

Short Math Guide for L^AT_EX

Michael Downes

American Mathematical Society

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1. Introduction This is a concise summary of recommended features in L^AT_EX and a couple of extension packages for **writing math formulas**. Readers needing greater depth of detail are referred to the sources listed in the bibliography, especially [Lamport], [LaTeX-U], [AMUG], [LaTeX-F], [LaTeX-G], and [GMS]. A certain amount of familiarity with standard L^AT_EX terminology is assumed; if your memory needs refreshing on the L^AT_EX meaning of *command*, *optional argument*, *environment*, *package*, and so forth, see [Lamport].

The features described here are available to you if you use L^AT_EX with two extension packages published by the American Mathematical Society: **amssymb** and **amsmath**. Thus, the source file for this document begins with

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

The **amssymb** package might be omissible for documents whose math symbol usage is relatively modest; the easiest way to test this is to leave out the **amssymb** reference and see if any math symbols in the document stop working.

Many noteworthy features found in other packages are not covered here; see Section 9.

2. Inline math formulas and displayed equations

2.1. THE FUNDAMENTALS Entering and leaving math mode in L^AT_EX is normally done with the following commands and environments.

inline formulas	displayed equations	
\dots	<code>\[...\]</code>	unnumbered
(\dots)	<code>\begin{equation*}</code>	unnumbered
	<code>\end{equation*}</code>	
	<code>\begin{equation}</code>	automatically
	<code>\end{equation}</code>	numbered

Note. Alternative environments `\begin{math} \dots \end{math}`, `\begin{displaymath} \dots \end{displaymath}` are seldom needed in practice. Using the plain T_EX notation $\$ \dots \$$ for displayed equations is not recommended. Even though it is not expressly forbidden in L^AT_EX, it interferes with the proper operation of various features such as the **fleqn** option.

Environments for handling equation groups and multi-line equations are shown in Table 1.

2.2. AUTOMATIC NUMBERING AND CROSS-REFERENCING To get an auto-numbered equation, use the **equation** environment; to assign a label for cross-referencing, use the `\label` command:

```
\begin{equation}\label{reio}
\dots
\end{equation}
```

Table 1: Multi-line equations and equation groups (vertical lines indicating nominal margins).

<pre> \begin{equation}\label{xx} \begin{split} a&=b+c-d\\ &\quad +e-f\\ &=g+h\\ &=i \end{split} \end{equation} </pre>	$ \begin{aligned} a &= b + c - d \\ &\quad + e - f \\ &= g + h \\ &= i \end{aligned} \tag{2.1} $
<pre> \begin{multline} a+b+c+d+e+f\\ +i+j+k+l+m+n \end{multline} </pre>	$ \begin{aligned} a + b + c + d + e + f \\ + i + j + k + l + m + n \end{aligned} \tag{2.2} $
<pre> \begin{gather} a_1=b_1+c_1\\ a_2=b_2+c_2-d_2+e_2 \end{gather} </pre>	$a_1 = b_1 + c_1 \tag{2.3}$ $a_2 = b_2 + c_2 - d_2 + e_2 \tag{2.4}$
<pre> \begin{align} a_1&=b_1+c_1\\ a_2&=b_2+c_2-d_2+e_2 \end{align} </pre>	$a_1 = b_1 + c_1 \tag{2.5}$ $a_2 = b_2 + c_2 - d_2 + e_2 \tag{2.6}$
<pre> \begin{align} a_{11}&=b_{11}& a_{12}&=b_{12}\\ a_{21}&=b_{21}& a_{22}&=b_{22}+c_{22} \end{align} </pre>	$ \begin{aligned} a_{11} &= b_{11} & a_{12} &= b_{12} \\ a_{21} &= b_{21} & a_{22} &= b_{22} + c_{22} \end{aligned} \tag{2.7} $
<pre> \begin{flalign*} a_{11}&=b_{11}& a_{12}&=b_{12}\\ a_{21}&=b_{21}& a_{22}&=b_{22}+c_{22} \end{flalign*} </pre>	$ \begin{aligned} a_{11} &= b_{11} & a_{12} &= b_{12} \\ a_{21} &= b_{21} & a_{22} &= b_{22} + c_{22} \end{aligned} $

Note 1. The `split` environment is something of a special case. It is a subordinate environment that can be used as the contents of an `equation` environment or the contents of one “line” in a multiple-equation structure such as `align` or `gather`.

Note 2. The `eqnarray` and `eqnarray*` environments described in [Lamport] are not recommended because they produce inconsistent spacing of the equal signs and make no attempt to prevent overprinting of the equation body and equation number.

To get a cross-reference to an auto-numbered equation, use the `\eqref` command:

... using equations `\eqref{ax1}` and `\eqref{bz2}`, we can derive ...

The above example would produce something like

using equations (3.2) and (3.5), we can derive

In other words, `\eqref{ax1}` is equivalent to `(\ref{ax1})`.

To give your equation numbers the form *m.n* (*section-number.equation-number*), use the `\numberwithin` command in the preamble of your document:

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

For more details on custom numbering schemes see [Lamport, §6.3, §C.8.4].

