This is an updated version of chapter 8 of the *LaTeX Companion* reflecting changes in the AMS-LaTeX distribution that made parts of this chapter obsolete. It is based in structure and content on the original documentation in the *Companion* with obsolete parts corrected but otherwise unchanged and should not be considered as part of a general revision of this book.

Chapter 8 of "The LaTeX Companion", updated for AMS-LaTeX version 1.2 (Sep. 1st 1997).

CHAPTER 8

Higher Mathematics

Basic LaTeX offers a high level of mathematical typesetting capabilities. However, when complex equations or other mathematical constructs have to be input repeatedly, it is up to you to define new commands or environments to ease the burden of typing. The American Mathematical Society (AMS), recognizing that fact, has sponsored the development of extensions to TeX, known as AMS-TeX. They make the preparation of mathematical compuscripts less time-consuming and the copy more consistent.

Recently these extensions were ported to LaTeX in the form of a set of packages known as "AMS-LaTeX" [?]. As some parts of AMS-TeX had to do with mathematics fonts the corresponding LaTeX packages went into a separate distribution called "AMSFonts", rather than into AMS-LaTeX.

8.1 The AMS-LaTeX Project

AMS-TeX was originally released for general use in 1982. Its main strength is that it facilitates mathematical typesetting, while producing output that satisfies the high standards of mathematical publishing. It provides a predefined set of natural commands such as `\matrix` and `\text` that make complicated mathematics reasonably convenient to type. These commands incorporate the typesetting experience and standards of the American Mathematical Society, to handle problematic possibilities, such as matrices within matrices or a word of text within a subscript, without burdening the user.

AMS-TeX lacks certain useful LaTeX features such as automatic numbering that adjusts to addition or deletion of material being the primary one. Nor does it have the laborsaving abilities of LaTeX for preparing indexes, bibliographies, tables, or simple diagrams. These features are such a convenience for authors that the use of LaTeX spread rapidly in the mid-1980s (a reasonably mature version of LaTeX was available by the end of 1983), and the American Mathematical Society began to be asked by its authors to accept electronic submissions in LaTeX.

Thus, the AMS-LaTeX project came into being in 1987 and three years later AMS-LaTeX version 1.0 was released. The conversion of AMS-TeX's mathematical capabilities to LaTeX, and the integration with the NFSS, were done by Frank Mittelbach and Rainer Schöpf, working as consultants to the AMS, with assistance from Michael Downes of the AMS technical support staff.

The most often used packages are amsmath (from AMS-LaTeX) and amssymb (from the AMSFonts distribution). To invoke them in a document you write, e.g., `\usepackage{amsmath}` in the usual way. Installation and usage documentation is included with the packages. For amssymb the principal piece of documentation is the *AMSFonts User's Guide* (`amsfndoc.tex`); for amsmath it is the *AMS-LaTeX User's Guide* (`amsldoc.tex`).[1]

8.2 Fonts and Symbols in Formulae

8.2.1 Mathematical Symbols

($\mathcal{L}$ 42–47) Tables 8.2 on the next page to 8.11 on page 227 review the mathematical symbols available in standard LaTeX. You can put a slash through a LaTeX symbol by ($\mathcal{L}$ 44) preceding it with the `\not` command, for instance.

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

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

Tables 8.12 on page 227 to 8.19 on page 229 show the extra math symbols of the AMS-Fonts, which are automatically available when you specify the amssymb package.[2] However, if you want to define only some of them (perhaps because your TeX installation has insufficient memory to define all the symbol names), you can use the amsfonts package and the `\DeclareMathSymbol` command, which is explained in section 7.7.6.

[1] The AMS distribution also contains a file `diff12.tex` which describes differences between version 1.1 and 1.2 of AMS-LaTeX. Note in particular that in versions 1.0 and 1.1 of AMS-LaTeX, which predated LaTeX 2_ε, the amsmath package was named "amstex" and included some of the font-related features that are now separated in the amssymb and amsfonts packages.

[2] Note that the Companion uses Lucida math fonts which contain the standard LaTeX and AMS symbols but with different shapes compared to the Computer Modern math fonts.

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

Table 8.1: Math mode accents (available in LaTeX)

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

Table 8.2: Greek letters (available in LaTeX)

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

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

Table 8.3: Binary operation symbols (available in LaTeX)

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

Table 8.4: Relation symbols (available in LaTeX)

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

Table 8.5: Arrow symbols (available in LaTeX)

$\ldots$	`\ldots`	$\cdots$	`\cdots`	$\vdots$	`\vdots`	$\ddots$	`\ddots`	$\aleph$	`\aleph`
$\prime$	`\prime`	$\forall$	`\forall`	∞	`\infty`	$\hbar$	`\hbar`	$\emptyset$	`\emptyset`
$\exists$	`\exists`	∇	`\nabla`	$\surd$	`\surd`	$\Box$	`\Box`[a]	$\triangle$	`\triangle`
$\Diamond$	`\Diamond`[a]	$\imath$	`\imath`	$\jmath$	`\jmath`	ℓ	`\ell`	$\neg$	`\neg`
$\top$	`\top`	$\flat$	`\flat`	$\natural$	`\natural`	$\sharp$	`\sharp`	$\wp$	`\wp`
$\bot$	`\bot`	$\clubsuit$	`\clubsuit`	$\diamondsuit$	`\diamondsuit`	$\heartsuit$	`\heartsuit`	$\spadesuit$	`\spadesuit`
$\mho$	`\mho`[a]	$\Re$	`\Re`	$\Im$	`\Im`	$\angle$	`\angle`	∂	`\partial`

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

Table 8.6: Miscellaneous symbols (available in LaTeX)

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

Table 8.7: Variable-sized symbols (available in LaTeX)

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

Table 8.8: Log-like symbols (available in LaTeX)

$\uparrow$	`\uparrow`	$\Uparrow$	`\Uparrow`	$\downarrow$	`\downarrow`	$\Downarrow$	`\Downarrow`
$\{$	`\{`	$\}$	`\}`	$\updownarrow$	`\updownarrow`	$\Updownarrow$	`\Updownarrow`
$\lfloor$	`\lfloor`	$\rfloor$	`\rfloor`	$\lceil$	`\lceil`	$\rceil$	`\rceil`
$\langle$	`\langle`	$\rangle$	`\rangle`	$/$	`/`	$\backslash$	`\backslash`
$\vert$	`|`	$\Vert$	`\\|`				

Table 8.9: Delimiters (available in LaTeX)

$\rmoustache$	\rmoustache	$\lmoustache$	\lmoustache	$\rgroup$	\rgroup	$\lgroup$	\lgroup
$\arrowvert$	\arrowvert	$\Arrowvert$	\Arrowvert	$\bracevert$	\bracevert		

Table 8.10: Large delimiters (available in LaTeX)

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

Table 8.11: LaTeX math constructs

$\digamma$	\digamma	$\varkappa$	\varkappa	$\beth$	\beth	$\daleth$	\daleth	$\gimel$	\gimel

Table 8.12: AMS Greek and Hebrew (available with amssymb package)

$\ulcorner$	\ulcorner	$\urcorner$	\urcorner	$\llcorner$	\llcorner	$\lrcorner$	\lrcorner

Table 8.13: AMS delimiters (available with amssymb package)

$\Rrightarrow$	\Rrightarrow	$\rightsquigarrow$	\rightsquigarrow	$\leftleftarrows$	\leftleftarrows
$\leftrightarrows$	\leftrightarrows	$\Lleftarrow$	\Lleftarrow	$\twoheadleftarrow$	\twoheadleftarrow
$\leftarrowtail$	\leftarrowtail	$\looparrowleft$	\looparrowleft	$\leftrightharpoons$	\leftrightharpoons
$\curvearrowleft$	\curvearrowleft	$\circlearrowleft$	\circlearrowleft	$\Lsh$	\Lsh
$\upuparrows$	\upuparrows	$\upharpoonleft$	\upharpoonleft	$\downharpoonleft$	\downharpoonleft
$\multimap$	\multimap	$\leftrightsquigarrow$	\leftrightsquigarrow	$\rightleftarrows$	\rightleftarrows
$\rightrightarrows$	\rightrightarrows	$\twoheadrightarrow$	\twoheadrightarrow	$\rightarrowtail$	\rightarrowtail
$\looparrowright$	\looparrowright	$\rightleftharpoons$	\rightleftharpoons	$\curvearrowright$	\curvearrowright
$\circlearrowright$	\circlearrowright	$\Rsh$	\Rsh	$\downdownarrows$	\downdownarrows
$\downharpoonright$	\downharpoonright	$\upharpoonright$	\upharpoonright,\restriction		

Table 8.14: AMS arrows (available with amssymb package)

$\nleftarrow$	\nleftarrow	$\nrightarrow$	\nrightarrow	$\nLeftarrow$	\nLeftarrow
$\nRightarrow$	\nRightarrow	$\nleftrightarrow$	\nleftrightarrow	$\nLeftrightarrow$	\nLeftrightarrow

Table 8.15: AMS negated arrows (available with amssymb package)

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

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

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

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

$\dotplus$	`\dotplus`	$\smallsetminus$	`\smallsetminus`	$\Cap$	`\Cap,\doublecap`
$\Cup$	`\Cup,\doublecup`	$\barwedge$	`\barwedge`	$\veebar$	`\veebar`
$\doublebarwedge$	`\doublebarwedge`	$\boxminus$	`\boxminus`	$\boxtimes$	`\boxtimes`
$\boxdot$	`\boxdot`	$\boxplus$	`\boxplus`	$\divideontimes$	`\divideontimes`
$\ltimes$	`\ltimes`	$\rtimes$	`\rtimes`	$\leftthreetimes$	`\leftthreetimes`
$\rightthreetimes$	`\rightthreetimes`	$\curlywedge$	`\curlywedge`	$\curlyvee$	`\curlyvee`
$\circleddash$	`\circleddash`	$\circledast$	`\circledast`	$\circledcirc$	`\circledcirc`
$\centerdot$	`\centerdot`	$\intercal$	`\intercal`		

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

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

Table 8.19: AMS miscellaneous (available with amssymb package)

8.2.2 Names of Math Font Commands

The list of math font commands provided by the $\mathcal{A}\kern-.1667em\lower.5ex\hbox{$\mathcal{M}$}\kern-.125em\mathcal{S}$ packages is shown in table 8.20 on the next page, where for each case an example is shown. In addition, the math font commands of table 7.4 on page 183 can be used.

In the amsmath package, `\boldsymbol` is to be used for individual bold math symbols and bold Greek letters—everything in math except for letters (where one would use `\mathbf`). For example, to obtain a bold $\boldsymbol{\infty}$, or `\boldsymbol{\infty}`, `\boldsymbol{+}`, `\boldsymbol{\pi}`, or `\boldsymbol{0}`.

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

$$B_\infty + \pi B_1 \sim \mathbf{B}_{\boldsymbol{\infty}} \boldsymbol{+} \boldsymbol{\pi} \mathbf{B}_{\boldsymbol{1}}$$

```
\newcommand{\bpi}{\boldsymbol{\pi}}
\newcommand{\binfty}{\boldsymbol{\infty}}
\[ B_\infty + \pi B_1 \sim
   \mathbf{B}_{\binfty} \boldsymbol{+}
   \bpi \mathbf{B}_{\boldsymbol{1}}
\]
```

For those math symbols where the command `\boldsymbol` has no effect because the bold version of the symbol does not exist in the currently available fonts, there exists a command "Poor man's bold" (`\pmb`), which simulates bold

`\mathbb`	Blackboard bold alphabet, e.g., `$\mathbb{NQRZ}$` gives: $\mathbb{NQRZ}$ (not available in amsmath, need to load amssymb).
`\mathfrak`	Euler Fraktur alphabet, e.g., `$\mathfrak{E}=\mathfrak{mc}^2$` gives: $\mathfrak{E}=\mathfrak{mc}^2$ (not available in amsmath, need to load amssymb).
`\boldsymbol`	Used to obtain bold numbers and other nonalphabetic symbols, as well as bold Greek letters (defined in amsbsy).
`\pmb`	"Poor man's bold," used for math symbols when bold versions don't exist in the available fonts, e.g., `$\pmb{\oint}$` gives: $\pmb{\oint}$ and `$\pmb{\triangle}$` gives: $\pmb{\triangle}$ (defined in amsbsy).
`\text`	Produce normal text with correct text-spacing in the current font used outside math, e.g., `$E=mc^2\quad\text{(Einstein)}$` gives: $E=mc^2\quad\text{(Einstein)}$ (defined in amstext).

