# Short Math Guide for LaTeX

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Version 1.09 (2002-03-22), currently available at
`http://www.ams.org/tex/short-math-guide.html`

**1. Introduction** This is a concise summary of recommended features in LaTeX 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], [LUG], [AMUG], [LFG], [LGG], and [LC]. A certain amount of familiarity with standard LaTeX terminology is assumed; if your memory needs refreshing on the LaTeX meaning of *command*, *optional argument*, *environment*, *package*, and so forth, see [Lamport].

The features described here are available to you if you use LaTeX 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 produce 'Undefined control sequence' messages.

Many noteworthy features found in other packages are not covered here; see Section 10. Regarding math symbols, please note especially that the list given here is not intended to be comprehensive, but to illustrate such symbols as users will normally find already present in their LaTeX system and usable without installing any additional fonts or doing other setup work.

If you have a need for a symbol not shown here, you will probably want to consult *The Comprehensive LaTeX Symbols List* (Pakin):

`http://www.ctan.org/tex-archive/info/symbols/comprehensive/`.

## 2. Inline math formulas and displayed equations

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

| **inline formulas** | **displayed equations** | |
|---|---|---|
| `$ ... $`<br>`\( ... \)` | `\[...\]` | unnumbered |
| | `\begin{equation*}`<br>...<br>`\end{equation*}` | unnumbered |
| | `\begin{equation}`<br>...<br>`\end{equation}` | automatically numbered |

*Note.* Alternative environments `\begin{math}` ... `\end{math}`, `\begin{displaymath}` ... `\end{displaymath}` are seldom needed in practice. Using the plain TeX notation `$$` ... `$$` for displayed equations is not recommended. Although it is not expressly forbidden in LaTeX, it is not documented anywhere in the LaTeX book as being part of the LaTeX command set, and 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.

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

```
\begin{equation}\label{xx}
\begin{split}
a& =b+c-d\\
 & \quad +e-f\\
 & =g+h\\
 & =i
\end{split}
\end{equation}
```

$$\begin{split} a&=b+c-d\\ &\quad +e-f\\ &=g+h\\ &=i \end{split} \tag{2.1}$$

```
\begin{multline}
a+b+c+d+e+f\\
+i+j+k+l+m+n
\end{multline}
```

$$\begin{multline} a+b+c+d+e+f\\ +i+j+k+l+m+n \tag{2.2} \end{multline}$$

```
\begin{gather}
a_1=b_1+c_1\\
a_2=b_2+c_2-d_2+e_2
\end{gather}
```

$$a_1=b_1+c_1 \tag{2.3}$$
$$a_2=b_2+c_2-d_2+e_2 \tag{2.4}$$

```
\begin{align}
a_1& =b_1+c_1\\
a_2& =b_2+c_2-d_2+e_2
\end{align}
```

$$\begin{aligned} a_1&=b_1+c_1 && (2.5)\\ a_2&=b_2+c_2-d_2+e_2 && (2.6) \end{aligned}$$

```
\begin{align}
a_{11}& =b_{11}&
  a_{12}& =b_{12}\\
a_{21}& =b_{21}&
  a_{22}& =b_{22}+c_{22}
\end{align}
```

$$\begin{aligned} a_{11}&=b_{11} & a_{12}&=b_{12} && (2.7)\\ a_{21}&=b_{21} & a_{22}&=b_{22}+c_{22} && (2.8) \end{aligned}$$

```
\begin{flalign*}
a_{11}& =b_{11}&
  a_{12}& =b_{12}\\
a_{21}& =b_{21}&
  a_{22}& =b_{22}+c_{22}
\end{flalign*}
```

$$\begin{aligned} a_{11}&=b_{11} & a_{12}&=b_{12}\\ a_{21}&=b_{21} & a_{22}&=b_{22}+c_{22} \end{aligned}$$

*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.