The `subequations` environment provides a convenient way to number equations in a group with a subordinate numbering scheme. For example, supposing that the current equation number is 2.1, write

```
\begin{equation}\label{first}
a=b+c
\end{equation}
some intervening text
\begin{subequations}\label{grp}
\begin{align}
a&=b+c\label{second}\\
d&=e+f+g\label{third}\\
h&=i+j\label{fourth}
\end{align}
\end{subequations}
```

to get

$$a = b + c \tag{2.9}$$

some intervening text

$$a = b + c \tag{2.10a}$$

$$d = e + f + g \tag{2.10b}$$

$$h = i + j \tag{2.10c}$$

By putting a `\label` command immediately after `\begin{subequations}` you can get a reference to the parent number; `\eqref{grp}` from the above example would produce (2.10) while `\eqref{second}` would produce (2.10a).

3. Math symbols and math fonts

3.1. CLASSES OF MATH SYMBOLS The symbols in a math formula fall into different classes that correspond more or less to the part of speech each symbol would have if the formula were expressed in words. Certain spacing and positioning cues are traditionally used for the different symbol classes to increase the readability of formulas.

Class number	Mnemonic	Description (part of speech)	Examples
0	Ord	simple/ordinary (“noun”)	$A \ 0 \ \Phi \ \infty$
1	Op	prefix operator	$\sum \prod \int$
2	Bin	binary operator (conjunction)	$+ \cup \wedge$
3	Rel	relation/comparison (verb)	$= < \subset$
4	Open	left/opening delimiter	$([\{ \langle$
5	Close	right/closing delimiter	$)] \} \rangle$
6	Pun	postfix/punctuation	$. , ; !$

Note 1. The distinction in T_EX between class 0 and an additional class 7 has to do only with font selection issues and is immaterial here.

Note 2. Symbols of class Bin, notably the minus sign $-$, are automatically coerced to class 0 (no space) if they do not have a suitable left operand.

The spacing for a few symbols follows tradition instead of the general rule: although $/$ is (semantically speaking) of class 2, we write $k/2$ with no space around the slash rather than $k / 2$. And compare $p|q$ $p|q$ (no space) with $p\mid q$ $p \mid q$ (class-3 spacing).

The proper way to define a new math symbol is discussed in L^AT_EX 2_ε *font selection* [LaTeX-F]. It is not really possible to give a useful synopsis here because one needs first to understand the ramifications of font specifications.

3.2. SOME SYMBOLS INTENTIONALLY OMITTED HERE The following math symbols that are mentioned in the L^AT_EX book [Lamport] are intentionally omitted from this discussion because they are superseded by equivalent symbols when the **amssymb** package is loaded. If you are using the **amssymb** package anyway, the only thing that you are likely to gain by using the alternate name is an unnecessary increase in the number of fonts used by your document.

`\Box`, see `\square` \square
`\Diamond`, see `\lozenge` \diamond
`\leadsto`, see `\rightsquigarrow` \rightsquigarrow
`\Join`, see `\bowtie` \bowtie
`\lhd`, see `\vartriangleleft` \triangleleft
`\unlhd`, see `\trianglelefteq` \trianglelefteq
`\rhd`, see `\vartriangleright` \triangleright
`\unrhd`, see `\trianglerighteq` \trianglerighteq

3.3. LATIN LETTERS AND ARABIC NUMERALS The Latin letters are simple symbols, class 0. The default font for them in math formulas is italic.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z

When adding an accent to an i or j in math, dotless variants can be obtained with `\imath` and `\jmath`:

\imath `\imath` \jmath `\jmath` $\hat{\jmath}$ `\hat{\jmath}`

Arabic numerals 0–9 are also of class 0. Their default font is upright/roman.

0 1 2 3 4 5 6 7 8 9

3.4. GREEK LETTERS Like the Latin letters, the Greek letters are simple symbols, class 0. For obscure historical reasons, the default font for lowercase Greek letters in math formulas is italic while the default font for capital Greek letters is upright/roman. (In other fields such as physics and chemistry, however, the typographical traditions are somewhat different.) The capital Greek letters not present in this list are the letters that have the same appearance as some Latin letter: A for Alpha, B for Beta, and so on. In the list of lowercase letters there is no omicron because it would be identical in appearance to Latin o . In practice, the Greek letters that have Latin look-alikes are seldom used in math formulas,

to avoid confusion.

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

3.5. OTHER ALPHABETIC SYMBOLS These are also class 0.

\aleph \aleph	\complement \complement	\hslash \hslash	\circledS \circledS	\Im \Im
\beth \beth	ℓ \ell	\mho \mho	\Bbbk \Bbbk	\Re \Re
\daleth \daleth	\eth \eth	∂ \partial	\Finv \Finv	
\gimel \gimel	\hbar \hbar	\wp \wp	\Game \Game	

3.6. MISCELLANEOUS SIMPLE SYMBOLS These symbols are also of class 0 (ordinary) which means they do not have any built-in spacing.