Table 8.20: Font commands available in mathematics with the $\mathcal{AMS}$ packages

by typesetting several copies of the symbol with slight offsets. This procedure must be used for the extension and large operator symbols from the `cmex` font, as well as the $\mathcal{AMS}$ extra math symbols from the `msam` and `msbm` fonts.

$$\frac{\partial w}{\partial u}\pmb{\Bigg\vert}\frac{\partial u}{\partial v}$$

```
\[ \frac{\partial w}{\partial u}
   \pmb{\Bigg\vert}
   \frac{\partial u}{\partial v} \]
```

With large operators and extension symbols (for example, $\sum$ and $\prod$) `\pmb` does not currently work very well because the proper spacing and treatment of limits is not preserved. Therefore, the TeX operator `\mathop` needs to be used (see table 7.13 on page 213).

$$\sum_{j<P}\prod_\lambda \lambda R(r_i) \qquad \mathop{\pmb{\sum}}_{x_j}\mathop{\pmb{\prod}}_\lambda \lambda R(x_j)$$

```
\[ \sum_{j<P}
   \prod_\lambda \lambda R(r_i) \qquad
   \mathop{\pmb{\sum}}_{x_j}
   \mathop{\pmb{\prod}}_\lambda \lambda R(x_j)
\]
```

To make an entire math formula bold (or as much of it as possible, depending on the available fonts), use `\boldmath` preceding the formula.

The sequence `\mathbf{\hat{A}}` produces a bold accent character over the **A**. However, combinations like `\mathcal{\hat{A}}` will not work in ordinary LaTeX because the `\mathcal` font does not have its own accents. In the amsmath package the font change commands are defined in such a way that accent characters will be taken from the `\mathrm` font if they are not available in the current font (in addition to the `\mathcal` font, the `\mathbb` and `\mathfrak` fonts don't contain accents).

8.3 Compound Symbols, Delimiters, Operators

This section[3] presents the math commands that are available through the amsmath package, which supplements LaTeX in the area of compound symbols, large delimiters, etc. In the examples, amsmath's alignment environments are used. In principle a detailed understanding of how they work is not necessary at this stage, but an interested reader can turn to section 8.5 for more information.

8.3.1 Multiple Integral Signs

`\iint`, `\iiint`, and `\iiiint` give multiple integral signs, with the spacing between them nicely adjusted, in both text and display style. `\idotsint` gives two integral signs with dots between them.

$$\iint\limits_V \mu(u,v)\,du\,dv \tag{8.1}$$
$$\iiint\limits_V \mu(u,v,w)\,du\,dv\,dw \tag{8.2}$$
$$\iiiint\limits_V \mu(t,u,v,w)\,dt\,du\,dv\,dw \tag{8.3}$$
$$\idotsint\limits_V \mu(u_1,\dots,u_k) \tag{8.4}$$

```
\begin{gather}
\iint\limits_V \mu(u,v)\,du\,dv                \\
\iiint\limits_V \mu(u,v,w)\,du\,dv\,dw         \\
\iiiint\limits_V \mu(t,u,v,w)\,dt\,du\,dv\,dw\\
\idotsint\limits_V \mu(u_1,\dots,u_k)
\end{gather}
```

8.3.2 Over and Under Arrows

Some extra over and under arrow operations are available. (In standard LaTeX one has `\overrightarrow` and `\overleftarrow`.)

$$\begin{aligned}
\overrightarrow{\psi_\delta(t) E_t h} &= \underrightarrow{\psi_\delta(t) E_t h}\\
\overleftarrow{\psi_\delta(t) E_t h} &= \underleftarrow{\psi_\delta(t) E_t h}\\
\overleftrightarrow{\psi_\delta(t) E_t h} &= \underleftrightarrow{\psi_\delta(t) E_t h}
\end{aligned}$$

```
\begin{align*}
 \overrightarrow{\psi_\delta(t) E_t h}      &
=\underrightarrow{\psi_\delta(t) E_t h}     \\
 \overleftarrow{\psi_\delta(t) E_t h}       &
=\underleftarrow{\psi_\delta(t) E_t h}      \\
 \overleftrightarrow{\psi_\delta(t) E_t h}  &
=\underleftrightarrow{\psi_\delta(t) E_t h}
\end{align*}
```

These arrows all scale properly in subscript sizes, as seen in the following integral $\int_{\overrightarrow{uv}} vt\,dt$, which was coded as `$ \int_{\overrightarrow{uv}} vt\,dt $`.

[3] Some material in this and the following sections is reprinted from the electronic document `testmath.tex` (distributed with AMS-LaTeX) with permission of the American Mathematical Society.

8.3.3 Dots

Ellipsis dots should almost always be typed as `\dots`. Positioning (on the baseline or centered) is automatically selected according to whatever follows the `\dots`. If the next character is a plus sign, the dots will be centered; if it's a comma, they will be on the baseline. These default dot placements provided by the amsmath package can be changed if different conventions are wanted.

If the dots fall at the end of a math formula, the next character will be something like `\end` or `\)` or `$`, which does not give any information about how to place the dots. If that is the case, you must help by using `\dotsc` for "dots with commas," or `\dotsb` for "dots with binary operators/relations," or `\dotsm` for "multiplication dots," or `\dotsi` for "dots with integrals." In the example below, low dots are produced in the first instance and centered dots in the others, with the spacing on either side of the dots nicely adjusted.

A series $H_1, H_2, \dotsc$, a regional sum $H_1+H_2+\dotsb$, an orthogonal product $H_1H_2\dotsm$, and an infinite integral

$$\int_{H_1}\int_{H_2}\dotsi$$

.

```
A series $H_1,H_2,\dotsc$,
a regional sum $H_1+H_2+\dotsb$, an
orthogonal product $H_1H_2\dotsm$, and
an infinite integral
\[\int_{H_1}\int_{H_2}\dotsi\].
```

8.3.4 Accents in Math

The following accent commands automatically position double accents correctly:

$$\acute{\acute{A}} \qquad \bar{\bar{B}} \qquad \breve{\breve{C}} \qquad \check{\check{D}}$$
$$\ddot{\ddot{E}} \qquad \dot{\dot{F}} \qquad \grave{\grave{G}} \qquad \hat{\hat{H}}$$
$$\tilde{\tilde{I}} \qquad \vec{\vec{J}}$$

```
\begin{gather*}
\Acute{\Acute{A}} \qquad\Bar{\Bar{B}} \qquad
\Breve{\Breve{C}} \qquad\Check{\Check{D}}   \\
\Ddot{\Ddot{E}}   \qquad\Dot{\Dot{F}} \qquad
\Grave{\Grave{G}} \qquad\Hat{\Hat{H}}       \\
\Tilde{\Tilde{I}} \qquad\Vec{\Vec{J}}
\end{gather*}
```

This double accent operation is complicated and tends to slow down the processing of a LaTeX file. If the document contains many double accents, you can load the amsxtra package. It defines the `\accentedsymbol` command, which you can use in the preamble of your document to help speed things up. It stores the result of the double accent command in a box register for quick retrieval. `\accentedsymbol` is used like `\newcommand`:

This is a double hat $\hat{\hat{A}}$ and this $\dot{\bar{\delta}}$ a delta with a bar and a dot.

```
\accentedsymbol{\Ahathat}{\Hat{\Hat A}}
\accentedsymbol{\dbardot}{\Dot{\Bar \delta}}
This is a double hat \(\Ahathat\) and this
\(\dbardot\) a delta with a bar and a dot.
```

8.3.5 Superscripted Accents

Some accents have a wide form: typing `$\widehat {xy},\widetilde{xy}$` produces $\widehat{xy}, \widetilde{xy}$. Because these wide accents have a certain maximum size, the amsxtra package introduces a different notation to handle extremely long expressions: $(AmBD)\sphat$ instead of $\widehat{AmBD}$. amsxtra has the following control sequences to achieve this easily:

$$
\begin{gather}
(AmBD)\sphat \qquad (AmBD)\spcheck \tag{8.5}\\
(AmBD)\sptilde \qquad (AmBD)\spdot \tag{8.6}\\
(AmBD)\spddot \qquad (AmBD)\spdddot \tag{8.7}\\
(AmBD)\spbreve \tag{8.8}
\end{gather}
$$

```
\begin{gather}
(AmBD)\sphat   \qquad (AmBD)\spcheck \\
(AmBD)\sptilde \qquad (AmBD)\spdot   \\
(AmBD)\spddot  \qquad(AmBD)\spdddot  \\
(AmBD)\spbreve
\end{gather}
```

8.3.6 Dot Accents

`\dddot` and `\ddddot` are available to produce tripled and quadrupled dot accents in addition to the `\dot` and `\ddot` accents already available in LaTeX:

$\dddot{Q} \qquad \ddddot{R}$

```
$   \dddot{Q}  \qquad  \ddddot{R}  $
```

8.3.7 Roots

In ordinary LaTeX the placement of root indices is sometimes not good. With amsmath the commands `\leftroot` and `\uproot` allow the adjustment of the position of the root. Positive arguments to these commands will move the root index to the left and up respectively, while a negative argument will move them right and down. The units of increment are quite small, which is useful for such adjustments. In the example below, the root index β is moved 2 units to the left and 4 units up.

$$\sqrt[\beta]{k} \qquad \sqrt[\leftroot{2}\uproot{4}\beta]{k}$$

```
\[ \sqrt[\beta]{k} \qquad
   \sqrt[\leftroot{2}\uproot{4}\beta]{k} \]
```

8.3.8 Boxed Formulae

The command `\boxed` puts a box around its argument, similar to `\fbox`, except that the contents are in math mode:

$$\boxed{W_t - F \subseteq V(P_i) \subseteq W_t}$$

```
\[ \boxed{W_t - F \subseteq
          V(P_i)  \subseteq W_t} \]
```

8.3.9 Extensible Arrows

`\xleftarrow` and `\xrightarrow` produce arrows that extend automatically to accommodate unusually wide subscripts or superscripts. The text of the subscript or superscript are given as an optional and mandatory argument, respectively:

$$0 \xleftarrow[\zeta]{\alpha} F\times\triangle[n-1] \xrightarrow{\partial_0\alpha(b)} E^{\partial_0b}$$

```
\[0 \xleftarrow[\zeta]{\alpha}
    F\times\triangle[n-1]
    \xrightarrow{\partial_0\alpha(b)}
    E^{\partial_0b}
\]
```

8.3.10 `\overset`, `\underset`, and `\sideset`

LaTeX provides `\stackrel` for placing a superscript above a binary relation. amsmath introduces somewhat more general commands, `\overset` and `\underset`. These can be used to place one symbol above or below another symbol, independently of whether it is a relation or something else. The input `\overset{*}{X}` will place a superscript-size $*$ above the X; `\underset` performs the parallel operation that one would expect.

$$\overset{*}{X} \qquad \underset{*}{X} \qquad \overset{a}{\underset{b}{X}}$$

```
\[ \overset{*}{X}           \qquad
   \underset{*}{X}          \qquad
   \overset{a}{\underset{b}{X}}    \]
```

There is also a command called `\sideset` that serves a rather special purpose: it puts symbols in the subscript and superscript positions of large operator symbols such as $\sum$ and $\prod$. A prime example is the case when you want to put a prime on a sum symbol. If there are no limits above or below the sum, you could just use `\nolimits`:

$$\sum\nolimits' E_n. \tag{8.9}$$

```
\begin{equation}
   \sum\nolimits' E_n.
\end{equation}
```

But if you want not only the prime but also limits on the sum symbol, things are not so easy. Suppose you want to add a prime on the sum symbol in an expression, like

$$\sum_{n<k,\;n\ \mathrm{odd}}nE_n \tag{8.10}$$

```
\begin{equation}
   \sum_{n<k,\;n\ \mathrm{odd}}nE_n
\end{equation}
```

then you can use `\sideset` like this: `\sideset{}{'}\sum_{...}nE_n`. The extra pair of empty braces is explained by the fact that `\sideset` has the capability of putting an extra symbol or symbols at each corner of a large operator.

$$\sideset{_1^2}{_3^4}\prod_k \qquad \sideset{}{'}\sum_{0\le i\le m} E_i\beta x$$

```
\[
  \sideset{_1^2}{_3^4}\prod_k          \qquad
  \sideset{}{'}\sum_{0\le i\le m} E_i\beta x
\]
```

8.3.11 The `\smash` Command

The plain TEX command `\smash` retains the contents of a box but annihilates its height and depth. The amsmath package introduces the optional arguments `t` and `b` with the `\smash` command. `\smash[t]{...}` annihilates only the top of the box contents, retaining the bottom part, while `\smash[b]{...}` annihilates the bottom part and keeps the top.

$$X_j=(1/\sqrt{\smash[b]{\lambda_j}})X_j' \qquad X_j=(1/\sqrt{\lambda_j})X_j'$$

```
\[ X_j=(1/\sqrt{\smash[b]{\lambda_j}})X_j'
 \qquad
  X_j=(1/\sqrt{\lambda_j})X_j'             \]
```

The previous example shows how the `\smash` command was used to limit the depth of the radical, which otherwise extends to encompass the depth of the subscript (right-hand formula in the baove example).

