# The TEXbook

The fine print in the upper right-hand
corner of each page is a draft of intended
index entries; it won't appear in the real book.
Some index entries will be in `typewriter type`
and/or preceded by \ or enclosed in ⟨...⟩, etc;
such typographic distinctions aren't shown here.
An index entry often extends for several pages;
the actual scope will be determined later.
Please note things that should be indexed but aren't.

symbols in math, table

Now that the font layouts have all been displayed, it's time to consider the names of the various mathematical symbols. Plain TEX defines more than 200 control sequences by which you can refer to math symbols without having to find their numerical positions in the layouts. It's generally best to call a symbol by its name, for then you can easily adapt your manuscripts to other fonts, and your manuscript will be much more readable.

The symbols divide naturally into groups based on their mathematical class (Ord, Op, Bin, Rel, Open, Close, or Punct), so we shall follow that order as we discuss them. N.B.: Unless otherwise stated, math symbols are available only in math modes. For example, if you say '`\alpha`' in horizontal mode, TEX will report an error and try to insert a `$` sign.

*1. Lowercase Greek letters.*

| | | | | | |
|---|---|---|---|---|---|
| $\alpha$ | `\alpha` | $\iota$ | `\iota` | $\varrho$ | `\varrho` |
| $\beta$ | `\beta` | $\kappa$ | `\kappa` | $\sigma$ | `\sigma` |
| $\gamma$ | `\gamma` | $\lambda$ | `\lambda` | $\varsigma$ | `\varsigma` |
| $\delta$ | `\delta` | $\mu$ | `\mu` | $\tau$ | `\tau` |
| $\epsilon$ | `\epsilon` | $\nu$ | `\nu` | $\upsilon$ | `\upsilon` |
| $\varepsilon$ | `\varepsilon` | $\xi$ | `\xi` | $\phi$ | `\phi` |
| $\zeta$ | `\zeta` | $o$ | `o` | $\varphi$ | `\varphi` |
| $\eta$ | `\eta` | $\pi$ | `\pi` | $\chi$ | `\chi` |
| $\theta$ | `\theta` | $\varpi$ | `\varpi` | $\psi$ | `\psi` |
| $\vartheta$ | `\vartheta` | $\rho$ | `\rho` | $\omega$ | `\omega` |

alpha
iota
varrho
beta
kappa
sigma
gamma
lambda
varsigma
delta
mu
tau
epsilon
nu
upsilon
varepsilon
xi
phi
zeta
varphi
eta
pi
chi
theta
varpi
psi
vartheta
rho
omega

There's no `\omicron`, because it would look the same as `o`. Notice that the letter `\upsilon` ($\upsilon$) is a bit wider than `v` ($v$); both of them should be distinguished from `\nu` ($\nu$). Similarly, `\varsigma` ($\varsigma$) should not be confused with `\zeta` ($\zeta$). It turns out that `\varsigma` and `\upsilon` are almost never used in math formulas; they are included in plain TEX primarily because they are sometimes needed in short Greek citations (cf. Appendix J).

omicron
Gamma
Xi
Phi
Delta
Pi
Psi
Theta
Sigma
Omega
Lambda
Upsilon

*2. Uppercase Greek letters.*

| | | | | | |
|---|---|---|---|---|---|
| $\Gamma$ | `\Gamma` | $\Xi$ | `\Xi` | $\Phi$ | `\Phi` |
| $\Delta$ | `\Delta` | $\Pi$ | `\Pi` | $\Psi$ | `\Psi` |
| $\Theta$ | `\Theta` | $\Sigma$ | `\Sigma` | $\Omega$ | `\Omega` |
| $\Lambda$ | `\Lambda` | $\Upsilon$ | `\Upsilon` | | |

Alpha
Beta

The other Greek capitals appear in the roman alphabet (`\Alpha` $\equiv$ `{\rm A}`, `\Beta` $\equiv$ `{\rm B}`, etc.). It's conventional to use unslanted letters for uppercase Greek, and slanted letters for lowercase Greek; but you can obtain ($\mit\Gamma, \mit\Delta, \ldots, \mit\Omega$) by typing `$({\mit\Gamma}, {\mit\Delta}, \ldots, {\mit\Omega})$`.

mit

*3. Calligraphic capitals.* To get the letters $\mathcal{A} \ldots \mathcal{Z}$ that appear in Figure 5, type `${\cal A}\ldots{\cal Z}$`. Several other alphabets are also used with mathematics (notably Fraktur, script, and "blackboard bold"); they don't come with plain TEX, but more elaborate formats like $\mathcal{AMS}$-TEX do provide them.