$\#$ \#	\clubsuit \clubsuit	\lozenge \lozenge	\square \square
$\&$ \&	\diagdown \diagdown	\measuredangle \measuredangle	\surd \surd
\angle \angle	\diagup \diagup	∇ \nabla	\top \top
\backprime \backprime	\diamondsuit \diamondsuit	\natural \natural	\triangle \triangle
\bigstar \bigstar	\emptyset \emptyset	\neg \neg	\triangledown \triangledown
\blacklozenge \blacklozenge	\exists \exists	\nexists \nexists	\varnothing \varnothing
\blacksquare \blacksquare	\flat \flat	\prime \prime	
\blacktriangle \blacktriangle	\forall \forall	\sharp \sharp	
\blacktriangledown \blacktriangledown	\heartsuit \heartsuit	\spadesuit \spadesuit	
\bot \bot	∞ \infty	\sphericalangle \sphericalangle	

Note 1. A common mistake in the use of the symbols \square and $\#$ is to try to make them serve as binary operators or relation symbols without using a properly defined math symbol command. If you merely use the existing commands `\square` or `\#` the inter-symbol spacing will be incorrect because those commands produce a class-0 symbol.

Note 2. Synonyms: \neg \lnot

3.7. BINARY OPERATOR SYMBOLS

$\ast \ast$	\cdot \cdot	$\overline{\overline{\wedge}}$ \doublebarwedge	\smallsetminus \smallsetminusminus
$++$	\cdot \centerdot	\triangleright \gtrdot	\sqcap \sqcap
$--$	\circ \circ	\intercal \intercal	\sqcup \sqcup
\amalg	\circledast \circledast	\leftthreetimes \leftthreetimes	\star \star
\ast \ast	\circledcirc \circledcirc	\lessdot \lessdot	\times \times
$\bar{\wedge}$ \barwedge	\ominus \circledcircdash	\ltimes \ltimes	\triangleleft \triangleleft
\bigcirc \bigcirc	\cup \cup	\mp \mp	\triangleright \triangleright
\bigtriangledown \bigtriangledown	\cup \Cup	\odot \odot	\uplus \uplus
\bigtriangleup \bigtriangleup	\curlyvee \curlyvee	\ominus \ominus	\vee \vee
\boxdot \boxdot	\curlywedge \curlywedge	\oplus \oplus	\veebar \veebar
\boxminus \boxminus	\dagger \dagger	\oslash \oslash	\wedge \wedge
\boxplus \boxplus	\ddagger \ddagger	\otimes \otimes	\wr \wr
\boxtimes \boxtimes	\diamond \diamond	\pm \pm	
\bullet \bullet	\div \div	\rightthreetimes \rightthreetimes	
\cap \cap	\divideontimes \divideontimes	\rtimes \rtimes	
\Cap \Cap	\dotplus \dotplus	\setminus \setminusminus	

Synonyms: \wedge \land, \vee \lor, \cup \doublecup, \cap \doublecap

3.8. RELATION SYMBOLS: $< = > \succ \sim$ AND VARIANTS

$<<$	\leqslant \eqslantless	\leq \leq	\ngtr \ngtr	\sim \sim
$=$	\equiv \equiv	\leqslant \leqslant	\nleq \nleq	\simeq \simeq
$>>$	\fallingdotseq \fallingdotseq	\lessapprox \lessapprox	\nleqq \nleqq	\succ \succ
\approx \approx	\geq \geq	\lesseqgtr \lesseqgtr	\nleqslant \nleqslant	\succapprox \succapprox
\approxeq \approxeq	\geqq \geqq	\lesseqqgtr \lesseqqgtr	\nless \nless	\succcurlyeq \succcurlyeq
\asymp \asymp	\geqslant \geqslant	\lessgtr \lessgtr	\nprec \nprec	\succeq \succeq
\backsim \backsim	\gg \gg	\lesssim \lesssim	\npreceq \npreceq	\succnapprox \succnapprox
\backsimeq \backsimeq	\ggg \ggg	\ll \ll	\nsim \nsim	\succneqq \succneqq
\bumpeq \bumpeq	\gtrapprox \gtrapprox	\lll \lll	\nsucc \nsucc	\succnsim \succnsim
\Bumpeq \Bumpeq	\gneq \gneq	\lnapprox \lnapprox	\nsucceq \nsucceq	\succsim \succsim
\circeq \circeq	\gneqq \gneqq	\lneq \lneq	\prec \prec	\thickapprox \thickapprox
\cong \cong	\gnsim \gnsim	\lneqq \lneqq	\precapprox \precapprox	\thicksim \thicksim
\curlyeqprec \curlyeqprec	\gtrapprox \gtrapprox	\lnsim \lnsim	\preccurlyeq \preccurlyeq	\triangleq \triangleq
\curlyeqsucc \curlyeqsucc	\gtreqless \gtreqless	\lvertneqq \lvertneqq	\preceq \preceq	
\doteq \doteq	\gtreqqless \gtreqqless	\ncong \ncong	\precnapprox \precnapprox	
\doteqdot \doteqdot	\gtrless \gtrless	\neq \neq	\precneqq \precneqq	
\eqcirc \eqcirc	\gtrsim \gtrsim	\ngeq \ngeq	\precnsim \precnsim	
\eqsim \eqsim	\gvertneqq \gvertneqq	\ngeqq \ngeqq	\precsim \precsim	
\eqslantgtr \eqslantgtr	\leq \leq	\ngeqslant \ngeqslant	\risingdotseq \risingdotseq	

