vert$
\top	$\top$	\bot	$\bot$
\P	¶	\S	§
\dag	†	\ddag	‡
\flat	$\flat$	\natural	$\natural$
\sharp	$\sharp$	\angle	$\angle$
\clubsuit	$\clubsuit$	\diamondsuit	$\diamondsuit$
\heartsuit	$\heartsuit$	\spadesuit	$\spadesuit$
\neg	$\neg$		
\Box	$\Box$	\Diamond	$\Diamond$
\mho	$\mho$		
\hslash	$\varnothing$	\complement	$\backprime$
\backprime	$\vartriangle$	\vartriangle	$\blacktriangle$
\Bbbk	$\Bbbk$	\varnothing	$\diagup$
\diagup	$\diagdown$	\diagdown	$\Game$
\blacktriangle	$\blacktriangledown$	\blacktriangledown	$\triangledown$
\triangledown	$\square$	\Game	$\Finv$
\square	$\blacksquare$	\blacksquare	$\lozenge$
\lozenge	$\blacklozenge$	\blacklozenge	$\measuredangle$
\measuredangle	$\sphericalangle$	\sphericalangle	$\circledS$
\circledS	$\bigstar$	\bigstar	$\ulcorner$
\Finv	$\nexists$	\eth	$\eth$
\nexists			

This table is divided into two parts. The top part contains the symbols provided by LaTeX; the last three commands require the latexsym package. The bottom table lists symbols from the $\mathcal{AMS}$; they all require the amssymb package.

A.9 Math spacing commands

Short form:	Full form:	Size:	Short form:	Full form:
`\,`	`\thinspace`	␣	`\!`	`\negthinspace`
`\:`	`\medspace`	␣		`\negmedspace`
`\;`	`\thickspace`	␣		`\negthickspace`
	`\quad`	␣		
	`\qquad`	␣␣		

The `\medspace`, `\thickspace`, `\negmedspace`, and `\negthickspace` commands require the amsmath package.

A.10 Delimiters

<table>
<tr><th>Name:</th><th>Type:</th><th>Print:</th><th>Name:</th><th>Type:</th><th>Print:</th></tr>
<tr><td>Left paren</td><td><code>(</code></td><td>$($</td><td>Right paren</td><td><code>)</code></td><td>$)$</td></tr>
<tr><td>Left bracket</td><td><code>[</code></td><td>$[$</td><td>Right bracket</td><td><code>]</code></td><td>$]$</td></tr>
<tr><td>Left brace</td><td><code>\{</code></td><td>$\{$</td><td>Right brace</td><td><code>\}</code></td><td>$\}$</td></tr>
<tr><td>Reverse slash</td><td><code>\backslash</code></td><td>$\backslash$</td><td>Forward slash</td><td><code>/</code></td><td>$/$</td></tr>
<tr><td>Left angle</td><td><code>\langle</code></td><td>$\langle$</td><td>Right angle</td><td><code>\rangle</code></td><td>$\rangle$</td></tr>
<tr><td>Vertical line</td><td><code>|</code></td><td>$\vert$</td><td>Double vert. line</td><td><code>\|</code></td><td>$\Vert$</td></tr>
<tr><td>Left floor</td><td><code>\lfloor</code></td><td>$\lfloor$</td><td>Right floor</td><td><code>\rfloor</code></td><td>$\rfloor$</td></tr>
<tr><td>Left ceiling</td><td><code>\lceil</code></td><td>$\lceil$</td><td>Right ceiling</td><td><code>\rceil</code></td><td>$\rceil$</td></tr>
<tr><td>Upper left corner</td><td><code>\ulcorner</code></td><td>⌝</td><td>Upper right corner</td><td><code>\urcorner</code></td><td>⌞</td></tr>
<tr><td>Lower left corner</td><td><code>\llcorner</code></td><td>⌟</td><td>Lower right corner</td><td><code>\lrcorner</code></td><td></td></tr>
</table>

The corners require the amsmath package.

Name:	Type:	Print:
Upward arrow	`\uparrow`	$\uparrow$
Double upward arrow	`\Uparrow`	$\Uparrow$
Downward arrow	`\downarrow`	$\downarrow$
Double downward arrow	`\Downarrow`	$\Downarrow$
Up-and-down arrow	`\updownarrow`	$\updownarrow$
Double up-and-down arrow	`\Updownarrow`	$\Updownarrow$

A.11 Operators

\arccos	\arcsin	\arctan	\arg
\cos	\cosh	\cot	\coth
\csc	\dim	\exp	\hom
\ker	\lg	\ln	\log
\sec	\sin	\sinh	\tan
\tanh			
\varliminf	\varlimsup	\varinjlim	\varprojlim

The `\var` commands require the amsmath package.

\det	\gcd	\inf	\injlim
\lim	\liminf	\limsup	\max
\min	\projlim	\Pr	\sup

The `\injlim` and `\projlim` commands require the amsmath package.