8.3.12 The `\text` Command

The main use of the `\text` command, which is also available separately with the amstext package, is for words or phrases in a display. It is similar to the LATEX command `\mbox` in its effects, but has a couple of advantages. If you would like a word or phrase of text in a subscript, you can type

```
..._{\text{word or phrase}}
```

which, apart from having a more descriptive name, is also slightly easier to enter than the equivalent `\mbox`, since the correct size is automatically chosen:

```
..._{\mbox{\scriptsize word or phrase}}
```

$$\mathbf{y}=\mathbf{y}' \quad \text{if and only if} \quad y'_k=\delta_k y_{\tau(k)}$$

```
\[  \mathbf{y}=\mathbf{y}'       \quad
    \text{if and only if}       \quad
    y'_k=\delta_k y_{\tau(k)}         \]
```

8.3.13 Operator Names

Math functions such as log, sin, and lim are traditionally set in roman type to help avoid confusion with single math variables, set in math italic. The more common ones have predefined names: `\log`, `\sin`, `\lim`, and so forth (see table 8.8 on page 226). New ones, however, come up all the time in mathematical papers. The amsmath package provides `\DeclareMathOperator` and `\DeclareMathOperator*` for producing new function names that will have the same typographical treatment. For instance, `\DeclareMathOperator{\xxx}{xxx}` produces xxx in the proper font and automatically adds proper spacing on either side when necessary, so that you get $A \operatorname{xxx} B$ instead of $AxxxB$. Examples of definitions of operator names are shown below (the `\,` in the definition of `\esssup` adds some space; see table 8.21 on page 252):

Input text

```
\DeclareMathOperator*{\esssup}{ess\,sup}
\DeclareMathOperator{\meas}{meas}
\newcommand{\abs}[1]{\lvert#1\rvert}
\newcommand{\norm}[1]{\lVert#1\rVert}
\begin{align*}
\norm{f}_\infty                                          & =
\esssup_{x\in R^n}\abs{f(x)}                                \\
\meas_1\{u\in R_+^1\colon f^*(u)>\alpha\}                & =
\meas_n\{x\in R^n\colon\abs{f(x)}\geq\alpha\}\qquad\forall\alpha>0.
\end{align*}
```

$$
\begin{aligned}
\|f\|_\infty &= \operatorname*{ess\,sup}_{x\in R^n}|f(x)| \\
\operatorname{meas}_1\{u\in R_+^1\colon f^*(u)>\alpha\} &= \operatorname{meas}_n\{x\in R^n\colon |f(x)|\geq\alpha\}\qquad\forall\alpha>0.
\end{aligned}
$$

Output text

The starred form `\DeclareMathOperator*` is like `\DeclareMathOperator`; the only difference is the placement of subscripts and superscripts, as seen in the example above. In order to make the use of the vertical bar notation more flexible, amsmath defines the new commands `\lvert`, `\rvert`, `\lVert`, and `\rVert`, which are comparable to LaTeX's `\langle` and `\rangle`.

With amsmath the following operators are predefined: `\varlimsup`, `\varliminf`, `\varinjlim`, and `\varprojlim`. Here's what they look like in use:

$$\varlimsup_{n\rightarrow\infty}\mathcal{Q}(u_n,u_n-u^{\#}) \le 0 \quad (8.11)$$
$$\varliminf_{n\rightarrow\infty}\left|a_{n+1}\right|/\left|a_n\right| = 0 \quad (8.12)$$
$$\varinjlim (m_i^\lambda\cdot)^* \le 0 \quad (8.13)$$
$$\varprojlim_{p\in S(A)}A_p \le 0 \quad (8.14)$$

```
\begin{gather}
\varlimsup_{n\rightarrow\infty}
  \mathcal{Q}(u_n,u_n-u^{\#}) \le 0           \\
\varliminf_{n\rightarrow\infty}
 \left|a_{n+1}\right|/\left|a_n\right| = 0    \\
\varinjlim (m_i^\lambda\cdot)^* \le 0         \\
\varprojlim_{p\in S(A)}A_p \le 0
\end{gather}
```

8.3.14 `\mod` and Its Relatives

Commands `\mod`, `\bmod`, `\pmod`, and `\pod` are provided by the `amsopn` package to deal with the rather special spacing conventions of "mod" notation. `\bmod` and `\pmod` are available in LaTeX, but with `amsopn` the spacing of `\pmod` will adjust to a smaller value if it is used in a nondisplay formula. `\mod` and `\pod` are variants of `\pmod` preferred by some authors; `\mod` omits the parentheses, whereas `\pod` omits the "mod" and retains the parentheses.

$$\gcd(k, l \bmod k) \quad (8.15)$$

$$u \equiv v + 1 \pmod{n^2} \quad (8.16)$$
$$u \equiv v + 1 \mod{n^2} \quad (8.17)$$
$$u \equiv v + 1 \pod{n^2} \quad (8.18)$$

```
\begin{equation}
 \gcd (k , l \bmod k)
\end{equation}
\begin{align}
  u & \equiv v + 1 \pmod{n^2}  \\
  u & \equiv v + 1 \mod{n^2}   \\
  u & \equiv v + 1 \pod{n^2}
\end{align}
```

8.3.15 Fractions and Related Constructions

In addition to `\frac` (available in LaTeX), `amsmath` provides `\dfrac` and `\tfrac` as convenient abbreviations for `{\displaystyle\frac ... }` and `{\textstyle\frac ... }`.

$$\frac{1}{k}\log_2 c(f)\quad \tfrac{1}{k}\log_2 c(f)$$

and $\sqrt{\frac{1}{k}\log_2 c(f)}\quad \sqrt{\dfrac{1}{k}\log_2 c(f)}$.

```
\[ \frac{1}{k}\log_2 c(f)\quad
   \tfrac{1}{k}\log_2 c(f)      \]
and
$  \sqrt{\frac{1}{k}\log_2 c(f)}\quad
   \sqrt{\dfrac{1}{k}\log_2 c(f)}    $.
```

For binomial expressions such as $\binom{n}{k}$ the `amsmath` packages defines the commands `\binom`, `\dbinom`, and `\tbinom`.

$$\binom{k}{1}2^{k-1}+\tbinom{k}{2}2^{k-2} \tag{8.19}$$

and $\binom{k}{1}2^{k-1}+\dbinom{k}{2}2^{k-2}$.

```
\begin{equation}
\binom{k}{1}2^{k-1}+\tbinom{k}{2}2^{k-2}
\end{equation}
and
$\binom{k}{1}2^{k-1}+\dbinom{k}{2}2^{k-2}$.
```

`\binom`, and its variants `\dbinom` and `\tbinom`, as well as `\frac` and its variants `\dfrac` and `\tfrac` are implemented using the generalized fraction command `\genfrac`, which has six parameters.

`\genfrac{`*ldelim*`}{`*rdelim*`}{`*thick*`}{`*style*`}{`*num*`}{`*denom*`}`

The first two parameters *ldelim* and *rdelim* are the left and right delimiters, respectively. The third parameter *thick* allows you to override the line thickness (for instance `\binom` uses this to set the line thickness to zero, i.e., invisible). If this argument is left empty, the line thickness defaults to "normal". The fourth parameter is the mathematics style override. It can take integer values in the range 0–3 to select, respectively, `\displaystyle`, `\textstyle`, `\scriptstyle`, and `\scriptscriptstyle`. Finally, the fifth argument *num* is the numerator, while the sixth *denom* is the denominator of the fraction.

To illustrate, here is how `\frac`, `\tfrac`, and `\binom` might be defined.

```
\newcommand{\frac}[2]{\genfrac{}{}{}{}{#1}{#2}}
\newcommand{\tfrac}[2]{\genfrac{}{}{}{1}{#1}{#2}}
\newcommand{\binom}[2]{\genfrac{(}{)}{0pt}{}{#1}{#2}}
```

Other examples are the following re-implementation of TEX's fraction primitives.

$$\frac{n+1}{n} \qquad \left\langle\frac{n+1}{n}\right\rangle$$

$$\genfrac{}{}{0pt}{}{n+2}{n} \qquad \binom{n+2}{n}$$

$$\genfrac{}{}{1pt}{}{n-3}{n} \qquad \genfrac{[}{]}{1pt}{}{n-3}{n}$$

```
\renewcommand{\over}[2]{%
  \genfrac{}{}{}{}{#1}{#2}}
\renewcommand{\overwithdelims}[2]{%
  \genfrac{\langle}{\rangle}{}{}{#1}{#2}}
\[ \over{n+1}{n}\qquad\overwithdelims{n+1}{n} \]
\renewcommand{\atop}[2]{%
  \genfrac{}{}{0pt}{}{#1}{#2}}
\renewcommand{\atopwithdelims}[2]{%
  \genfrac{(}{)}{0pt}{}{#1}{#2}}
\[ \atop{n+2}{n}\qquad\atopwithdelims{n+2}{n} \]
\renewcommand{\above}[2]{%
  \genfrac{}{}{1pt}{}{#1}{#2}}
\renewcommand{\abovewithdelims}[2]{%
  \genfrac{[}{]}{1pt}{}{#1}{#2}}
\[ \above{n-3}{n}\qquad\abovewithdelims{n-3}{n} \]
```

Of course, if you want to use a particular notation implemented with `\genfrac` repeatedly throughout your document you will do yourself (and your publisher) a favor if you define a meaningful command name with `\newcommand` as an abbreviation for that notation, as in the examples above.

8.3.16 Continued Fractions

A continued fraction can be obtained as follows:

$$\cfrac{1}{\sqrt{2}+\cfrac{1}{\sqrt{3}+\cfrac{1}{\sqrt{4}+\cfrac[l]{1}{\sqrt{5}+\cfrac[r]{1}{\sqrt{6}+\dotsb}}}}} \tag{8.20}$$

```
\begin{equation}
\cfrac{1}{\sqrt{2}+
 \cfrac{1}{\sqrt{3}+
  \cfrac{1}{\sqrt{4}+
   \cfrac[l]{1}{\sqrt{5}+
    \cfrac[r]{1}{\sqrt{6}+\dotsb
}}}}}
\end{equation}
```

Left or right positioning of any of the numerators is achieved by using the optional argument `[l]` or `[r]` with the `\cfrac` command.

8.3.17 Big-g-g-g Delimiters

In order to better control the sizes of math delimiters, basic TEX introduces four commands `\big`, `\Big`, `\bigg` and `\Bigg`, which produce ever larger versions of the delimiter specified as parameter. These commands can be used with any of the delimiters that can follow the `\left` or `\right` command (see tables 8.9, 8.10, and 8.13 on page 227). Moreover, for each of the four commands above, three variants exist for use as an opening symbol (e.g., `\bigl`), as a binary relation (e.g., `\Bigm`), or as a closing symbol (e.g., `\Biggr`).[4] Whereas, with basic TEX, the sizes of these delimiters are fixed, with the amsmath package the sizes adapt to the size of the surrounding material.

$$\biggl(\mathbf{E}_{y}\int_0^{t_\varepsilon} L_{x,y^x(s)}\varphi(x)\,ds \biggr)$$

$$\biggl(\mathbf{E}_{y}\int_0^{t_\varepsilon} L_{x,y^x(s)}\varphi(x)\,ds \biggr)$$

```
\[
   \biggl(\mathbf{E}_{y}\int_0^{t_\varepsilon}
     L_{x,y^x(s)}\varphi(x)\,ds \biggr)
\]
{\Large
\[
   \biggl(\mathbf{E}_{y}\int_0^{t_\varepsilon}
      L_{x,y^x(s)}\varphi(x)\,ds \biggr)
\]}
```

[4] See table 7.13 on page 213 for a discussion of the various math symbol types.