Synonyms: \neq \ne, \leq \le, \geq \ge, \doteq \Doteq, \lll \llless, \ggg \gggtr

3.9. RELATION SYMBOLS: ARROWS See also Section 4.

\circlearrowleft	\Lleftarrow	\nwarrow
\circlearrowright	\longleftarrow	\rightarrow
\curvearrowleft	\Longleftarrow	\Rightarrow
\curvearrowright	\longleftrightarrow	\rightarrowtail
\downdownarrows	\Longleftrightarrow	\rightarrowharpoonright
\downharpoonleft	\longmapsto	\rightarrowharpoonup
\downharpoonright	\longrightarrow	\rightleftarrows
\hookleftarrow	\Longrightarrow	\rightleftharpoons
\hookrightarrow	\looparrowleft	\rightrightarrows
\leftarrow	\looparrowright	\rightsquigarrow
\Leftarrow	\Lsh	\Rightarrow
\leftarrowtail	\mapsto	\Rsh
\leftharpoonright	\multimap	\searrow
\leftharpoonup	\nLeftarrow	\swarrow
\leftleftarrows	\nLeftrightarrow	\twoheadleftarrow
\leftrightarrow	\nRightarrow	\twoheadrightarrow
\Leftrightarrow	\nearrow	\upharpoonleft
\leftrightsquigarrow	\nleftarrow	\upharpoonright
	\nlefttrightarrow	\upuparrows
	\rightarrow	

Synonyms: \leftarrow \gets, \rightarrow \to, \upharpoonleft \restriction

3.10. RELATION SYMBOLS: MISCELLANEOUS

\backsimeq	\nsubseteq	\smile	\therefore
\because	\supseteq	\smile	\trianglelefteq
\between	\supseteq	\sqsubset	\trianglerighteq
\blacktriangleleft	\triangleleft	\sqsubseteq	\varpropto
\blacktriangleright	\trianglelefteq	\sqsupset	\varsubsetneq
\bowtie	\triangleright	\sqsupseteq	\varsubsetneqq
\dashv	\trianglerighteq	\subset	\varsupsetneq
\frown	\nvdash	\subseteq	\varsupsetneqq
\in	\nVdash	\subseteq	\vartriangle
\mid	\nVDash	\subseteqeq	\vartriangleleft
\models	\nVDash	\subseteqneq	\vartriangleright
\ni	\parallel	\subseteqneqq	\vdash
\nmid	\perp	\supset	\Vdash
\notin	\pitchfork	\supseteq	\vDash
\nparallel	\propto	\supseteq	\Vvdash
\nshortmid	\shortmid	\supseteqeq	
\nshortparallel	\shortparallel	\supsetneq	
\nsubseteq	\smallfrown	\supsetneqq	

Synonyms: \ni \owns

3.11. CUMULATIVE (VARIABLE-SIZE) OPERATORS

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

3.12. PUNCTUATION

\dots	$;$	$??$	\dots \dotsm	\vdots \vdots
$/$	$:$ \colon	\dots \dotsb	\dots \dotso	
$ $	$::$	\dots \dotsc		
$,$	$!!$	\dots \dotsi	\ddots \ddots	

Note 1. The $:$ by itself produces a colon with class-3 (relation) spacing. The command \colon produces special spacing for use in constructions such as $f\colon A\rightarrow B$ or $f:A\rightarrow B$.

Note 2. Although the commands \cdots and \ldots are frequently used, we recommend the more semantically oriented commands \dotsb \dotsc \dotsi \dotsm \dotso for most purposes (see 4.6).

3.13. PAIRING DELIMITERS (EXTENSIBLE) See Section 6 for more information.

$()$	$\ \ $ \lVert \rVert	$()$ \lgroup \rgroup
$[]$	$\langle \rangle$ \langle \rangle \rangle \rangle	$\int \int$ \lmoustache \rmoustache
$\{ \}$ \lbrace \rbrace	$\lceil \rceil$ \lceil \rceil	
$\ $ \lvert \rvert	$\lfloor \rfloor$ \lfloor \rfloor	

3.14. NONPAIRING EXTENSIBLE SYMBOLS

$ $ \vert	$\ $ \Vert	$/$	\backslash \backslash	\uparrow \arrowup	\Uparrow \Upwardarrow	\downarrow \arrowdown
-----------	------------	-----	-------------------------	---------------------	-------------------------	-------------------------

Note 1. Using \vert, |, \Vert, or \l for paired delimiters is not recommended (see 6.2).