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}
...
\end{equation}
```

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 TeX 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 $k\mathbin{/}2$. 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 *LaTeX 2ε font selection* [LFG]. 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 LaTeX 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` $\lozenge$
`\leadsto`, see `\rightsquigarrow` $\rightsquigarrow$
`\Join`, see `\bowtie` $\bowtie$
`\lhd`, see `\vartriangleleft` $\vartriangleleft$
`\unlhd`, see `\trianglelefteq` $\trianglelefteq$
`\rhd`, see `\vartriangleright` $\vartriangleright$
`\unrhd`, see `\trianglerighteq` $\trianglerighteq$

Furthermore, there are **many, many additional symbols** available for LaTeX use above and beyond the ones included here. This list is not intended to be comprehensive. For a much more comprehensive list of symbols, including nonmathematically oriented ones such as phonetic alphabetic or dingbats, see *The Comprehensive LaTeX Symbols List* (Pakin):

`http://www.ctan.org/tex-archive/info/symbols/comprehensive/`.

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.

| | | | |
|---|---|---|---|
| $\Gamma$ `\Gamma` | $\alpha$ `\alpha` | $\xi$ `\xi` | $\digamma$ `\digamma` |
| $\Delta$ `\Delta` | $\beta$ `\beta` | $\pi$ `\pi` | $\varepsilon$ `\varepsilon` |
| $\Lambda$ `\Lambda` | $\gamma$ `\gamma` | $\rho$ `\rho` | $\varkappa$ `\varkappa` |
| $\Phi$ `\Phi` | $\delta$ `\delta` | $\sigma$ `\sigma` | $\varphi$ `\varphi` |
| $\Pi$ `\Pi` | $\epsilon$ `\epsilon` | $\tau$ `\tau` | $\varpi$ `\varpi` |
| $\Psi$ `\Psi` | $\zeta$ `\zeta` | $\upsilon$ `\upsilon` | $\varrho$ `\varrho` |
| $\Sigma$ `\Sigma` | $\eta$ `\eta` | $\phi$ `\phi` | $\varsigma$ `\varsigma` |
| $\Theta$ `\Theta` | $\theta$ `\theta` | $\chi$ `\chi` | $\vartheta$ `\vartheta` |
| $\Upsilon$ `\Upsilon` | $\iota$ `\iota` | $\psi$ `\psi` | |
| $\Xi$ `\Xi` | $\kappa$ `\kappa` | $\omega$ `\omega` | |
| $\Omega$ `\Omega` | $\lambda$ `\lambda` | | |
| | $\mu$ `\mu` | | |
| | $\nu$ `\nu` | | |

3.5. Other alphabetic symbols These are also class 0.

| | | | | |
|---|---|---|---|---|
| $\aleph$ `\aleph` | $\complement$ `\complement` | $\hslash$ `\hslash` | $\circledS$ `\circledS` | $\Im$ `\Im` |
| $\beth$ `\beth` | $\ell$ `\ell` | $\mho$ `\mho` | $\Bbbk$ `\Bbbk` | $\Re$ `\Re` |
| $\daleth$ `\daleth` | $\eth$ `\eth` | $\partial$ `\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` | $\nabla$ `\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` | $\infty$ `\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

| | | | |
|---|---|---|---|
| $*$ `*` | $\cdot$ `\cdot` | $\doublebarwedge$ `\doublebarwedge` | $\smallsetminus$ `\smallsetminus` |
| $+$ `+` | $\centerdot$ `\centerdot` | $\gtrdot$ `\gtrdot` | $\sqcap$ `\sqcap` |
| $-$ `-` | $\circ$ `\circ` | $\intercal$ `\intercal` | $\sqcup$ `\sqcup` |
| $\amalg$ `\amalg` | $\circledast$ `\circledast` | $\leftthreetimes$ `\leftthreetimes` | $\star$ `\star` |
| $\ast$ `\ast` | $\circledcirc$ `\circledcirc` | $\lessdot$ `\lessdot` | $\times$ `\times` |