8.4 Matrix-Like Environments and Commutative Diagrams

8.4.1 The cases Environment

"Case" constructions can be produced using the `cases` environment.

$$P_{r-j}=\begin{cases} 0 & \text{if $r-j$ is odd},\\ r!\,(-1)^{(r-j)/2} & \text{if $r-j$ is even}. \end{cases} \tag{8.21}$$

```
\begin{equation}
P_{r-j}=
  \begin{cases}
    0&  \text{if $r-j$ is odd},\\
    r!\,(-1)^{(r-j)/2}& \text{if $r-j$ is even}.
  \end{cases}
\end{equation}
```

Notice the use of `\text` and the embedded math.

8.4.2 The Matrix Environments

The matrix environments are similar to LaTeX's `array`, except they do not have an argument specifying the format of the columns. Instead, a default format is provided: up to 10 centered columns. The examples below show how to use the matrix environments `matrix`, `pmatrix`, `bmatrix`, `vmatrix`, and `Vmatrix`:

$$\begin{matrix} 0 & 1 \\ 1 & 0\end{matrix} \quad \begin{pmatrix}0 &-i \\ i & 0\end{pmatrix}\quad \begin{bmatrix}1 & 0 \\ 0 &-1\end{bmatrix}\\ \begin{vmatrix}a & b \\ c & d\end{vmatrix}\quad \begin{Vmatrix}1 & 0 \\ 0 & 1\end{Vmatrix}$$

```
\begin{gather*}
\begin{matrix} 0 & 1 \\ 1 & 0\end{matrix} \quad
\begin{pmatrix}0 &-i \\ i & 0\end{pmatrix}\quad
\begin{bmatrix}1 & 0 \\ 0 &-1\end{bmatrix}\\
\begin{vmatrix}a & b \\ c & d\end{vmatrix}\quad
\begin{Vmatrix}1 & 0 \\ 0 & 1\end{Vmatrix}
\end{gather*}
```

The maximum number of columns is determined by the counter `MaxMatrixCols`, which you can change using LaTeX's standard counter commands. For example, suppose you have a large matrix with 19 or 20 columns, then you can do something like this:

```
\begin{equation}
\setcounter{MaxMatrixCols}{20}
A=\begin{pmatrix}
...&...&...&...&...&...&...&...&...&...&...&   ... \\
  ...  \\
  ...
\end{pmatrix}
\end{equation}
\setcounter{MaxMatrixCols}{10}
```

As counters are global in LaTeX, you might want to reset the value of `MaxMatrixCols` to its default value of 10 after finishing your wide matrix, since with a high value, LaTeX must work a lot harder to typeset a matrix.

To produce a small matrix suitable for use in text, use the `smallmatrix` environment.

To show the effect of the matrix on surrounding lines inside a paragraph, we put it here: $\left(\begin{smallmatrix} a&b\\ c&d \end{smallmatrix} \right)$ and follow it with enough text to ensure that there is at least one full line below the matrix.

```
To show the effect of the matrix on surrounding
lines inside a paragraph, we put it here:
\begin{math}
  \left( \begin{smallmatrix}
      a&b\\ c&d
    \end{smallmatrix} \right)
\end{math}
and follow it with enough text to ensure that
there is at least one full line below the matrix.
```

A row of dots in a matrix, spanning a given number of columns, can be obtained with the command:

`\hdotsfor[`*spacing-factor*`]{`*number*`}`

The spacing of the dots can be varied by using the optional parameter *spacing-factor*, for example, `\hdotsfor[1.5]{3}`. The number in square brackets multiplies the spacing between the dots; the normal value is one.

Input text

```
\[ W(\Phi)= \begin{Vmatrix}
  \dfrac\varphi{(\varphi_1,\varepsilon_1)}          &0&
   \hdotsfor{2}                                     &0        \\
  \dfrac{\varphi k_{n2}}{(\varphi_2,\varepsilon_1)} &
  \dfrac\varphi{(\varphi_2,\varepsilon_2)}          &0&\dots&0\\
  \hdotsfor{5}                                              \\
  \dfrac{\varphi k_{n1}}{(\varphi_n,\varepsilon_1)} &
   \dfrac{\varphi k_{n2}}{(\varphi_n,\varepsilon_2)}&\dots&
   \dfrac{\varphi k_{n\,n-1}}{(\varphi_n,\varepsilon_{n-1})}&
   \dfrac{\varphi}{(\varphi_n,\varepsilon_n)}
\end{Vmatrix}\]
```

$$W(\Phi)= \begin{Vmatrix} \dfrac\varphi{(\varphi_1,\varepsilon_1)} &0& \hdotsfor{2} &0 \\ \dfrac{\varphi k_{n2}}{(\varphi_2,\varepsilon_1)} & \dfrac\varphi{(\varphi_2,\varepsilon_2)} &0&\dots&0\\ \hdotsfor{5} \\ \dfrac{\varphi k_{n1}}{(\varphi_n,\varepsilon_1)} & \dfrac{\varphi k_{n2}}{(\varphi_n,\varepsilon_2)}&\dots& \dfrac{\varphi k_{n\,n-1}}{(\varphi_n,\varepsilon_{n-1})}& \dfrac{\varphi}{(\varphi_n,\varepsilon_n)} \end{Vmatrix}$$

Output text

8.4.3 The \substack command

The `\substack` command can be used to typeset several lines as a subscript or superscript, using `\\` as the row delimiter. This command can be used anywhere an ordinary subscript or superscript can be used.

$$\sum_{\substack{0\le i\le m\\ 0<j<n}} P(i,j) \tag{8.22}$$

```
\begin{equation}
  \sum
    _{\substack{0\le i\le m\\ 0<j<n}}
  P(i,j)
\end{equation}
```

Each line can be left-adjusted instead of centered by using the `subarray` environment.

$$\sum_{\begin{subarray}{l} i\in \Lambda\\ 0<j<n \end{subarray}} P(i,j) \tag{8.23}$$

```
\begin{equation}
  \sum_{\begin{subarray}{l}
          i\in \Lambda\\ 0<j<n
        \end{subarray}}
  P(i,j)
\end{equation}
```

8.4.4 Commutative Diagrams

The commutative diagram commands of $\mathcal{A}\kern-.1667em\lower.5ex\hbox{$\mathcal{M}$}\kern-.125em\mathcal{S}$-TEX are not included in the amsmath package, but are available as a separate package, amscd. This conserves memory for users who do not need commutative diagrams. The `picture` environment can be used for complex commutative diagrams, but for simple diagrams without diagonal arrows the amscd commands are more convenient.[5]

$$\begin{CD}
S^{\mathcal{W}_\Lambda}\otimes T @>j>> T \\
@VVV @VV{\operatorname{End} P}V \\
(S\otimes T)/I @= (Z\otimes T)/J
\end{CD}$$

```
\DeclareMathOperator{\End}{End}
\[\begin{CD}
S^{\mathcal{W}_\Lambda}\otimes T
                       @>j>>        T  \\
   @VVV                     @VV{\End P}V\\
(S\otimes T)/I         @=   (Z\otimes T)/J
\end{CD}\]
```

A similar result, which does not look quite as good, can be produced in ordinary LaTeX by:

$$\begin{array}{ccc}
S^{\mathcal{W}_\Lambda}\otimes T & \stackrel{j}{\longrightarrow} & T \\
\Big\downarrow & & \Big\downarrow\vcenter{\rlap{$\scriptstyle{\mathrm{End}}\,P$}} \\
(S\otimes T)/I & = & (Z\otimes T)/J
\end{array}$$

```
\[\begin{array}{ccc}
    S^{\mathcal{W}_\Lambda}\otimes T &
      \stackrel{j}{\longrightarrow}  &
    T                                         \\
    \Big\downarrow                   &   &
    \Big\downarrow\vcenter{%
      \rlap{$\scriptstyle{\mathrm{End}}\,P$}}\\
    (S\otimes T)/I                   & = &
    (Z\otimes T)/J
  \end{array}\]
```

When using the amscd package, you will obtain longer horizontal arrows and improved spacing between elements of the diagram.

In the `CD` environment the commands `@>>>`, `@<<<`, `@VVV`, and `@AAA` give (respectively) right, left, down, and up arrows. For people with keyboards lacking the angle brackets the notations `@)))` and `@(((` are available as alternatives.

For the horizontal arrows, material between the first and second `>` or `<` symbols will be typeset as a superscript, and material between the second and third will be typeset as a subscript. Similarly, material between the first and second, or second and third, `A`'s or `V`'s of vertical arrows will be typeset as left or right "sidescripts." This was used in the first example above to place the operator "End P" to the right of the arrow.

The final example again shows the use of `\DeclareMathOperator`.

[5] Much more extensive commutative diagram packages are Kristoffer Rose's XY-pic system [?], Paul Taylor's Commutative Diagram package [?], and the Diagram 3 system by Francis Borceux [?].

$$\begin{CD}
\operatorname{cov}(\mathcal{L}) @>>> \operatorname{non}(\mathcal{K}) @>>> \operatorname{cf}(\mathcal{K})\\
@VVV @AAA @AAA \\
\operatorname{add}(\mathcal{L}) @>>> \operatorname{add}(\mathcal{K}) @>>> \operatorname{cov}(\mathcal{K})
\end{CD}$$

```
\begin{equation*}
\DeclareMathOperator{\add}{add}
\DeclareMathOperator{\cf}{cf}
\DeclareMathOperator{\cov}{cov}
\DeclareMathOperator{\non}{non}
\begin{CD}
 \cov(\mathcal{L}) @>>> \non(\mathcal{K})
                   @>>> \cf(\mathcal{K})\\
 @VVV @AAA @AAA                         \\
 \add(\mathcal{L}) @>>> \add(\mathcal{K})
                   @>>> \cov(\mathcal{K})\\
\end{CD}
\end{equation*}
```

8.5 Alignment Structures for Equations

The amsmath package defines several environments for creating multiline display equations. They perform similarly to LaTeX's equation and eqnarray environments. The following structures are discussed in the next sections.

align	align*	alignment at a single place
flalign	flalign*	spaced-out variants of the above
alignat	alignat*	alignment with space control
equation	equation*	one-line formula
gather	gather*	combining formula without alignment
multline	multline*	multiline equation (one equation number)
split		splitting long formulas

Some of these multiline display environments allow you to align parts of the formula. In contrast to the original LaTeX environments eqnarray and eqnarray*, the structures implemented by the amsmath package use a different concept for marking the alignment points: while eqnarray is similar to an array environment with a {rcl} preamble and therefore uses two ampersand characters surrounding the part that should be aligned, in the amsmath structures you should mark the alignment point (or points in alignat, for example) only with a single ampersand character, placing it to the left of the character that should be aligned with previous or following lines.

The amsmath structures give correct spacing around the alignment points, while the eqnarray environment produces extra spaces depending on the parameter settings for array. The difference can be seen clearly in the next example, where we typeset the same equation using the equation, align, and eqnarray environments; ideally all three should produce the same result, but the eqnarray environment comes out too wide.

$$x^2 + y^2 = z^2 \tag{8.24}$$

$$x^2 + y^2 = z^2 \tag{8.25}$$
$$x^3 + y^3 < z^3 \tag{8.26}$$

$$x^2 + y^2 \quad = \quad z^2 \tag{8.27}$$
$$x^3 + y^3 \quad < \quad z^3 \tag{8.28}$$

```
\begin{equation}
  x^2+y^2  =  z^2
\end{equation}
\begin{align}
  x^2+y^2 &= z^2 \\   x^3+y^3 &< z^3
\end{align}
\begin{eqnarray}
  x^2+y^2 &=& z^2 \\ x^3+y^3 &<& z^3
\end{eqnarray}
```

8.5.1 Equation Groups without alignment

The `gather` environment is used for two or more equations, when no alignment desired among them. Each one is centered separately between the left and right margins.

$$(a + b)^2 = a^2 + 2ab + b^2 \tag{8.29}$$
$$(a + b) \cdot (a - b) = a^2 - b^2 \tag{8.30}$$

```
\begin{gather}
(a + b)^2 = a^2 + 2ab + b^2\\
(a + b) \cdot (a - b) = a^2 - b^2
\end{gather}
```

More examples are shown in section 8.7.3 on page 259.