Synonyms: \| \l

3.15. EXTENSIBLE VERTICAL ARROWS

\uparrow \uparrow	\Uparrow \Upwardarrow	\downarrow \downarrow	\Downarrow \Downarrow	\updownarrow \updownarrow	\Updownarrow \Updownarrow
---------------------	-------------------------	-------------------------	-------------------------	-----------------------------	-----------------------------

3.16. ACCENTS

\acute{x} \acute{x}	\bar{x} \bar{x}	\vec{x} \vec{x}	\widetilde{xxx} \widetilde{xxx}
\grave{x} \grave{x}	\breve{x} \breve{x}	\dot{x} \dot{x}	\widehat{xxx} \widehat{xxx}
\ddot{x} \ddot{x}	\check{x} \check{x}	\ddot{x} \ddot{x}	
\tilde{x} \tilde{x}	\hat{x} \hat{x}	\dddot{x} \dddot{x}	

3.17. NAMED OPERATORS These operators are represented by a multiletter abbreviation.

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

To define additional named operators outside the above list, use the \DeclareMathOperator command; for example, after


```
\DeclareMathOperator{\rank}{rank}
\DeclareMathOperator{\esssup}{ess\,sup}
```

one could write

$$\begin{array}{ll} \backslash\mathrm{rank}(x) & \mathrm{rank}(x) \\ \backslash\mathrm{esssup}(y,z) & \mathrm{ess\,sup}(y,z) \end{array}$$

The star form `\DeclareMathOperator*` creates an operator that takes limits in a displayed formula like `\sup` or `\max`.

3.18. MATH FONT SWITCHES Not all of the fonts necessary to support comprehensive math font switching are commonly available in a typical L^AT_EX setup. Here are the results of applying various font switches to a wide range of math symbols when the standard set of Computer Modern fonts is in use. It can be seen that the only symbols that respond correctly to all of the font switches are the uppercase Latin letters. In fact, *nearly all* math symbols apart from Latin letters remain unaffected by font switches; and although the lowercase Latin letters, capital Greek letters, and numerals do respond properly to some font switches, they produce bizarre results for other font switches. (Use of alternative math font sets such as Lucida New Math may ameliorate the situation somewhat.)

default	<code>\mathbf</code>	<code>\mathsf</code>	<code>\mathit</code>	<code>\mathcal</code>	<code>\mathbb</code>	<code>\mathfrak</code>
X	X	X	<i>X</i>	\mathcal{X}	\mathbb{X}	\mathfrak{X}
x	x	x	<i>x</i>	\S	\curvearrowright	\mathfrak{x}
0	0	0	<i>0</i>	\prime	\nless	\mathfrak{o}
$[]$	[]	[]	<i>[]</i>	$[]$	$[]$	$[]$
$+$	+	+	<i>+</i>	$+$	$+$	$+$
$-$	-	-	<i>-</i>	$-$	$-$	$-$
$=$	=	=	<i>=</i>	$=$	$=$	$=$
Ξ	\Xi	Ξ	<i>\Xi</i>	\div	\nless	\mathfrak{g}
ξ	\xi	ξ	<i>\xi</i>	ξ	ξ	ξ
∞	\infty	∞	<i>\infty</i>	∞	∞	∞
\aleph	\aleph	\aleph	<i>\aleph</i>	\aleph	\aleph	\aleph
Σ	\Sigma	Σ	<i>\Sigma</i>	Σ	Σ	Σ
Π	\Pi	Π	<i>\Pi</i>	Π	Π	Π
\Re	\Re	\Re	<i>\Re</i>	\Re	\Re	\Re

A common desire is to get a bold version of a particular math symbol. For those symbols where `\mathbf` is not applicable, the `\boldsymbol` or `\pmb` commands can be used.

$$A_\infty + \pi A_0 \sim \mathbf{A}_\infty + \pi \mathbf{A}_0 \sim A_\infty + \pi A_0 \quad (3.1)$$

```
A_\infty + \pi A_0
\sim \mathbf{A}_{\boldsymbol{\infty}} \boldsymbol{+}
\boldsymbol{\pi} \mathbf{A}_{\boldsymbol{0}}
\sim \pmb{A}_{\pmb{\infty}} \pmb{+} \pmb{\pi} \pmb{A}_{\pmb{0}}
```

The `\boldsymbol` command is obtained preferably by using the `bm` package, which provides a newer, more powerful version than the one provided by the `amsmath` package. Generally speaking, it is ill-advised to apply `\boldsymbol` to more than one symbol at a time.

3.18.1. Calligraphic letters (`\cmsy`; no lowercase)

Usage: `\mathcal{M}`.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

3.18.2. Blackboard Bold letters (msbm; no lowercase)Usage: `\mathbb{R}`.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

3.18.3. Fraktur letters (eufm)Usage: `\mathfrak{S}`.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z

4. Notations

4.1. TOP AND BOTTOM EMBELLISHMENTS These are visually similar to accents but generally span multiple symbols rather than being applied to a single base symbol. For ease of reference, `\widetilde` and `\widehat` are redundantly included here and in the table of math accents.

\widetilde{xxx} <code>\widetilde{xxx}</code>	\overbrace{xxx} <code>\overbrace{xxx}</code>	\overrightarrow{xxx} <code>\overrightarrow{xxx}</code>
\widehat{xxx} <code>\widehat{xxx}</code>	\underbrace{xxx} <code>\underbrace{xxx}</code>	\underrightarrow{xxx} <code>\underrightarrow{xxx}</code>
\overline{xxx} <code>\overline{xxx}</code>	\overleftarrow{xxx} <code>\overleftarrow{xxx}</code>	\overleftrightarrow{xxx} <code>\overleftrightarrow{xxx}</code>
\underline{xxx} <code>\underline{xxx}</code>	\underleftarrow{xxx} <code>\underleftarrow{xxx}</code>	$\underleftrightarrow{xxx}$ <code>\underleftrightarrow{xxx}</code>