calligraphic letters
Fraktur
script
blackboard bold

*4. Miscellaneous symbols of type Ord.*

| | | |
|---|---|---|
| $\aleph$ `\aleph` | $\prime$ `\prime` | $\forall$ `\forall` |
| $\hbar$ `\hbar` | $\emptyset$ `\emptyset` | $\exists$ `\exists` |
| $\imath$ `\imath` | $\nabla$ `\nabla` | $\neg$ `\neg` |
| $\jmath$ `\jmath` | $\surd$ `\surd` | $\flat$ `\flat` |
| $\ell$ `\ell` | $\top$ `\top` | $\natural$ `\natural` |
| $\wp$ `\wp` | $\bot$ `\bot` | $\sharp$ `\sharp` |
| $\Re$ `\Re` | $\|$ `\|` | $\clubsuit$ `\clubsuit` |
| $\Im$ `\Im` | $\angle$ `\angle` | $\diamondsuit$ `\diamondsuit` |
| $\partial$ `\partial` | $\triangle$ `\triangle` | $\heartsuit$ `\heartsuit` |
| $\infty$ `\infty` | $\backslash$ `\backslash` | $\spadesuit$ `\spadesuit` |

The dotless letters `\imath` and `\jmath` should be used when $i$ and $j$ are accented; for example, `$\hat\imath$` yields $\hat\imath$. The `\prime` symbol is intended for use in subscripts and superscripts, as explained in Chapter 16, so you usually see it in a smaller size. On the other hand, the `\angle` symbol has been built up from other pieces; it does not get smaller when it appears in a subscript or superscript.

*5. Digits.* To get italic digits *0123456789*, say `{\it0123456789}`; to get boldface digits **0123456789**, say `{\bf0123456789}`; to get oldstyle digits 0123456789, say `{\oldstyle0123456789}`. These conventions work also outside of math mode.

*6. "Large" operators.* The following symbols come in two sizes, for text and display styles:

| | | |
|---|---|---|
| $\sum$ $\sum$ `\sum` | $\cap$ $\bigcap$ `\bigcap` | $\odot$ $\bigodot$ `\bigodot` |
| $\prod$ $\prod$ `\prod` | $\cup$ $\bigcup$ `\bigcup` | $\otimes$ $\bigotimes$ `\bigotimes` |
| $\coprod$ $\coprod$ `\coprod` | $\sqcup$ $\bigsqcup$ `\bigsqcup` | $\oplus$ $\bigoplus$ `\bigoplus` |
| $\int$ $\int$ `\int` | $\vee$ $\bigvee$ `\bigvee` | $\uplus$ $\biguplus$ `\biguplus` |
| $\oint$ $\oint$ `\oint` | $\wedge$ $\bigwedge$ `\bigwedge` | |

It is important to distinguish these large Op symbols from the similar but smaller Bin symbols whose names are the same except for a '`big`' prefix. Large operators usually occur at the beginning of a formula or subformula, and they usually are subscripted; binary operations usually occur between two symbols or subformulas, and they rarely are subscripted. For example,

`$\bigcup_{n=1}^m(x_n\cup y_n)$` yields $\bigcup_{n=1}^m(x_n\cup y_n)$

The large operators `\sum`, `\prod`, `\coprod`, and `\int` should also be distinguished from smaller symbols called `\Sigma` ($\Sigma$), `\Pi` ($\Pi$), `\amalg` ($\amalg$), and `\smallint` ($\smallint$), respectively; the `\smallint` operator is rarely used.

aleph
prime
forall
hbar
emptyset
exists
imath
nabla
neg
jmath
surd
flat
ell
top
natural
wp
bot
sharp
Re
escvert
clubsuit
Im
angle
diamondsuit
partial
triangle
heartsuit
infty
backslash
spadesuit
Weierstrass, see wp
dotless letters
accent
digits
sum
bigcap
bigodot
prod
bigcup
bigotimes
coprod
bigsqcup
bigoplus
int
bigvee
biguplus
oint
bigwedge
binary operations
smallint

*7. Binary operations.* Besides + and −, you can type

| | | |
|---|---|---|
| $\pm$ `\pm` | $\cap$ `\cap` | $\vee$ `\vee` |
| $\mp$ `\mp` | $\cup$ `\cup` | $\wedge$ `\wedge` |
| $\setminus$ `\setminus` | $\uplus$ `\uplus` | $\oplus$ `\oplus` |
| $\cdot$ `\cdot` | $\sqcap$ `\sqcap` | $\ominus$ `\ominus` |
| $\times$ `\times` | $\sqcup$ `\sqcup` | $\otimes$ `\otimes` |
| $*$ `\ast` | $\triangleleft$ `\triangleleft` | $\oslash$ `\oslash` |
| $\star$ `\star` | $\triangleright$ `\triangleright` | $\odot$ `\odot` |
| $\diamond$ `\diamond` | $\wr$ `\wr` | $\dagger$ `\dagger` |
| $\circ$ `\circ` | $\bigcirc$ `\bigcirc` | $\ddagger$ `\ddagger` |
| $\bullet$ `\bullet` | $\bigtriangleup$ `\bigtriangleup` | $\amalg$ `\amalg` |
| $\div$ `\div` | $\bigtriangledown$ `\bigtriangledown` | |