| $\barwedge$ `\barwedge` | $\circleddash$ `\circleddash` | $\ltimes$ `\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` | $\setminus$ `\setminus` | |

*Synonyms:* $\land$ `\land`, $\lor$ `\lor`, $\doublecup$ `\doublecup`, $\doublecap$ `\doublecap`

### 3.8. Relation symbols: $< = > \succ \sim$ and variants

| | | | | |
|---|---|---|---|---|
| $<$ `<` | $\eqslantless$ `\eqslantless` | $\leqq$ `\leqq` | $\ngtr$ `\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` | $\gnapprox$ `\gnapprox` | $\lll$ `\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:* $\ne$ `\ne`, $\le$ `\le`, $\ge$ `\ge`, $\Doteq$ `\Doteq`, $\llless$ `\llless`, $\gggtr$ `\gggtr`

3.9. Relation symbols: arrows See also Section 4.

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

*Synonyms:* $\gets$ \gets, $\to$ \to, $\restriction$ \restriction

3.10. Relation symbols: miscellaneous

$\backepsilon$ \backepsilon
$\because$ \because
$\between$ \between
$\blacktriangleleft$ \blacktriangleleft
$\blacktriangleright$ \blacktriangleright
$\bowtie$ \bowtie
$\dashv$ \dashv
$\frown$ \frown
$\in$ \in
$\mid$ \mid
$\models$ \models
$\ni$ \ni
$\nmid$ \nmid
$\notin$ \notin
$\nparallel$ \nparallel
$\nshortmid$ \nshortmid
$\nshortparallel$ \nshortparallel
$\nsubseteq$ \nsubseteq
$\nsubseteqq$ \nsubseteqq
$\nsupseteq$ \nsupseteq
$\nsupseteqq$ \nsupseteqq
$\ntriangleleft$ \ntriangleleft
$\ntrianglelefteq$ \ntrianglelefteq
$\ntriangleright$ \ntriangleright
$\ntrianglerighteq$ \ntrianglerighteq
$\nvdash$ \nvdash
$\nVdash$ \nVdash
$\nvDash$ \nvDash
$\nVDash$ \nVDash
$\parallel$ \parallel
$\perp$ \perp
$\pitchfork$ \pitchfork
$\propto$ \propto
$\shortmid$ \shortmid
$\shortparallel$ \shortparallel
$\smallfrown$ \smallfrown
$\smallsmile$ \smallsmile
$\smile$ \smile
$\sqsubset$ \sqsubset
$\sqsubseteq$ \sqsubseteq
$\sqsupset$ \sqsupset
$\sqsupseteq$ \sqsupseteq
$\subset$ \subset
$\Subset$ \Subset
$\subseteq$ \subseteq
$\subseteqq$ \subseteqq
$\subsetneq$ \subsetneq
$\subsetneqq$ \subsetneqq
$\supset$ \supset
$\Supset$ \Supset
$\supseteq$ \supseteq
$\supseteqq$ \supseteqq
$\supsetneq$ \supsetneq
$\supsetneqq$ \supsetneqq
$\therefore$ \therefore
$\trianglelefteq$ \trianglelefteq
$\trianglerighteq$ \trianglerighteq
$\varpropto$ \varpropto
$\varsubsetneq$ \varsubsetneq
$\varsubsetneqq$ \varsubsetneqq
$\varsupsetneq$ \varsupsetneq
$\varsupsetneqq$ \varsupsetneqq
$\vartriangle$ \vartriangle
$\vartriangleleft$ \vartriangleleft
$\vartriangleright$ \vartriangleright
$\vdash$ \vdash
$\Vdash$ \Vdash
$\vDash$ \vDash
$\Vvdash$ \Vvdash

*Synonyms:* $\owns$ \owns

3.11. Cumulative (variable-size) operators

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

### 3.12. Punctuation

| | | | | |
|---|---|---|---|---|
| $.$ `.` | $;$ `;` | $?$ `?` | $\cdots$ `\dotsm` | $\vdots$ `\vdots` |
| $/$ `/` | $\colon$ `\colon` | $\cdots$ `\dotsb` | $\ldots$ `\dotso` | |
| $\vert$ `|` | $:$ `:` | $\ldots$ `\dotsc` | $\ddots$ `\ddots` | |
| $,$ `,` | $!$ `!` | $\cdots$ `\dotsi` | | |

*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\to B` $f\colon A\to B$.

*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.