4.2. EXTENSIBLE ARROWS `\xleftarrow` and `\xrightarrow` produce arrows that extend automatically to accommodate unusually wide subscripts or superscripts. These commands take one optional argument (the subscript) and one mandatory argument (the superscript, possibly empty):

$$A \xleftarrow{n+\mu-1} B \xrightarrow[T]{n\pm i-1} C \quad (4.1)$$

`\xleftarrow{n+\mu-1}` `\quad` `\xrightarrow[T]{n\pm i-1}`

4.3. AFFIXING SYMBOLS TO OTHER SYMBOLS In addition to the standard accents (Section 3.16), other symbols can be placed above or below a base symbol with the `\overset` and `\underset` commands. For example, writing `\overset{*}{X}` will place a superscript-size * above the X, thus: X^* . See also the description of `\sideset` in Section 8.3.

4.4. MATRICES The environments `pmatrix`, `bmatrix`, `Bmatrix`, `vmatrix` and `Vmatrix` have (respectively) `()`, `[]`, `{ }`, `||`, and `|||` delimiters built in. There is also a `matrix` environment sans delimiters, and an `array` environment that can be used to obtain left alignment or other variations in the column specs.

```
\begin{pmatrix}
\alpha& \beta^*\\
\gamma^*& \delta
\end{pmatrix}
```

To produce a small matrix suitable for use in text, there is a `smallmatrix` environment (e.g., $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$) that comes closer to fitting within a single text line than a normal matrix. This example was produced by

```
\bigl( \begin{smallmatrix}
a&b\\ c&d
\end{smallmatrix} \bigr)
```

To produce a row of dots in a matrix spanning a given number of columns, use `\hdotsfor`. For example, `\hdotsfor{3}` in the second column of a four-column matrix will print a row of dots across the final three columns.

For piece-wise function definitions there is a `cases` environment:

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

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

Note. The plain T_EX form `\matrix{... \cr ... \cr}` and the related commands `\pmatrix`, `\cases` should be avoided in L^AT_EX (and when the `amsmath` package is loaded they are disabled).

4.5. MATH SPACING COMMANDS When the `amsmath` package is used, all of these math spacing commands can be used both in and out of math mode.

Abbrev.	Spelled out	Example	Abbrev.	Spelled out	Example
	no space	34		no space	34
<code>\,</code>	<code>\thinspace</code>	3 4	<code>\!</code>	<code>\negthinspace</code>	34
<code>\:</code>	<code>\medspace</code>	3 4		<code>\negmedspace</code>	34
<code>\;</code>	<code>\thickspace</code>	3 4		<code>\negthickspace</code>	34
	<code>\quad</code>	3 4			
	<code>\qquad</code>	3 4			

For finer control over math spacing, use `\mspace` and ‘math units’. One math unit, or `\mu`, is equal to 1/18 em. Thus to get a negative half `\quad` write `\mspace{-9.0mu}`.

4.6. DOTS For preferred placement of ellipsis dots (raised or on-line) in various contexts there is no general consensus. It may therefore be considered a matter of taste. By using the semantically oriented commands

- `\dotsc` for “dots with commas”
- `\dotsb` for “dots with binary operators/relations”
- `\dotsm` for “multiplication dots”
- `\dotsi` for “dots with integrals”
- `\dotso` for “other dots” (none of the above)

instead of `\ldots` and `\cdots`, you make it possible for your document to be adapted to different conventions on the fly, in case (for example) you have to submit it to a publisher who insists on following house tradition in this respect. The default treatment for the various kinds follows American Mathematical Society conventions:

We have the series A_1, A_2, \dotsc ,
the regional sum $A_1 + A_2 + \dotsb$,
the orthogonal product $A_1 A_2 \dotsm$,
and the infinite integral
 $\int_{A_1} \int_{A_2} \dotso$.

We have the series A_1, A_2, \dots , the re-
gional sum $A_1 + A_2 + \dots$, the orthogonal
product $A_1 A_2 \dots$, and the infinite integral

$$\int_{A_1} \int_{A_2} \dots$$

4.7. NONBREAKING DASHES The command `\nobreakdash` suppresses the possibility of a linebreak after the following hyphen or dash. For example, if you write ‘pages 1–9’ as `pages 1\nobreakdash--9` then a linebreak will never occur between the dash and the 9. You can also use `\nobreakdash` to prevent undesirable hyphenations in combinations like `p-adic`. For frequent use, it’s advisable to make abbreviations, e.g.,

```
\newcommand{\p}{$p$\nobreakdash}% for "\p-adic"
\newcommand{\Ndash}{\nobreakdash\textendash}% for "pages 1\Ndash 9"
% For "\n dimensional" ("n-dimensional"):
\newcommand{\n}[1]{\n$\nobreakdash-\hspace{0pt}}
```

The last example shows how to prohibit a linebreak after the hyphen but allow normal hyphenation in the following word. (It suffices to add a zero-width space after the hyphen.)