8.5.2 Equation Groups with alignment

The `align` environment is used for two or more equations when vertical alignment is desired (usually binary relations such as equal signs are aligned). The term "equation" is used rather loosely here to mean any math formula that is intended by an author to be a self-contained subdivision of the larger display, usually, but not always, containing a binary relation.

$$\begin{aligned} x^2 + y^2 &= 1 & x^3 + y^3 &= 1 \qquad (8.31) \\ x &= \sqrt{1 - y^2} & x &= \sqrt[3]{1 - y^3} \\ & & & \qquad (8.32) \end{aligned}$$

```
\begin{align}
x^2  + y^2 & = 1 &
x^3  + y^3 & = 1 \\
x          & = \sqrt{1-y^2}    &
x          & = \sqrt[3]{1-y^3}
\end{align}
```

More examples are shown in section 8.7.4 on page 259.

With the `align` environment the material is spread out uniformly over the lines. If you want to control the space between equation columns then you can use an `alignat` environment. It has one required argument, for specifying the number of "align" structures. For an argument of n, the number of ampersand characters per line is $2n-1$ (one ampersand for alignment within each align structure, and ampersands to separate the align structures from one another).

The special environment `flalign` is a form of the `align` environment with added space between the component align structures.

$$L_1 = R_1 \qquad L_2 = R_2 \qquad (8.33)$$
$$L_3 = R_3 \qquad L_4 = R_4 \qquad (8.34)$$

```
\begin{align}
L_1 & = R_1 & \qquad L_2 & = R_2  \\
L_3 & = R_3 & \qquad L_4 & = R_4
\end{align}
```

$$L_1 = R_1 \quad L_2 = R_2 \qquad (8.35)$$
$$L_3 = R_3 \quad L_4 = R_4 \qquad (8.36)$$

```
\begin{alignat}{2}
L_1 & = R_1 & \qquad L_2 & = R_2  \\
L_3 & = R_3 & \qquad L_4 & = R_4
\end{alignat}
```

$$L_1 = R_1 \qquad\qquad L_2 = R_2 \quad (8.37)$$
$$L_3 = R_3 \qquad\qquad L_4 = R_4 \quad (8.38)$$

```
\begin{flalign}
L_1 & = R_1 & \qquad L_2 & = R_2  \\
L_3 & = R_3 & \qquad L_4 & = R_4
\end{flalign}
```

$$L_1 = R_1 \qquad\qquad L_2 = R_2$$
$$L_3 = R_3 \qquad\qquad L_4 = R_4$$

```
\begin{flalign*}
L_1 & = R_1 & \qquad L_2 & = R_2  \\
L_3 & = R_3 & \qquad L_4 & = R_4
\end{flalign*}
```

More examples are shown in section 8.7.6 on page 261.

8.5.3 Split Equations without Alignment

The `multline` environment is a variation of the `equation` environment used for equations that do not fit on a single line. The first line of a `multline` will be at the left margin and the last line at the right margin except for an indention on both sides whose amount is equal to `\multlinegap`. The value of `\multlinegap` can be changed using LaTeX's `\setlength` and `\addtolength` commands. If `multline` contains more than two lines, any lines other than the first and last will be centered individually within the display width (unless option fleqn is in effect). It is, however, possible to force a line to the left or the right with the `\shoveleft` and `\shoveright` commands.

First line of equation
Centered Middle line
Right Middle line
Other centered Middle
Left Middle line
Last line of equation (8.39)

```
\begin{multline}
\text{First line of equation}        \\
\text{Centered Middle line}          \\
\shoveright{\text{Right Middle line}} \\
\text{Other centered Middle}         \\
\shoveleft{\text{Left Middle line}}   \\
\text{Last line of equation}
\end{multline}
```

More examples are shown in section 8.7.2 on page 258.

8.5.4 Split Equations with Alignment

Like `multline`, the `split` environment is for single equations that are too long to fit on a single line and hence must be split into multiple lines. Unlike `multline`, however, the `split` environment provides for alignment among the split lines, using an ampersand to mark alignment points, as usual. In addition (unlike the other amsmath equation structures) the `split` environment provides no numbering because it is intended to be used only inside some other displayed equation structure, such as `equation`, `align`, or `gather`. These outer environments will provide the numbering.

$$\begin{split}(a+b)^4 &= (a+b)^2 (a+b)^2 \\ &= (a^2+2ab+b^2)(a^2+2ab+b^2) \\ &= a^4+4a^3b+6a^2b^2+4ab^3+b^4\end{split} \tag{8.40}$$

```
\begin{equation}
\begin{split}
(a+b)^4 &= (a+b)^2 (a+b)^2             \\
        &= (a^2+2ab+b^2)(a^2+2ab+b^2)  \\
        &= a^4+4a^3b+6a^2b^2+4ab^3+b^4 \\
\end{split}
\end{equation}
```

When the tbtags option is specified, the equation number for the `split` environment will be put on the last (resp. first) line if the equation number is on the right (resp. left). By default, the centertags option is in effect, putting the equation number centered vertically on the height of the `split`, provided there is enough room for it.

$$\begin{split}(a+b)^3 &= (a+b)(a+b)^2 \\ &= (a+b)(a^2+2ab+b^2) \\ &= a^3+3a^2b+3ab^2+b^3\end{split} \tag{8.41}$$

```
\begin{equation}
\begin{split}
(a+b)^3 &= (a+b) (a+b)^2       \\
        &= (a+b)(a^2+2ab+b^2)  \\
        &= a^3+3a^2b+3ab^2+b^3 \\
\end{split}
\end{equation}
```

More examples are shown in section 8.7.1 on page 255.

8.5.5 Alignment Environments as Parts of Displays

In addition to the `split` environment, there are some other equation alignment environments that do not constitute an entire display. They are self-contained units that can be used inside other formulae, or set side by side. The environment names are: `aligned`, `gathered`, and `alignedat`. These environments take an optional argument to specify their vertical positioning with respect to the material on either side. The default alignment is centered (`[c]`), and its effect is seen in the following example.

$$\begin{aligned} x^2 + y^2 &= 1 \\ x &= \sqrt{1-y^2} \end{aligned} \qquad \begin{gathered} (a+b)^2 = a^2 + 2ab + b^2 \\ (a+b)\cdot(a-b) = a^2 - b^2 \end{gathered}$$

```
\begin{equation*}
\begin{aligned}
  x^2  + y^2 & = 1            \\
           x & = \sqrt{1-y^2}
\end{aligned}                              \qquad
\begin{gathered}
  (a + b)^2 = a^2 + 2ab + b^2 \\
  (a + b) \cdot (a - b) = a^2 - b^2
\end{gathered}
\end{equation*}
```

The same mathematics can now be typeset using different vertical alignments for the environments.

$$\begin{aligned}[b] x^2 + y^2 &= 1 \\ x &= \sqrt{1-y^2} \end{aligned} \qquad \begin{gathered}[t] (a+b)^2 = a^2 + 2ab + b^2 \\ (a+b)\cdot(a-b) = a^2 - b^2 \end{gathered}$$

```
\begin{equation*}
\begin{aligned}[b]
  x^2  + y^2 & = 1            \\
           x & = \sqrt{1-y^2}
\end{aligned}                              \qquad
\begin{gathered}[t]
  (a + b)^2 = a^2 + 2ab + b^2 \\
  (a + b) \cdot (a - b) = a^2 - b^2
\end{gathered}
\end{equation*}
```

8.5.6 Vertical Spacing and Page Breaks in Equation Structures

You can use the `\\[`*dimension*`]` command to get extra vertical space between lines in all the `amsmath` displayed equation environments, as is usual in LaTeX. Unlike `eqnarray`, the `amsmath` environments do not allow page breaks between lines, unless `\displaybreak` or `\allowdisplaybreaks` is used. The reason for this is that page breaks in such situations should receive individual attention from the author. `\displaybreak` must go before the `\\` where it is supposed to take effect. Like LaTeX's `\pagebreak`, `\displaybreak` takes an optional argument between zero and four denoting the desirability of the page break. `\displaybreak[0]` means "it is permissible to break here" without encouraging a break; `\displaybreak` with no optional argument is the same as `\displaybreak[4]` and forces a break.

There is also an optional argument for `\allowdisplaybreaks`. This command obeys the usual LaTeX scoping rules. The normal way of limiting its scope is to put `{\allowdisplaybreaks` at the beginning and `}` at the end of the desired range. Within the scope of an `\allowdisplaybreaks` command, the `\\*` command can be used to prohibit a page break, as usual.

8.5.7 The `\intertext` Command

The `\intertext` command is used for a short interjection of one or two lines of text in the middle of a display alignment. Its salient feature is the preservation of alignment, which would not be possible if you simply ended the display and then started it up again afterwards. `\intertext` may only appear immediately after a `\\` or `\\*` command.

$$A_1 = N_0(\lambda;\Omega') - \phi(\lambda;\Omega'), \tag{8.42}$$
$$A_2 = \phi(\lambda;\Omega')\phi(\lambda;\Omega), \tag{8.43}$$

and finally

$$A_3 = \mathcal{N}(\lambda;\omega). \tag{8.44}$$

```
\begin{align}
A_1&=N_0(\lambda;\Omega') -
               \phi(\lambda;\Omega'), \\
A_2&=\phi(\lambda;\Omega')
               \phi(\lambda;\Omega),  \\
\intertext{and finally}
A_3&=\mathcal{N}(\lambda;\omega).
\end{align}
```

Here the words "and finally" fall outside the display at the left margin.

8.6 Miscellaneous

This section discusses amsmath commands that have not been introduced yet, and it gives a list of the document class files that come with the AMS-LaTeX distribution.

8.6.1 Equation Numbers

Each environment, except for `split`, has both starred and unstarred forms, where the unstarred forms have automatic numbering, using LaTeX's `equation` counter. The number on any particular line can be suppressed by putting `\notag` before the `\\`. You can also override it with a tag of your own design using

`\tag{`*label*`}` `\tag*{`*label*`}`

where *label* can be any arbitrary text to be used to number the equation.

The starred form, `\tag*`, causes the *label* to be typeset without any annotations like parentheses that might otherwise be added by the document class. `\tag` and `\tag*` can also be used in the starred versions of all the amsmath alignment environments.

$$
\begin{gather}
x^2+y^2=z^2 \tag{8.45}\\
x^3+y^3=z^3 \notag\\
x^4+y^4=r^4 \tag{$*$}\\
x^5+y^5=r^5 \tag*{$*$}\\
x^6+y^6=r^6 \tag{8.45$'$}
\end{gather}
$$

```
\begin{gather}
  x^2+y^2 = z^2 \label{eq:r2}     \\
  x^3+y^3 = z^3 \notag            \\
  x^4+y^4 = r^4 \tag{$*$}         \\
  x^5+y^5 = r^5 \tag*{$*$}        \\
  x^6+y^6 = r^6 \tag{\ref{eq:r2}$'$}
\end{gather}
```

Notice the use of the `\label` and `\ref` commands in the previous example to allow subnumbering of equations.

When leqno is specified as an option to the amsmath package, the equation number will be printed at the left side of the equation (by default, with amsmath, it comes out at the right).

$$(8.46) \qquad \sin^2\eta + \cos^2\eta = 1$$

```
\begin{equation}
  \sin^2\eta + \cos^2\eta = 1
\end{equation}
```

8.6.2 Resetting the Equation Counter

In LaTeX, if you want to have equations numbered within sections—that is, have equation numbers (1.1), (1.2), ..., (2.1), (2.2), ..., in sections 1, 2, and so forth—you would probably redefine `\theequation`:

```
\renewcommand{\theequation}{\thesection.\arabic{equation}}
```

But now you have to reset the equation number by hand at the beginning of each new section or chapter. To make this a little more convenient, amsmath provides a command `\numberwithin`. To have equation numbering tied to section numbering, with automatic reset of the equation counter, the command is

```
\numberwithin{equation}{section}
```

As the name implies, `\numberwithin` can be applied to other counters besides the equation counter, but the results may not be satisfactory in all cases because of potential complications. Normal LaTeX methods should be used where available, for example, in `\newtheorem`.[6]

To make cross-references to equations easier, an `\eqref` command is provided. This automatically supplies the parentheses around the equation number, and adds an italic correction before the closing parenthesis, if necessary. To refer to an equation that was labeled with the label `e:baset`, the usage would be `\eqref{e:baset}`.