| | | |
|---|---|---|
| $\big( \big)$ `( )` | $\big\lVert \big\rVert$ `\lVert \rVert` | $\big\lgroup \big\rgroup$ `\lgroup \rgroup` |
| $\big[ \big]$ `[ ]` | $\big\langle \big\rangle$ `\langle \rangle` | $\big\lmoustache \big\rmoustache$ `\lmoustache \rmoustache` |
| $\big\lbrace \big\rbrace$ `\lbrace \rbrace` | $\big\lceil \big\rceil$ `\lceil \rceil` | |
| $\big\lvert \big\rvert$ `\lvert \rvert` | $\big\lfloor \big\rfloor$ `\lfloor \rfloor` | |

### 3.14. Nonpairing extensible symbols

| | | | | | | |
|---|---|---|---|---|---|---|
| $\big\vert$ `\vert` | $\big\Vert$ `\Vert` | $\big/$ `/` | $\big\backslash$ `\backslash` | $\big\arrowvert$ `\arrowvert` | $\big\Arrowvert$ `\Arrowvert` | $\big\bracevert$ `\bracevert` |

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

*Synonyms:* $\|$ `\|`

### 3.15. Extensible vertical arrows

| | | | | | |
|---|---|---|---|---|---|
| $\big\uparrow$ `\uparrow` | $\big\Uparrow$ `\Uparrow` | $\big\downarrow$ `\downarrow` | $\big\Downarrow$ `\Downarrow` | $\big\updownarrow$ `\updownarrow` | $\big\Updownarrow$ `\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

| | |
|---|---|
| `\rank(x)` | $\operatorname{rank}(x)$ |
| `\esssup(y,z)` | $\operatorname{ess\,sup}(y,z)$ |

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

When predefining such a named operator is problematic (e.g., when using one in the title or abstract of an article), there is an alternative form that can be used directly:

`\operatorname{rank}(x)` $\rightarrow$ $\operatorname{rank}(x)$

3.18. Math font switches Not all of the fonts necessary to support comprehensive math font switching are commonly available in a typical LaTeX 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 | `\mathbf` | `\mathsf` | `\mathit` | `\mathcal` | `\mathbb` | `\mathfrak` |
|---|---|---|---|---|---|---|
| $X$ | $\mathbf{X}$ | $\mathsf{X}$ | $\mathit{X}$ | $\mathcal{X}$ | $\mathbb{X}$ | $\mathfrak{X}$ |
| $x$ | $\mathbf{x}$ | $\mathsf{x}$ | $\mathit{x}$ | § | $\curvearrowleft$ | $\mathfrak{x}$ |
| $0$ | $\mathbf{0}$ | $\mathsf{0}$ | $\mathit{0}$ | $\prime$ | $\nvdash$ | $\mathfrak{0}$ |
| $[]$ | $[]$ | $[]$ | $[]$ | $[]$ | $[]$ | $[]$ |
| $+$ | $+$ | $+$ | $+$ | $+$ | $+$ | $+$ |
| $-$ | $-$ | $-$ | $-$ | $-$ | $-$ | $-$ |
| $=$ | $=$ | $=$ | $=$ | $=$ | $=$ | $=$ |
| $\Xi$ | $\mathbf{\Xi}$ | $\mathsf{\Xi}$ | $\mathit{\Xi}$ | $\div$ | $\nless$ | $\mathfrak{g}$ |
| $\xi$ | $\xi$ | $\xi$ | $\xi$ | $\xi$ | $\xi$ | $\xi$ |
| $\infty$ | $\infty$ | $\infty$ | $\infty$ | $\infty$ | $\infty$ | $\infty$ |
| $\aleph$ | $\aleph$ | $\aleph$ | $\aleph$ | $\aleph$ | $\aleph$ | $\aleph$ |
| $\sum$ | $\sum$ | $\sum$ | $\sum$ | $\sum$ | $\sum$ | $\sum$ |
| II | II | II | II | II | II | II |
| $\Re$ | $\Re$ | $\Re$ | $\Re$ | $\Re$ | $\Re$ | $\Re$ |

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.

$$A_\infty + \pi A_0 \sim \mathbf{A}_{\boldsymbol{\infty}} \boldsymbol{+} \boldsymbol{\pi} \mathbf{A}_{\boldsymbol{0}} \sim \boldsymbol{A}_{\boldsymbol{\infty}} \boldsymbol{+} \boldsymbol{\pi} \boldsymbol{A}_{\boldsymbol{0}} \tag{3.1}$$