4.8. **ROOTS** The command `\sqrt` produces a square root. To specify an alternate radix give an optional argument.

$$\sqrt[n]{S}, \quad \sqrt[3]{2} = \sqrt[3]{2}$$

4.9. **BOXED FORMULAS** The command `\boxed` puts a box around its argument, like `\fbox` except that the contents are in math mode:

$$\boxed{\eta \leq C(\delta(\eta) + \Lambda_M(0, \delta))} \quad (4.2)$$

`\boxed{\eta \leq C(\delta(\eta) + \Lambda_M(0, \delta))}`

If you need to box an equation including the equation number, see the FAQ that comes with the `amsmath` package.

5. Fractions and related constructions

5.1. **THE `\frac`, `\dfrac`, AND `\tfrac` COMMANDS** The `\frac` command takes two arguments—numerator and denominator—and typesets them in normal fraction form. Use `\dfrac` or `\tfrac` to overrule L^AT_EX's guess about the proper size to use for the fraction's contents (t = text-style, d = display-style).

$$\frac{1}{k} \log_2 c(f) \quad \frac{1}{k} \log_2 c(f) \quad (5.1)$$

```
\begin{equation}
\frac{1}{k} \log_2 c(f); \tfrac{1}{k} \log_2 c(f);
\end{equation}
```

$$\Re z = \frac{n\pi \frac{\theta + \psi}{2}}{\left(\frac{\theta + \psi}{2}\right)^2 + \left(\frac{1}{2} \log \left| \frac{B}{A} \right| \right)^2}. \quad (5.2)$$

```
\begin{equation}
\Re{z} = \frac{n\pi \dfrac{\theta + \psi}{2}}{\left(\dfrac{\theta + \psi}{2}\right)^2 + \left(\dfrac{1}{2} \log \left| \dfrac{B}{A} \right| \right)^2}.
\end{equation}
```

5.2. **THE `\binom`, `\dbinom`, AND `\tbinom` COMMANDS** For binomial expressions such as $\binom{n}{k}$ there are `\binom`, `\dbinom` and `\tbinom` commands:

$$2^k - \binom{k}{1} 2^{k-1} + \binom{k}{2} 2^{k-2} \quad (5.3)$$

`2^k - \binom{k}{1} 2^{k-1} + \binom{k}{2} 2^{k-2}`

5.3. **THE `\genfrac` COMMAND** The capabilities of `\frac`, `\binom`, and their variants are subsumed by a generalized fraction command `\genfrac` with six arguments. The last two correspond to `\frac`'s numerator and denominator; the first two are optional delimiters (as seen in `\binom`); the third is a line thickness override (`\binom` uses this to set the fraction line thickness to 0—i.e., invisible); and the fourth argument is a mathstyle override: integer values 0–3 select respectively `\displaystyle`, `\textstyle`, `\scriptstyle`, and `\scriptscriptstyle`. If the third argument is left empty, the line thickness defaults to 'normal'.

`\genfrac{left-delim}{right-delim}{thickness}`
`{mathstyle}{numerator}{denominator}`

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}}
```

Note. For technical reasons, using the primitive fraction commands `\over`, `\atop`, `\above` in a L^AT_EX document is not recommended (see, e.g., `amsmath.faq`).

5.4. CONTINUED FRACTIONS The continued fraction

$$\frac{1}{\sqrt{2} + \frac{1}{\sqrt{2} + \frac{1}{\sqrt{2} + \dots}}} \quad (5.4)$$

can be obtained by typing

```
\cfrac{1}{\sqrt{2}+
\cfrac{1}{\sqrt{2}+
\cfrac{1}{\sqrt{2}+\dotsb
}}}
```

This produces better-looking results than straightforward use of `\frac`. Left or right placement of any of the numerators is accomplished by using `\cfrac[l]` or `\cfrac[r]` instead of `\cfrac`.

6. Delimiters

6.1. DELIMITER SIZES Unless you indicate otherwise, delimiters in math formulas will remain at the standard size regardless of the height of the enclosed material. To get larger sizes, you can either select a particular size using a `\big...` prefix (see below), or you can use `\left` and `\right` prefixes for autosizing.

The automatic delimiter sizing done by `\left` and `\right` has two limitations: First, it is applied mechanically to produce delimiters large enough to encompass the largest contained item, and second, the range of sizes has fairly large quantum jumps. This means that an expression that is infinitesimally too large for a given delimiter size will get the next larger size, a jump of 6pt or so (3pt top and bottom) in normal-sized text. There are two or three situations where the delimiter size is commonly adjusted. These adjustments are done using the following commands:

Delimiter size	text size	<code>\left</code> <code>\right</code>	<code>\bigl</code> <code>\bigr</code>	<code>\Bigl</code> <code>\Bigr</code>	<code>\biggl</code> <code>\biggr</code>	<code>\Biggl</code> <code>\Biggr</code>
Result	$(b)(\frac{c}{d})$	$(b)(\frac{c}{d})$	$(b)(\frac{c}{d})$	$(b)(\frac{c}{d})$	$(b)(\frac{c}{d})$	$(b)(\frac{c}{d})$

The first kind of adjustment is done for cumulative operators with limits, such as summation signs. With `\left` and `\right` the delimiters usually turn out larger than necessary, and using the `Big` or `bigg` sizes instead gives better results:

$$\left[\sum_i a_i \left| \sum_j x_{ij} \right|^p \right]^{1/p} \quad \text{versus} \quad \left[\sum_i a_i \left| \sum_j x_{ij} \right|^p \right]^{1/p}$$