8.6.3 Subordinate numbering sequences

The amsmath package provides also a `subequations` environment to make it easy to number equations in a particular group with a subordinate numbering scheme. For example

```
\begin{subequations}
...
\end{subequations}
```

causes all numbered equations within that part of the document to be numbered (4.9a) (4.9b) (4.9c) . . . , if the preceding numbered equation was (4.8). A `\label` command immediately following `\begin{subequations}` produces a `\ref` of the parent number 4.9, not 4.9a. The counters used by the `subequations` environment are `parentequation` and `equation`. They can be set by the LaTeX commands `\addtocounter`, `\setcounter`, `\value`, etc.. Moreover, the style of the subordinate numbers, are controlled using standard LaTeX methods (see Section A.1.3). For example, redefining `\theequation` as follows will produce roman numerals.

```
\begin{subequations}
\renewcommand{\theequation}{\theparentequation \roman{equation}}
...
```

8.6.4 Fine-Tuning Spacing in Math Mode

Although TeX generally does a good job of spacing elements of formulae inside mathematics, it is sometimes necessary to fine-tune the position of one or two of those elements. Therefore, the spacing commands shown in table 8.21 on the next page are provided. Both the spelled-out and abbreviated forms of these commands are robust, and they can also be used outside of math.

[6] See also the discussion of the `\@addtoreset` command on page 23.

Positive space			Negative space		
Abb.	ex.	Spelled out	Abb.	ex.	Spelled out
`\,`	$x\,x$	`\thinspace`	`\!`	$x\!x$	`\negthinspace`
`\:`	$x\:x$	`\medspace`		$x\mspace{-4mu}x$	`\negmedspace`
`\;`	$x\;x$	`\thickspace`		$x\mspace{-5mu}x$	`\negthickspace`
	$x\quad x$	`\quad`			
	$x\qquad x$	`\qquad`			

Table 8.21: The mathematical spacing commands

For allow you to further fine-tune the spacing in math expressions the command `\mspace` is defined. Its only argument is a LaTeX length expressed in 'math units'. One math unit, or `mu`, is equal to 1/18 em (see also table A.1 on page 476). Thus, to get a negative `\quad` you could write `\mspace{-18.0mu}`.

8.6.5 A Few Points to Note

($\mathcal{L}$ 151–52) Many of the commands added by the amsmath package are fragile and will need to be `\protect`ed in commands with "moving arguments."

With the various alignment environments available in the amsmath package, the `eqnarray` environment is no longer needed. Furthermore, since it does not prevent overlapping of the equation numbers with wide formulae, as most of the amsmath alignments do, using the amsmath alignments seems better. amsmath reimplements the LaTeX `equation` environment as a one-line `gather` environment, and adds an unnumbered version, `equation*`, for symmetry. Note, however, that the command `\verb` might not work in the alignment environments.

`\nonumber` is interchangeable with `\notag`; the latter seems slightly preferable, for consistency with the name `\tag`.

8.6.6 Options and Sub-Packages to the amsmath Package

A few options are recognized by the amsmath package and the classes provided by $\mathcal{AMS}$-LaTeX.[7] They affect the positioning of math operator limits or `\tag`s.

centertags (default) The text of the tag of a `split` environment is vertically centered with respect to its total height.

tbtags "Top-or-bottom tags". The text of the tag of a `split` environment is placed level with the last (resp. first) line, if numbers are on the right (resp. left).

[7] This is only true for the LaTeX 2_ε release of $\mathcal{AMS}$-LaTeX. Older versions of $\mathcal{AMS}$-LaTeX realize these options as sub-packages.

intlimits Like sumlimits, but for integral symbols.

nointlimits (default) Opposite of intlimits.

namelimits (default) Like sumlimits, but for certain "operator names" such as det, inf, lim, max, min, that traditionally have subscripts placed underneath when they occur in a displayed equation.

nonamelimits Opposite of namelimits.

sumlimits (default) Place subscripts and superscripts of summation symbols above and below, in displayed equations. This option also affects other symbols of the same type—$\prod$, $\coprod$, $\bigotimes$, $\bigoplus$, and so forth—but excluding integrals (see intlimits).

nosumlimits Place subscripts and superscripts of summation-type symbols to the side, even in displayed equations.

The following three options are usually global document options and are thus set on the `\documentclass` command. They are, however, also recognized when the amsmath package is loaded with the `\usepackage` command.

leqno Place equation numbers on the left.

reqno Place equation numbers on the right (default).

fleqn Position equations at a fixed indent from the left margin rather than centered in the text column.

The $\mathcal{A}\mathcal{M}\mathcal{S}$-LaTeX distribution consists of a set of components, which can be loaded independently with the `\usepackage` command. The single most noteworthy package is probably amsmath, but the others can be used individually. Note that the amsbsy, amsopn, and amstext packages are included automatically when you use the amsmath package.

amsmath Defines extra environments for multiline displayed equations, plus a number of other enhancements for math.

amsbsy Defines the `\boldsymbol` and `\pmb` (poor man's bold) commands.

amsopn Provides `\DeclareMathOperator` for defining new "operator names" like `\sin` and `\lim`.

amstext Provides a `\text` command for typesetting a fragment of text inside a display.

Other packages, providing supplementary functionality, should be loaded explicitly. Only parts of these packages are described in the present chapter.

They are mentioned here for completeness.

amscd Defines some commands for easing the generation of commutative diagrams by introducing the `CD` environment (see Section 8.4.4). There is no support for diagonal arrows.

amsintx Provides more descriptive command syntax for integrals and sums (not released yet).

amsthm Provides a `proof` environment and extensions for the `\newtheorem` command.

amsxtra Provides certain odds and ends such as `\fracwithdelims` and `\accentedsymbol` (see Section 8.3.4).

upref Makes `\ref` print cross-reference numbers always in an upright/roman font regardless of context.

Finally, there are a few packages which come with the `AMSFonts` distribution.

amsfonts defines the `\mathfrak` and `\mathbb` commands and sets up the fonts `msam` (extra math symbols A), `msbm` (extra math symbols B, and blackboard bold), `eufm` (Euler Fraktur), extra sizes of `cmmib` (bold math italic and bold lowercase Greek), and `cmbsy` (bold math symbols and bold script), for use in mathematics.

amssymb defines the names of all the math symbols available with the $\mathcal{AMS}$ fonts collection. This package loads the amsfonts package.

eufrak Set up the Fraktur letters.

eucal Makes `\mathcal` use the Euler script instead of the usual Computer Modern script letters.

All these packages recognize the psamsfonts option, which will use the Y&Y/Blue Sky Research version of the AMSFonts collection (which is free available on CTAN).

8.6.7 $\mathcal{AMS}$-LaTeX Document Classes

The $\mathcal{AMS}$-LaTeX package comes with a pair of document classes called amsart and amsbook, corresponding to LaTeX's article and book. They are primarily designed to prepare manuscripts for submission to the AMS, but there is nothing to prohibit their use for other purposes. With these class files the amsmath package is automatically included, so that you can start your document simply with `\documentclass{amsart}` or `\documentclass{amsbook}`.

8.7 Examples of Multiple-Line Equation Structures

On the following pages we show a lot of real-life examples of the alignment environments discussed earlier. The lines indicating the margins around the typeset examples are not part of the environments but have been added to make the marginal spacing stand out clearly.

8.7.1 The split Environment

The `split` environment is not an independent environment but should be used inside something else, such as `equation` or `align`.

If there is not enough room for it, the equation number for a `split` will be shifted to the previous line when equation numbers are on the left; the number shifts down to the next line when numbers are on the right.

When you do not want an equation number, use the `equation*` environment.

$$\begin{split} f_{h,\varepsilon}(x,y) &= \varepsilon \mathbf{E}_{x,y} \int_0^{t_\varepsilon} L_{x,y_\varepsilon(\varepsilon u)} \varphi(x) \, du \\ &= h \int L_{x,z} \varphi(x) \rho_x (dz) \\ & \quad +h \biggl[\frac{1}{t_\varepsilon} \biggl(\mathbf{E}_{y} \int_0^{t_\varepsilon} L_{x,y^x(s)} \varphi(x)\,ds -t_\varepsilon \int L_{x,z} \varphi(x) \rho_x(dz) \biggr) \\ & \phantom{{=}+h\biggl[}+\frac{1}{t_\varepsilon} \biggl(\mathbf{E}_{y} \int_0^{t_\varepsilon} L_{x,y^x(s)} \varphi(x) \,ds - \mathbf{E}_{x,y} \int_0^{t_\varepsilon} L_{x,y_\varepsilon(\varepsilon s)} \varphi(x) \,ds \biggr) \biggr] \end{split} \tag{8.47}$$

This was produced by the following input (the TeX command `\phantom` is used to leave a space equal to the width of its argument):

```
\begin{equation}
\begin{split}
f_{h,\varepsilon}(x,y)
  &= \varepsilon \mathbf{E}_{x,y} \int_0^{t_\varepsilon}
     L_{x,y_\varepsilon(\varepsilon u)} \varphi(x) \, du      \\
  &= h \int L_{x,z} \varphi(x) \rho_x (dz)                   \\
  & \quad +h \biggl[ \frac{1}{t_\varepsilon} \biggl(
    \mathbf{E}_{y} \int_0^{t_\varepsilon} L_{x,y^x(s)} \varphi(x)\,ds
    -t_\varepsilon \int L_{x,z} \varphi(x) \rho_x(dz) \biggr) \\
  & \phantom{{=}+h\biggl[}+\frac{1}{t_\varepsilon}
    \biggl( \mathbf{E}_{y} \int_0^{t_\varepsilon} L_{x,y^x(s)}
      \varphi(x) \,ds - \mathbf{E}_{x,y} \int_0^{t_\varepsilon}
      L_{x,y_\varepsilon(\varepsilon s)}
      \varphi(x) \,ds \biggr) \biggr]                        \\
```

```
\end{split}
\end{equation}
```

If the option centertags is included in the options list of the amsmath package, the equation numbers for `split` environments will be centered vertically on the height of the `split`, as shown in the example below.

$$\begin{split}
|I_2| &= \left| \int_{0}^T \psi(t) \left\{ u(a,t)-\int_{\gamma(t)}^a \frac{d\theta}{k(\theta,t)} \int_{a}^\theta c(\xi)u_t(\xi,t)\,d\xi \right\} dt \right| \\
&\le C_6 \left| \left| f\int_\Omega \left| \widetilde{S}^{-1,0}_{a,-} W_2(\Omega,\Gamma_l) \right| \right| \left| |u|\overset{\circ}\to W_2^{\widetilde{A}}(\Omega;\Gamma_r,T) \right| \right|.
\end{split} \tag{8.48}$$

This is produced by the following input:

```
\begin{equation}
\begin{split}
|I_2|
 &=\left| \int_{0}^T \psi(t)
     \left\{ u(a,t)-\int_{\gamma(t)}^a \frac{d\theta}{k(\theta,t)}
           \int_{a}^\theta c(\xi)u_t(\xi,t)\,d\xi \right\} dt
   \right| \\
 &\le C_6 \left| \left|
            f\int_\Omega
              \left| \widetilde{S}^{-1,0}_{a,-} W_2(\Omega,\Gamma_l)
               \right|
            \right|
            \left|
              |u|\overset{\circ}\to W_2^{\widetilde{A}}
              (\Omega;\Gamma_r,T)
          \right| \right|.
\end{split}
\end{equation}
```

One further example involving `split` and `align`. To obtain unnumbered equations use the `align*` environment instead.