```
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}`.

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

#### 3.18.2. Blackboard Bold letters (msbm; no lowercase)

Usage: `\mathbb{R}`.

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

#### 3.18.3. Fraktur letters (eufm)

Usage: `\mathfrak{S}`.

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

$$\mathfrak{a}\mathfrak{b}\mathfrak{c}\mathfrak{d}\mathfrak{e}\mathfrak{f}\mathfrak{g}\mathfrak{h}\mathfrak{i}\mathfrak{j}\mathfrak{k}\mathfrak{l}\mathfrak{m}\mathfrak{n}\mathfrak{o}\mathfrak{p}\mathfrak{q}\mathfrak{r}\mathfrak{s}\mathfrak{t}\mathfrak{u}\mathfrak{v}\mathfrak{w}\mathfrak{x}\mathfrak{y}\mathfrak{z}$$

## 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.

| | | |
|---|---|---|
| $\widetilde{xxx}$ `\widetilde{xxx}` | $\overbrace{xxx}$ `\overbrace{xxx}` | $\overrightarrow{xxx}$ `\overrightarrow{xxx}` |
| $\widehat{xxx}$ `\widehat{xxx}` | $\underbrace{xxx}$ `\underbrace{xxx}` | $\underrightarrow{xxx}$ `\underrightarrow{xxx}` |
| $\overline{xxx}$ `\overline{xxx}` | $\overleftarrow{xxx}$ `\overleftarrow{xxx}` | $\overleftrightarrow{xxx}$ `\overleftrightarrow{xxx}` |
| $\underline{xxx}$ `\underline{xxx}` | $\underleftarrow{xxx}$ `\underleftarrow{xxx}` | $\underleftrightarrow{xxx}$ `\underleftrightarrow{xxx}` |

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):

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

```
\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: $\overset{*}{X}$. See also the description of `\sideset` in Section 8.4.

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}
```

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

To produce a small matrix suitable for use in text, there is a `smallmatrix` environment (e.g., $\left(\begin{smallmatrix} a&b\\ c&d \end{smallmatrix}\right)$) 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 $r-j$ is odd},\\
    r!\,(-1)^{(r-j)/2}&  \text{if $r-j$ is even}.
  \end{cases}
```

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

*Note.* The plain TeX form `\matrix{...\cr...\cr}` and the related commands `\pmatrix`, `\cases` should be avoided in LaTeX (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 | $34$ |
| `\,` | `\thinspace` | $3\,4$ | `\!` | `\negthinspace` | $3\!4$ |
| `\:` | `\medspace` | $3\:4$ | | `\negmedspace` | $3\negmedspace4$ |
| `\;` | `\thickspace` | $3\;4$ | | `\negthickspace` | $3\negthickspace4$ |
| | `\quad` | $3\quad4$ | | | |
| | `\qquad` | $3\qquad4$ | | | |

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}`.

There are also three commands that leave a space equal to the height and/or width of a given fragment of LaTeX material:

| **Example** | **Result** |
|---|---|
| `\phantom{XXX}` | space as wide and high as three X's |
| `\hphantom{XXX}` | space as wide as three X's; height 0 |
| `\vphantom{X}` | space of width 0, height = height of X |

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 $A_1A_2\dotsm$,
and the infinite integral
\[\int_{A_1}\int_{A_2}\dotsi\].
```

We have the series $A_1,A_2,\dotsc$, the regional sum $A_1+A_2+\dotsb$, the orthogonal product $A_1A_2\dotsm$, and the infinite integral

$$\int_{A_1}\int_{A_2}\dotsi.$$

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{\frac{n}{n-1} S}` $\sqrt{\frac{n}{n-1}S}$, `\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:

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

```
\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 LaTeX's guess about the proper size to use for the fraction's contents (t = text-style, d = display-style).

$$\frac{1}{k}\log_2 c(f)\;\tfrac{1}{k}\log_2 c(f)\; \tag{5.1}$$

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

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

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

$$2^k-\binom{k}{1}2^{k-1}+\binom{k}{2}2^{k-2} \tag{5.3}$$

```
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 pt—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 LaTeX document is not recommended (see, e.g., `amsmath.faq`).