```
\biggl[\sum_i a_i\Bigl\lvert\sum_j x_{ij}\Bigr\rvert^p\biggr]^{1/p}
```

The second kind of situation is clustered pairs of delimiters where `\left` and `\right` make them all the same size (because that is adequate to cover the encompassed material) but what you really want is to make some of the delimiters slightly larger to make the nesting easier to see.

$$((a_1b_1) - (a_2b_2))((a_2b_1) + (a_1b_2)) \quad \text{versus} \quad ((a_1b_1) - (a_2b_2))((a_2b_1) + (a_1b_2))$$

```
\left((a_1 b_1) - (a_2 b_2)\right)
\left((a_2 b_1) + (a_1 b_2)\right)
\quad\text{versus}\quad
\bigl((a_1 b_1) - (a_2 b_2)\bigr)
\bigl((a_2 b_1) + (a_1 b_2)\bigr)
```

The third kind of situation is a slightly oversize object in running text, such as $\left|\frac{b'}{a'}\right|$ where the delimiters produced by `\left` and `\right` cause too much line spreading. In that case `\bigl` and `\bigr` can be used to produce delimiters that are larger than the base size but still able to fit within the normal line spacing: $\left|\frac{b'}{a'}\right|$.

6.2. VERTICAL BAR NOTATIONS The use of the `|` character to produce paired delimiters is not recommended. There is an ambiguity about the directionality of the symbol that will in rare cases produce incorrect spacing—e.g., $|k|=|-k|$ $|k|=|-k|$. Using `\lvert` for a “left vert bar” and `\rvert` for a “right vert bar” whenever they are used in pairs will prevent this problem. For double bars there are analogous `\lVert`, `\rVert` commands. Recommended practice is to define suitable commands in the document preamble for any paired-delimiter use of vert bar symbols:

```
\providecommand{\abs}[1]{\lvert#1\rvert}
\providecommand{\norm}[1]{\lVert#1\rVert}
```

whereupon `\abs{z}` would produce $|z|$ and `\norm{v}` would produce $\|v\|$.

7. The `\text` command The main use of the command `\text` is for words or phrases in a display. It is similar to `\mbox` in its effects but, unlike `\mbox`, automatically produces subscript-size text if used in a subscript.

$$f_{[x_{i-1}, x_i]} \text{ is monotonic, } i = 1, \dots, c+1 \quad (7.1)$$

```
f_{[x_{i-1}, x_i]} \text{ is monotonic,}
\quad i = 1, \dots, c+1
```

7.1. `\MOD` AND ITS RELATIVES Commands `\mod`, `\bmod`, `\pmod`, `\pod` deal with the special spacing conventions of “mod” notation. `\mod` and `\pod` are variants of `\pmod` preferred by some authors; `\mod` omits the parentheses, whereas `\pod` omits the “mod” and retains the parentheses.

$$\gcd(n, m \bmod n); \quad x \equiv y \pmod b; \quad x \equiv y \bmod c; \quad x \equiv y \pmod d \quad (7.2)$$

```
\gcd(n, m \bmod n); \quad x \equiv y \pmod b
; \quad x \equiv y \bmod c; \quad x \equiv y \pod d
```

8. Integrals and sums

8.1. MULTIPLE INTEGRAL SIGNS `\iint`, `\iiint`, and `\iiiiint` give multiple integral signs with the spacing between them nicely adjusted, in both text and display style. `\idotsint` is an extension of the same idea that gives two integral signs with dots between them.

$$\iint_A f(x, y) dx dy \quad \iiint_A f(x, y, z) dx dy dz \quad (8.1)$$

$$\iiidotsint_A f(w, x, y, z) dw dx dy dz \quad \int_A \cdots \int f(x_1, \dots, x_k) \quad (8.2)$$

8.2. MULTILINE SUBSCRIPTS AND SUPERSCRIPTS The `\substack` command can be used to produce a multiline subscript or superscript: for example

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

8.3. THE `\SIDESSET` COMMAND There's also a command called `\sideset`, for a rather special purpose: putting symbols at the subscript and superscript corners of a symbol like \sum or \prod . *Note: The `\sideset` command is only designed for use with large operator symbols; with ordinary symbols the results are unreliable.* With `\sideset`, you can write

$$\sum_{\substack{n < k, \\ \text{\textit{n odd}}}} n E_n$$

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; to put an asterisk at each corner of a product symbol, you would type

$$\prod_{**}^{**}$$

9. Other packages of interest Many other L^AT_EX packages that address some aspect of mathematical formulas are available from CTAN (the Comprehensive T_EX Archive Network). To recommend a few examples:

accents Under accents and accents using arbitrary symbols.

amsthm General theorem and proof setup.

bm Bold math package, provides a more general and more robust implementation of `\boldsymbol`.

cases Apply a large brace to two or more equations without losing the individual equation numbers.

delarray Delimiters spanning multiple rows of an array.

kuvio Commutative diagrams and other diagrams.

xypic Commutative diagrams and other diagrams.

rsfs Ralph Smith's Formal Script, font setup.

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