$$
\begin{aligned}
|I_1| &= \left| \int_\Omega gRu \,d\Omega \right| \\
&\le C_3 \left[\int_\Omega \left(\int_{a}^x g(\xi,t) \,d \xi \right)^2 d \Omega \right]^{1/2} \\
&\quad\times \left[\int_\Omega \left\{ u^2_x + \frac{1}{k} \left(\int_{a}^x cu_t \, d\xi \right)^2 \right\} c \Omega \right]^{1/2} \\
&\le C_4 \left| \left| f \left| \widetilde{S}^{-1,0}_{a,-} W_2(\Omega,\Gamma_l) \right| \right| \left| |u| \overset{\circ}{\to} W_2^{\widetilde{A}}(\Omega;\Gamma_r,T) \right| \right| .
\end{aligned}
\tag{8.49}
$$

$$
\begin{aligned}
|I_2| &= \left| \int_{0}^T \psi(t) \left\{ u(a,t) -\int_{\gamma(t)}^a \frac{d\theta}{k(\theta,t)} \int_{a}^\theta c(\xi) u_t(\xi,t) \,d \xi \right\} dt \right| \\
&\le C_6 \left| \left| f \int_\Omega \left| \widetilde{S}^{-1,0}_{a,-} W_2(\Omega,\Gamma_l) \right| \right| \left| |u| \overset{\circ}{\to} W_2^{\widetilde{A}}(\Omega;\Gamma_r,T) \right| \right| .
\end{aligned}
\tag{8.50}
$$

The input for the above formulae is:

```
\begin{align}
\begin{split}
|I_1| &= \left| \int_\Omega gRu \,d\Omega \right|                  \\
      &\le C_3 \left[ \int_\Omega \left( \int_{a}^x
         g(\xi,t) \,d \xi \right)^2d \Omega \right]^{1/2}           \\
      &\quad\times \left[ \int_\Omega \left\{ u^2_x + \frac{1}{k}
        \left( \int_{a}^x cu_t \, d\xi \right)^2 \right\}
        c \Omega \right]^{1/2}                                      \\
      &\le C_4 \left| \left| f \left| \widetilde{S}^{-1,0}_{a,-}
        W_2(\Omega,\Gamma_l) \right| \right|
        \left| |u| \overset{\circ} \to W_2^{\widetilde{A}}
         (\Omega;\Gamma_r,T) \right| \right|.
\end{split}\label{eq:A}                              \\
\begin{split}
|I_2| &= \left| \int_{0}^T \psi(t) \left\{ u(a,t)
          -\int_{\gamma(t)}^a \frac{d\theta}{k(\theta,t)}
          \int_{a}^\theta c(\xi) u_t(\xi,t) \,d \xi \right\} dt
         \right|                                                    \\
      &\le C_6 \left| \left| f \int_\Omega
          \left| \widetilde{S}^{-1,0}_{a,-}
             W_2(\Omega,\Gamma_l)  \right| \right|
          \left| |u| \overset{\circ} \to W_2^{\widetilde{A}}
            (\Omega;\Gamma_r,T) \right| \right|.
\end{split}
\end{align}
```

8.7.2 The `multline` Environment

Numbered version:

$$\begin{multline}\int_a^b \biggl\{ \int_a^b [f(x)^2 g(y)^2 + f(y)^2 g(x)^2] -2f(x) g(x) f(y) g(y) \,dx \biggr\} \,dy \\ =\int_a^b \biggl\{ g(y)^2 \int_a^b f^2 + f(y)^2 \int_a^b g^2 - 2f(y) g(y) \int_a^b fg \biggr\} \,dy \tag{8.51}\end{multline}$$

This was obtained with the lines shown below.

```
\begin{multline}\label{eq:E}
  \int_a^b \biggl\{ \int_a^b [ f(x)^2 g(y)^2 + f(y)^2 g(x)^2 ]
   -2f(x) g(x) f(y) g(y) \,dx \biggr\} \,dy                   \\
 =\int_a^b \biggl\{ g(y)^2 \int_a^b f^2 + f(y)^2
  \int_a^b g^2 - 2f(y) g(y) \int_a^b fg \biggr\} \,dy
\end{multline}
```

An unnumbered version of the above is obtained with the same input, except the `multline` environment is replaced by `multline*`.

$$\begin{multline*}\int_a^b \biggl\{ \int_a^b [f(x)^2 g(y)^2 + f(y)^2 g(x)^2] -2f(x) g(x) f(y) g(y) \,dx \biggr\} \,dy \\ =\int_a^b \biggl\{ g(y)^2 \int_a^b f^2 + f(y)^2 \int_a^b g^2 - 2f(y) g(y) \int_a^b fg \biggr\} \,dy\end{multline*}$$

And now an unnumbered version numbered with a `\tag*` command.

$$\begin{multline*}\int_a^b \biggl\{ \int_a^b [f(x)^2 g(y)^2 + f(y)^2 g(x)^2] -2f(x) g(x) f(y) g(y) \,dx \biggr\} \,dy \\ =\int_a^b \biggl\{ g(y)^2 \int_a^b f^2 + f(y)^2 \int_a^b g^2 - 2f(y) g(y) \int_a^b fg \biggr\} \,dy \tag*{[a]}\end{multline*}$$

This was generated with:

```
\begin{multline*}\tag*{[a]}   ...   \end{multline*}
```

This is the same display, but with `\multlinegap` set to zero. Notice that the space on the left of the first line does not change, because of the equation number, while the second line is pushed over to the right margin.

$$\begin{multline*}\int_a^b \biggl\{ \int_a^b [f(x)^2 g(y)^2 + f(y)^2 g(x)^2] -2f(x) g(x) f(y) g(y) \,dx \biggr\} \,dy \\ =\int_a^b \biggl\{ g(y)^2 \int_a^b f^2 + f(y)^2 \int_a^b g^2 - 2f(y) g(y) \int_a^b fg \biggr\} \,dy \tag*{[a]}\end{multline*}$$

This was generated with:

```
{\setlength{\multlinegap}{0pt}
\begin{multline*}\tag*{[a]}  ...  \end{multline*}}
```

8.7.3 The gather Environment

Numbered version with `\notag` on the second line:

$$
\begin{gather}
D(a,r) \equiv \{ z \in \mathbf{C}\colon |z-a|<r \}, \tag{8.52}\\
\operatorname{seg}(a,r) \equiv \{ z \in \mathbf{C}\colon \Im z = \Im a,\ |z-a|<r\}, \notag \\
c(e,\theta,r) \equiv \{ (x,y) \in \mathbf{C}\colon |x-e|<y \tan \theta,\ 0<y<r \}, \tag{8.53}\\
C(E,\theta,r) \equiv \bigcup_{e \in E}c(e,\theta,r). \tag{8.54}
\end{gather}
$$

This was generated with:

```
\begin{gather}
  D(a,r) \equiv \{ z \in \mathbf{C}: |z-a|<r \},        \\
  \operatorname{seg}(a,r) \equiv \{ z \in \mathbf{C}:
      \Im z = \Im a, \ |z-a|<r\},                 \notag \\
  c(e,\theta,r) \equiv \{ (x,y) \in \mathbf{C}:
      |x-e|<y \tan \theta, \  0<y<r \},                  \\
  C(E,\theta,r) \equiv \bigcup_{e \in E}c(e,\theta,r).
\end{gather}
```

8.7.4 The align Environment

Numbered version:

$$
\begin{align}
\gamma_x(t) &= (\cos tu + \sin tx, v), \tag{8.55}\\
\gamma_y(t) &= (u, \cos tv + \sin ty), \tag{8.56}\\
\gamma_z(t) &= \left(\cos tu + \frac\alpha\beta \sin tv, - \frac\beta\alpha \sin tu + \cos tv \right). \tag{8.57}
\end{align}
$$

This was produced using the following input:

```
\begin{align}
  \gamma_x(t) &= (\cos tu + \sin tx, v),                    \\
  \gamma_y(t) &= (u, \cos tv + \sin ty),                    \\
  \gamma_z(t) &= \left( \cos tu + \frac\alpha\beta \sin tv,
                 - \frac\beta\alpha \sin tu + \cos tv \right).
\end{align}
```

Unnumbered version:

$$\begin{aligned}
\gamma_x(t) &= (\cos tu + \sin tx, v),\\
\gamma_y(t) &= (u, \cos tv + \sin ty),\\
\gamma_z(t) &= \left(\cos tu + \frac{\alpha}{\beta}\sin tv, -\frac{\beta}{\alpha}\sin tu + \cos tv\right).
\end{aligned}$$

This was generated using the following construct:

```
\begin{align*}  ...  \end{align*}
```

8.7.5 Using the align and split Environments within gather

When using the `align` environment within the `gather` environment, one or the other, or both, should be unnumbered (using the `*` form), since having numbering for both the outer and inner environment would not be meaningful.

Automatically numbered `gather` with `split` and `align*`:

$$\begin{split}
\varphi(x,z) &= z - \gamma_{10} x - \sum_{m+n\ge2} \gamma_{mn} x^m z^n\\
&= z - M r^{-1} x - \sum_{m+n\ge2} M r^{-(m+n)} x^m z^n
\end{split} \tag{8.58}$$

$$\begin{aligned}
\zeta^0 &= (\xi^0)^2,\\
\zeta^1 &= \xi^0 \xi^1
\end{aligned}$$

Here the `split` environment gets a number from the outer `gather` environment; numbers for individual lines of the `align*` are suppressed because of the star.

```
\begin{gather}
  \begin{split}
    \varphi(x,z)
      &= z - \gamma_{10} x - \sum_{m+n\ge2} \gamma_{mn} x^m z^n \\
      &= z - M r^{-1} x - \sum_{m+n\ge2} M r^{-(m+n)} x^m z^n
  \end{split}                                                 \\[6pt]
  \begin{align*}
    \zeta^0   &= (\xi^0)^2,     \\
    \zeta^1   &= \xi^0 \xi^1
  \end{align*}
\end{gather}
```

Shown below, is the `*`-ed form of `gather` with the non-`*`-ed form of `align`.

$$\begin{split}\varphi(x,z) &= z - \gamma_{10}x - \sum_{m+n\ge 2}\gamma_{mn}x^m z^n\\ &= z - Mr^{-1}x - \sum_{m+n\ge 2}Mr^{-(m+n)}x^m z^n\end{split}$$

$$\zeta^0 = (\xi^0)^2, \tag{8.59}$$
$$\zeta^1 = \xi^0\xi^1 \tag{8.60}$$

The latter was produced with the following construct:

```
\begin{gather*}
     \begin{split} ...\end{split}            \\[6pt]
     \begin{align}...\end{align}
\end{gather*}
```

8.7.6 Using the `alignat` Environments

Numbered version:

$$V_i = v_i - q_i v_j, \qquad X_i = x_i - q_i x_j, \qquad U_i = u_i, \qquad \text{for } i \ne j\,; \tag{8.61}$$
$$V_j = v_j, \qquad X_j = x_j, \qquad U_j u_j + \sum_{i\ne j} q_i u_i. \tag{8.62}$$

This example was obtained with the commands below:

```
\begin{alignat}{3}
V_i &= v_i - q_i v_j,  &  \qquad X_i &= x_i - q_i x_j,
  & \qquad U_i &= u_i, \qquad \text{for $i\ne j\,$;}\label{eq:B}  \\
V_j &= v_j,            &  \qquad X_j &= x_j,
  & \qquad U_j & u_j + \sum_{i\ne j} q_i u_i.
\end{alignat}
```

Unnumbered version:

$$\begin{alignedat}{3} V_i &= v_i - q_i v_j, &\qquad X_i &= x_i - q_i x_j, &\qquad U_i &= u_i, \qquad \text{for } i \ne j\,;\\ V_j &= v_j, &\qquad X_j &= x_j, &\qquad U_j & u_j + \sum_{i\ne j} q_i u_i.\end{alignedat}$$

This was generated using the following construct:

```
\begin{alignat*}{3}  ...  \end{alignat*}
```

The most common use for `alignat` is for things like

$$
\begin{alignat}{2}
x &= y &&\qquad \text{by (8.49)} \tag{8.63}\\
x' &= y' &&\qquad \text{by (8.61)} \tag{8.64}\\
x + x' &= y + y' &&\qquad \text{by Axiom 1.} \tag{8.65}
\end{alignat}
$$

This example was obtained with the commands below:

```
\begin{alignat}{2}
 x      &= y     && \qquad \text{by (\ref{eq:A})}\label{eq:C} \\
 x'     &= y'    && \qquad \text{by (\ref{eq:B})}\label{eq:D} \\
 x + x' &= y+y'  && \qquad \text{by Axiom 1.}
\end{alignat}
```

The expanded version, `flalign`:

$$
\begin{flalign}
x &= y && \text{by (8.63)} \tag{8.66}\\
x' &= y' && \text{by (8.64)} \tag{8.67}\\
x + x' &= y + y' && \text{by Axiom 1.} \tag{8.68}
\end{flalign}
$$

This was generated using the following construct:

```
\begin{flalign}  ...  \end{flalign}
```

8.8 Extensions to the `theorem` Environment

$\mathcal{A}_{\mathcal{M}}\mathcal{S}$-LaTeX comes with the amsthm package, which extends LaTeX's `\newtheorem` command. Rather than describe amsthm (see, for instance, the section "Proclamations" in Grätzer's book [?] for more details) we will give some details about the theorem package, developed by Frank Mittelbach [?]. It
($\mathcal{L}$ 58, 174) also offers an extension of the LaTeX theorem mechanism by allowing the layout of theorems to be manipulated by specifying a style.