5.4. CONTINUED FRACTIONS The continued fraction

$$\cfrac{1}{\sqrt{2}+\cfrac{1}{\sqrt{2}+\cfrac{1}{\sqrt{2}+\dotsb}}} \tag{5.4}$$

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 | `\left` `\right` | `\bigl` `\bigr` | `\Bigl` `\Bigr` | `\biggl` `\biggr` | `\Biggl` `\Biggr` |
|---|---|---|---|---|---|---|
| Result | $(b)(\frac{c}{d})$ | $\left(b\right)\left(\frac{c}{d}\right)$ | $\bigl(b\bigr)\bigl(\frac{c}{d}\bigr)$ | $\Bigl(b\Bigr)\Bigl(\frac{c}{d}\Bigr)$ | $\biggl(b\biggr)\biggl(\frac{c}{d}\biggr)$ | $\Biggl(b\Biggr)\Biggl(\frac{c}{d}\Biggr)$ |

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:

$$\left[\sum_i a_i\left\lvert\sum_j x_{ij}\right\rvert^p\right]^{1/p} \quad\text{versus}\quad \biggl[\sum_i a_i\Bigl\lvert\sum_j x_{ij}\Bigr\rvert^p\biggr]^{1/p}$$

```
\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.

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

```
\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 $\left|\frac{b'}{d'}\right|$ 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: $\bigl|\frac{b'}{d'}\bigr|$.

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|` produces $|k|=|-k|$. Using `\lvert` for a "left vert bar" and `\rvert` for a "right vert bar" whenever they are used in pairs will prevent this problem: compare $\lvert -k\rvert$, produced by `\lvert -k\rvert`. 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 $\lvert z\rvert$ and `\norm{v}` would produce $\lVert v\rVert$.

**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.

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

```
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.

$$\gcd(n,m\bmod n);\quad x\equiv y\pmod b;\quad x\equiv y\mod c;\quad x\equiv y\pod d \tag{7.2}$$

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

## 8. Integrals and sums

8.1. Altering the placement of limits The limits on integrals, sums, and similar symbols are placed either to the side of or above and below the base symbol, depending on convention and context. LaTeX has rules for automatically choosing one or the other, and most of the time the results are satisfactory. In the event they are not, there are three LaTeX commands that can be used to influence the placement of the limits: `\limits`, `\nolimits`, `\displaylimits`. Compare

$$\int_{|x-x_z(t)|<X_0} z^6(t)\phi(x) \quad \text{and} \quad \int\limits_{|x-x_z(t)|<X_0} z^6(t)\phi(x)$$

`\int_{\abs{x-x_z(t)}<X_0} ...` `\int\limits_{\abs{x-x_z(t)}<X_0} ...`

The `\limits` command should follow immediately after the base symbol to which it applies, and its meaning is: shift the following subscript and/or superscript to the limits position, regardless of the usual convention for this symbol. `\nolimits` means to shift them to the side instead, and `\displaylimits`, which might be used in defining a new kind of base symbol, means to use standard positioning as for the `\sum` command.

See also the description of the `intlimits` and `nosumlimits` options in [AMUG].

8.2. 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` is an extension of the same idea that gives two integral signs with dots between them.

$$\iint\limits_A f(x,y)\,dx\,dy \qquad \iiint\limits_A f(x,y,z)\,dx\,dy\,dz \tag{8.1}$$

$$\iiiint\limits_A f(w,x,y,z)\,dw\,dx\,dy\,dz \qquad \idotsint\limits_A f(x_1,\dots,x_k) \tag{8.2}$$

8.3. Multiline subscripts and superscripts The `\substack` command can be used to produce a multiline subscript or superscript: for example

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

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

8.4. The `\sideset` 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

```
\sideset{}{'}
  \sum_{n<k,\;\text{$n$ odd}} nE_n
```

$$\sideset{}{'}\sum_{n<k,\;\text{$n$ odd}} nE_n$$

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