Type:	Inline	Displayed	Type:	Inline	Displayed
\prod_{i=1}^{n}	$\textstyle\prod_{i=1}^{n}$	$\displaystyle\prod_{i=1}^{n}$	\coprod_{i=1}^{n}	$\textstyle\coprod_{i=1}^{n}$	$\displaystyle\coprod_{i=1}^{n}$
\bigcap_{i=1}^{n}	$\textstyle\bigcap_{i=1}^{n}$	$\displaystyle\bigcap_{i=1}^{n}$	\bigcup_{i=1}^{n}	$\textstyle\bigcup_{i=1}^{n}$	$\displaystyle\bigcup_{i=1}^{n}$
\bigwedge_{i=1}^{n}	$\textstyle\bigwedge_{i=1}^{n}$	$\displaystyle\bigwedge_{i=1}^{n}$	\bigvee_{i=1}^{n}	$\textstyle\bigvee_{i=1}^{n}$	$\displaystyle\bigvee_{i=1}^{n}$
\bigsqcup_{i=1}^{n}	$\textstyle\bigsqcup_{i=1}^{n}$	$\displaystyle\bigsqcup_{i=1}^{n}$	\biguplus_{i=1}^{n}	$\textstyle\biguplus_{i=1}^{n}$	$\displaystyle\biguplus_{i=1}^{n}$
\bigotimes_{i=1}^{n}	$\textstyle\bigotimes_{i=1}^{n}$	$\displaystyle\bigotimes_{i=1}^{n}$	\bigoplus_{i=1}^{n}	$\textstyle\bigoplus_{i=1}^{n}$	$\displaystyle\bigoplus_{i=1}^{n}$
\bigodot_{i=1}^{n}	$\textstyle\bigodot_{i=1}^{n}$	$\displaystyle\bigodot_{i=1}^{n}$	\sum_{i=1}^{n}	$\textstyle\sum_{i=1}^{n}$	$\displaystyle\sum_{i=1}^{n}$

A.12 Math accents

`\hat{a}`	$\hat{a}$	`\Hat{a}`	$\hat{a}$	`\widehat{a}`	$\widehat{a}$	`a\sphat`	$a^{\wedge}$
`\tilde{a}`	$\tilde{a}$	`\Tilde{a}`	$\tilde{a}$	`\widetilde{a}`	$\widetilde{a}$	`a\sptilde`	$a^{\sim}$
`\acute{a}`	$\acute{a}$	`\Acute{a}`	$\acute{a}$				
`\bar{a}`	$\bar{a}$	`\Bar{a}`	$\bar{a}$				
`\breve{a}`	$\breve{a}$	`\Breve{a}`	$\breve{a}$			`a\spbreve`	$a^{\breve{}}$
`\check{a}`	$\check{a}$	`\Check{a}`	$\check{a}$			`a\spcheck`	$a^{\vee}$
`\dot{a}`	$\dot{a}$	`\Dot{a}`	$\dot{a}$			`a\spdot`	$a^{\cdot}$
`\ddot{a}`	$\ddot{a}$	`\Ddot{a}`	$\ddot{a}$			`a\spddot`	$a^{\cdot\cdot}$
`\dddot{a}`	$\dddot{a}$					`a\spdddot`	$a^{\cdots}$
`\ddddot{a}`	$\ddddot{a}$						
`\grave{a}`	$\grave{a}$	`\Grave{a}`	$\grave{a}$	`\imath`	$\imath$		
`\vec{a}`	$\vec{a}$	`\Vec{a}`	$\vec{a}$	`\jmath`	$\jmath$		

The `\dddot` and `\ddddot` commands and all the capitalized commands require the amsmath package; the commands in the fourth column require the amsxtra package.

A.13 Math font commands

Type:	Print:
`\mathbf{A}`	$\mathbf{A}$
`\mathit{A}`	A
`\mathsf{A}`	A
`\mathrm{A}`	A
`\mathtt{A}`	$\mathtt{A}$
`\mathnormal{A}`	$\mathnormal{A}$
`\mathbb{A}`	$\mathbb{A}$
`\mathfrak{A}`	$\mathfrak{A}$
`\mathcal{A}`	$\mathcal{A}$
`\boldsymbol{\alpha}`	$\boldsymbol{\alpha}$

The `\mathbb`, `\mathfrak`, and `\mathcal` commands require the amsfonts package. The `\boldsymbol` command requires the amsbsy package.

APPENDIX

B

Text symbol tables

B.1 Special text characters

<table>
<tr><th>Type:</th><th>Print:</th><th>Type:</th><th>Print:</th><th>Type:</th><th>Print:</th></tr>
<tr><td>\#</td><td>#</td><td>\$</td><td>$</td><td>\%</td><td>%</td></tr>
<tr><td>\&</td><td>&</td><td>\~{}</td><td>~</td><td>_</td><td>_</td></tr>
<tr><td>\^{}</td><td>^</td><td>\{</td><td>{</td><td>\}</td><td>}</td></tr>
<tr><td>$|$</td><td>|</td><td>@</td><td>@</td><td>$*$</td><td>*</td></tr>
<tr><td></td><td></td><td>$\backslash$</td><td>\</td><td></td><td></td></tr>
</table>

B.2 Text accents

Type:	Print:	Type:	Print:	Type:	Print:
\‘{o}	ò	\’{o}	ó	\"{o}	ö
\H{o}	ő	\^{o}	ô	\~{o}	õ
\v{o}	ǒ	\u{o}	ŏ	\={o}	ō
\b{o}	o̲	\.{o}	ȯ	\d{o}	ọ
\c{o}	o̧	\r{o}	o̊	\t{oo}	o͡o
\i	ı			\j	ȷ

B.3 Some European characters

Type:	Print:	Type:	Print:	Type:	Print:
\aa	å	\AA	Å	\ae	æ
\AE	Æ	\o	ø	\O	Ø
\oe	œ	\OE	Œ	\l	ł
\L	Ł	\ss	ß	\SS	SS
?‘	¿	!‘	¡		

B.4 Extra text symbols

Type:	Print:
\dag	†
\ddag	‡
\S	§
\P	¶
\copyright	©
\pounds	£
\textbullet	•
\textvisiblespace	␣
\textcircled{a}	ⓐ
\textperiodcentered	·