In the present context the word "theorem" is used for any kind of labeled enunciations, often set off from the main text by extra space and a font change. Theorems, corollaries, conjectures, definitions, and remarks are all instances of "theorems." The header of these structures is composed of a label (such as THEOREM or REMARK) and a number, which serializes an item in the sequence of items with the same label.

Often it is necessary, in order to satisfy the requirements of different mathematics journals, to customize the layout of the theorem environment. Additionally, different formats may be needed to differentiate the "sort of theorem": e.g., remarks and definitions are set in roman, while italic is employed for main theorems.

8.8.1 Defining New Theorem Environments

As in the original LaTeX version, the command `\newtheorem` defines a new "theorem-like structure." Two required arguments name the new environment and give the text to be typeset with each instance of the new environment, while an optional argument determines how the environment is enumerated:

`\newtheorem{`*env-name*`}{`*label-text*`}`

The above `\newtheorem` command defines the *env-name* environment and its printed name will be *label-text*. It uses its own counter.

`\newtheorem{`*env2-name*`}[`*env-name*`]{`*label-text2*`}`

The above `\newtheorem` command defines the *env2-name* environment, and its printed name will be *label-text2*. It uses the same counter as theorem set *env-name*.

`\newtheorem{`*env3-name*`}{`*label-text3*`}[`*section*`]`

The above variant defines the *env3-name* environment and its printed name is *label-text3*. Its counter is enumerated within the counter *section*, that is, with every new `\section` the enumeration starts again with one, and the enumeration is composed from the section number and the theorem counter itself.

`\theoremstyle{`*style*`}`

The `\theoremstyle` command can define the layout of various, or all, theorem sets. It should be noted that any theorem set defined by `\newtheorem` is typeset in the `\theoremstyle` that is current at the time of the definition.

Thus, the following

```
\theoremstyle{break}        \newtheorem{Cor}{Corollary}
\theoremstyle{plain}        \newtheorem{Exa}{Example}[section]
```

leads to the result that the set `Cor` is formatted in the style `break`, while the set `Exa` and all the following ones are formatted in the style `plain`, unless another `\theoremstyle` follows. Since the definitions installed by `\newtheorem` are global, you can also limit `\theoremstyle` locally by grouping braces.

`\theorembodyfont{`*font-declarations*`}`

The choice of the font for the theorem body is completely independent of the chosen `\theoremstyle`; this has proven to be very advantageous. For example,

```
{\theorembodyfont{\rmfamily}          \newtheorem{Rem}{Remark}}
```

`plain`	Emulates the original LaTeX definition, except that additionally the parameters `\theorempreskipamount` and `\theorempostskipamount` are used.
`break`	In this style, the theorem header is followed by a line break.
`marginbreak`	The theorem number is set in the margin, and there is a line break as in `break`.
`changebreak`	Like `break`, but with header number and text interchanged.
`change`	Header number and text are interchanged, without a line break.
`margin`	The number is set in the left margin, without a line break.

Table 8.22: List of existing theorem styles

All styles (except `plain`) select `\normalfont\slshape` as the default for `\theorembodyfont`.

defines a theorem set `Rem`, which will be set in `\rmfamily` in the current layout (which in our example is `plain`). As with `\theoremstyle`, the `\theorembodyfont` chosen is that which is current at the time of `\newtheorem`. If `\theorembodyfont` is not specified or you define `\theorembodyfont{}`, then the font used will be defined by `\theoremstyle`.

`\theoremheaderfont{`*font-declarations*`}`

It is also possible to customize the font used for the theorem headers. This is, however, a global declaration and, therefore, there should be at most one `\theoremheaderfont` command in the preamble. If it is actually necessary to have different header fonts, you will have to define new theorem styles (substituting the desired font).

Two additional parameters affect the vertical space around the theorem environments: `\theorempreskipamount` and `\theorempostskipamount` define, respectively, the spacing before and after such an environment. These parameters apply to all theorem sets and can be manipulated with the ordinary length macros. They are rubber lengths, and therefore can contain `plus` and `minus` parts. These parameters are set using the `\setlength` command.

The commands to define theorem sets, as described in this section, can only be placed in the document preamble or in a package file.

Theorem styles, which exist to date, are shown in table 8.22

8.8.2 Examples of the Definition and Use of Theorems

Suppose that the preamble contains the declarations:

```
\theoremstyle{break}        \newtheorem{Cor}{Corollary}
\theoremstyle{plain}        \newtheorem{Exa}{Example}[section]
```

```
{\theorembodyfont{\rmfamily} \newtheorem{Rem}{Remark}}
\theoremstyle{marginbreak}   \newtheorem{Lem}[Cor]{Lemma}
\theoremstyle{change}
\theorembodyfont{\itshape}   \newtheorem{Def}[Cor]{Definition}

\theoremheaderfont{\scshape}
```

Then the typical examples below show the typeset output resulting from their use.

COROLLARY 1
This is a sentence typeset in the theorem environment Cor*.*

```
\begin{Cor}
   This is a sentence typeset in the theorem
   environment \Lenv{Cor}.
\end{Cor}
```

EXAMPLE 8.8.1 *This is a sentence typeset in the theorem environment* Exa*.*

```
\begin{Exa}
   This is a sentence typeset in the theorem
   environment \Lenv{Exa}.
\end{Exa}
```

REMARK 1 This is a sentence typeset in the theorem environment Rem.

```
\begin{Rem}
   This is a sentence typeset in the theorem
   environment \Lenv{Rem}.
\end{Rem}
```

2 LEMMA (BEN USER)
This is a sentence typeset in the theorem environment Lem*.*

```
\begin{Lem}[Ben User]
   This is a sentence typeset in the theorem
   environment \Lenv{Lem}.
\end{Lem}
```

3 DEFINITION (VERY IMPRESSIVE DEFINITION)
This is a sentence typeset in the theorem environment Def*.*

```
\begin{Def}[Very impressive Definition]
   This is a sentence typeset in the theorem
   environment \Lenv{Def}.
\end{Def}
```

The last two examples show the effect of the optional argument to a theorem environment (it is typeset in parentheses right after the label).

8.8.3 Special Considerations

The theorem header and body are implemented as a single unit. This means that the `\theoremheaderfont` will inherit characteristics of the `\theorembodyfont` if the NFSS is being used. Thus, if, for example, `\theorembodyfont` is `\itshape` and `\theoremheaderfont` is `\bfseries` the font selected for the header will have the characteristics "bold extended italic." If this is not desired you should set it to something like `\theoremheaderfont{\normalfont\bfseries}`. That is, you should supply all the necessary font information explicitly. See chapter 7 for more details about how to do that.

8.9 Mathematical Style Parameters

This section explains how you can globally control the style of your mathematical formulae, and how you can modify the size of certain (sub)formula elements.

8.9.1 Controlling the Size of Characters

Letters and mathematical symbols sometimes get smaller when they appear in fractions, superscripts, or subscripts. In fact, TEX has eight different styles in which it can treat formulae, namely:

D, D'	`\displaystyle`	formulae displayed on lines by themselves
T, T'	`\textstyle`	formulae embedded in the text
S, S'	`\scriptstyle`	formulae used as super- or subscripts
SS, SS'	`\scriptscriptstyle`	second- and higher-order super- or subscripts

The accented symbols represent the so-called *cramped* styles, which are similar to the normal styles except that exponents are not raised so much. TEX also uses three different type sizes for mathematics, namely: text size, script size, and scriptscript size.

A formula set inside text (between a `$` pair, or between `\(...\)`) is typeset using text style (style T). A formula on a line by itself, e.g., entered between `\[...\]`, will be typeset in display style (style D). The size of the different parts of a formula can be determined according to the following scheme:

A symbol in style	will be typeset in	(example)
D, D', T, T'	text size	(text size)
S, S'	script size	(script size)
SS, SS'	scriptscript size	(scriptscript size)

The kind of style used in mathematics formulae is as follows:

style	superscript	subscript	numerator	denominator
D	S	S'	T	T'
D'	S'	S'	T'	T'
T	S	S'	S	S'
T'	S'	S'	S'	S'
S, SS	SS	SS'	SS	SS'
S', SS'	SS'	SS'	SS'	SS'

The last two columns describe the style used in the numerator or denominator of a fraction. An example of the various styles can be seen in the continued fraction below (see also section 8.3.16):

$$b^0 + \frac{a^1}{b_1 + \frac{a^2}{b_2 + \frac{a^3}{b_3}}}$$

```
\normalsize
\[ b^0 + \frac{a^1}{b_1 +
          \frac{a^2}{b_2 +
           \frac{a^3}{b_3}}}
\]
```

In the formula above the b of b^0 is in style D, with the 0 in style S; the a and b of a^1 and b_1 are in style T and T', respectively, with the exponent 1 in style S and the subscript 1 in style S'; the a and b of a^2 and b_2 are both in style S', with the exponent and subscript in style SS'; finally everything in a^3 and b_3 is in style SS'.

You can give a nicer look to the above example by deciding which style is to be used in each case. Note that to save typing, we define the abbreviation `\D` for the `\displaystyle` command.

$$b^0 + \frac{a^1}{\displaystyle b_1 + \frac{a^2}{\displaystyle b_2 + \frac{a^3}{b_3}}}$$

```
\newcommand{\D}{\displaystyle}
\normalsize
\[ b^0 +  \frac{a^1}{\D b_1 +
           \frac{a^2}{\D b_2 +
            \frac{a^3}{b_3}}}
\]
```

8.9.2 LaTeX Math Style Parameters

Because LaTeX uses much of the mathematical machinery from TeX, we briefly describe the mathematical style parameters that LaTeX uses to typeset formulae. All these are length parameters which you can redefine with the `\setlength` or `\addtolength` commands (see section A.1.4 on page 474). Moreover, two standard options, leqno and fleqn, control the numbering and alignment of formulae. ($\mathcal{L}$ 170) ($\mathcal{L}$ 82)

The option fleqn causes formulae to be aligned on the left, a fixed distance from the left margin (see `\mathindent` below), instead of being centered.

The option leqno causes formula numbers to appear on the left instead of at the right (see section 8.6.6 on page 252).

In the list of mathematics style parameters below, all lengths (except `\jot` and `\arraycolsep`) are rubber lengths. With the option fleqn, the four `displayskip` lengths are made equal to the list defining length `\topsep`, to which the value of `\partopsep` is added if the display starts a paragraph (see figure 3.5 on page 64). The four parameters `\abovedisplay...` and `\belowdisplay...` below depend on the current font size. For this reason they cannot be modified in the preamble of the document using `\setlength`, but they must be changed by modyfying `\normalsize`, etc.

`\arraycolsep` This gives half the width of the horizontal space between columns in an `array` environment (default value `5pt`, see also section 5.3.2).

`\jot` This is the extra vertical space that is added between rows in an `eqnarray` or `eqnarray*` environment (default value `3pt`).

`\mathindent` This defines the indentation from the left margin of displayed formulae for the fleqn option (the default value is equal to the indentation of a first level list, i.e., `2.5em`, and is defined by the option fleqn).

`\abovedisplayskip` This specifies the extra space left above a long displayed formula, except with the option fleqn, where `\topsep` is used. A long formula is one that lies closer to the left margin than does the end of the preceding line (default value `12pt plus 3pt minus 9pt`).

`\belowdisplayskip` This specifies the extra space left below a long displayed formula, except with the option fleqn, where `\topsep` is used (default value `12pt plus 3pt minus 9pt`).

`\abovedisplayshortskip` This specifies the extra space left above a short displayed formula, except with the option fleqn, where `\topsep` is used. A short formula is one which starts to the right of where the preceding line ends (default value `0pt plus 3pt`).

`\belowdisplayshortskip` This specifies the extra space left below a short displayed formula, except with the option fleqn, where `\topsep` is used (default value `7pt plus 3pt minus 4pt`).