```
\sideset{_*^*}{_*^*}\prod
```

$$\sideset{_*^*}{_*^*}\prod$$

**9. Changing the size of elements in a formula** The LaTeX mechanisms for changing font size inside a math formula are completely different from the ones used outside math formulas. If you try to make something larger in a formula with one of the text commands such as `\large` or `\huge`:

$$\#$$ `{\large \#}`

you will get a warning message

```
Command \large invalid in math mode
```

Such an attempt, however, often indicates a misunderstanding of how LaTeX math symbols work. If you want a # symbol analogous to a summation sign in its typographical properties, then in principle the best way to achieve that is to define it as a symbol of type "mathop" with the standard LaTeX `\DeclareMathSymbol` command (see [LFG]).

[In this particular example it is currently unlikely that you will be able to lay your hands on a math font with a suitable text-size/display-size pair, but that is probably best understood as a problem of inadequate fonts, not as a LaTeX problem.]

Consider the expression:

$$\frac{\sum_{n > 0} z^n}{\prod_{1\leq k\leq n} (1-q^k)}$$

```
\frac{\sum_{n > 0} z^n}
     {\prod_{1\leq k\leq n} (1-q^k)}
```

Using `\dfrac` instead of `\frac` wouldn't change anything in this case; if you want the sum and product symbols to appear full size, you need the `\displaystyle` command:

$$\frac{{\displaystyle\sum_{n > 0} z^n}}{{\displaystyle\prod_{1\leq k\leq n} (1-q^k)}}$$

```
\frac{{\displaystyle\sum_{n > 0} z^n}}
     {{\displaystyle\prod_{1\leq k\leq n} (1-q^k)}}
```

And if you want full-size symbols but with limits on the side, use the nolimits command also:

$$\frac{{\displaystyle\sum\nolimits_{n> 0} z^n}}{{\displaystyle\prod\nolimits_{1\leq k\leq n} (1-q^k)}}$$

```
\frac{{\displaystyle\sum\nolimits_{n> 0} z^n}}
  {{\displaystyle\prod\nolimits_{1\leq k\leq n} (1-q^k)}}
```

There are similar commands `\textstyle`, `\scriptstyle`, and `\scriptscriptstyle`, to force LaTeX to use the symbol size and spacing that would be applied in (respectively) inline math, first-order subscript, or second-order order subscript, even when the current context would normally yield some other size.

**Note:** These commands belong to a special class of commands referred to in the LaTeX book as "declarations". In particular, notice where the braces fall that delimit the effect of the command:

**Right:**`{\displaystyle ...}`**Wrong:**`\displaystyle{...}`

**10. Other packages of interest** Many other LaTeX packages that address some aspect of mathematical formulas are available from CTAN (the Comprehensive TeX 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.

The TeX Catalogue,

`http://www.tex.ac.uk/tex-archive/help/Catalogue/catalogue.html`,

is a good place to look if you know a package's name.

### 11. Other documentation of interest

### References


[AMUG] American Mathematical Society: *User's Guide for the* `amsmath` *package*, `amsldoc.tex`, 1999.

[CLSL] Pakin, Scott: *The Comprehensive LaTeX Symbols List*, `http://www.ctan.org/tex-archive/info/symbols/comprehensive/`, July 2001.

[Lamport] Lamport, Leslie: *LaTeX: a document preparation system*, 2nd edition, Addison-Wesley, 1994.

[LC] Goossens, Michel; Mittelbach, Frank; Samarin, Alexander: *The LaTeX Companion*, Addison-Wesley, 1994.

[LFG] LaTeX3 Project Team: *LaTeX 2ε font selection*, `fntguide.tex`, 1994.

[LGC] Goossens, Michel; Rahtz, Sebastian; Mittelbach, Frank: *The LaTeX Graphics Companion*, Addison Wesley Longman, 1997.

[LGG] Carlisle, D. P.: *Packages in the 'graphics' bundle*, `grfguide.tex`, 1995.

[LUG] LaTeX3 Project Team: *LaTeX 2ε for authors*, `usrguide.tex`, 1994.