It's customary to say `$G\backslash H$` to denote double cosets of $G$ by $H$ ($G\backslash H$), and `$p\backslash n$` to mean that $p$ divides $n$ ($p\backslash n$); but `$X\setminus Y$` denotes the elements of set $X$ minus those of set $Y$ ($X \setminus Y$). Both operations use the same symbol, but `\backslash` is type Ord, while `\setminus` is type Bin (so TEX puts more space around it).

*8. Relations.* Besides <, >, and =, you can type

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

The symbols `\mid` and `\parallel` define relations that use the same characters as you get from `|` and `\|`; TEX puts space around them when they are relations.

*9. Negated relations.* Many of the relations just listed can be negated or "crossed out" by prefixing them with `\not`, as follows:

| | | |
|---|---|---|
| $\not<$ `\not<` | $\not>$ `\not>` | $\not=$ `\not=` |
| $\not\leq$ `\not\leq` | $\not\geq$ `\not\geq` | $\not\equiv$ `\not\equiv` |
| $\not\prec$ `\not\prec` | $\not\succ$ `\not\succ` | $\not\sim$ `\not\sim` |
| $\not\preceq$ `\not\preceq` | $\not\succeq$ `\not\succeq` | $\not\simeq$ `\not\simeq` |
| $\not\subset$ `\not\subset` | $\not\supset$ `\not\supset` | $\not\approx$ `\not\approx` |
| $\not\subseteq$ `\not\subseteq` | $\not\supseteq$ `\not\supseteq` | $\not\cong$ `\not\cong` |
| $\not\sqsubseteq$ `\not\sqsubseteq` | $\not\sqsupseteq$ `\not\sqsupseteq` | $\not\asymp$ `\not\asymp` |

pm
cap
vee
mp
cup
wedge
setminus
uplus
oplus
cdot
sqcap
ominus
times
sqcup
otimes
ast
triangleleft
oslash
star
triangleright
odot
diamond
wr
dagger
circ
bigcirc
ddagger
bullet
bigtriangleup
amalg
div
bigtriangledown
leq
geq
equiv
prec
succ
approx
preceq
succeq
propto
ll
gg
asymp
subset
supset
sim
subseteq
supseteq
simeq
sqsubseteq
sqsupseteq
cong
in
ni
bowtie
vdash
dashv
models
smile
mid
doteq
frown
parallel
perp
not

The symbol `\not` is a relation character of width zero, so it will overlap a relation that comes immediately after it. The positioning isn't always ideal, because some relation symbols are wider than others; for example, `\not\in` gives '$\not\in$', but it is preferable to have a steeper cancellation, '$\notin$'. The latter symbol is available as a special control sequence called `\notin`. The definition of `\notin` in Appendix B indicates how similar symbols can be constructed.

*10. Arrows.* There's also another big class of relations, namely those that point:

| | | |
|---|---|---|
| $\leftarrow$ `\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` |
| $\rightleftharpoons$ `\rightleftharpoons` | | |

Up and down arrows will grow larger, like delimiters (see Chapter 17). To put symbols over left and right arrows, plain TEX provides a `\buildrel` macro: You type `\buildrel`⟨superscript⟩`\over`⟨relation⟩, and the superscript is placed on top of the relation just as limits are placed over large operators. For example,

$\xrightarrow{\alpha\beta}$ `\buildrel \alpha\beta \over \longrightarrow`

$\overset{\text{def}}{=}$ `\buildrel \rm def \over =`

(In this context, '`\over`' does not define a fraction.)

*11. Openings.* The following left delimiters are available, besides '(':

| | | |
|---|---|---|
| $[$ `\lbrack` | $\lfloor$ `\lfloor` | $\lceil$ `\lceil` |
| $\{$ `\lbrace` | $\langle$ `\langle` | |

You can also type simply '`[`' to get `\lbrack`. All of these will grow if you prefix them by `\bigl`, `\Bigl`, `\biggl`, `\Biggl`, or `\left`. Chapter 17 also mentions `\lgroup` and `\lmoustache`, which are available in sizes greater than `\big`. If you need more delimiters, the following combinations work reasonably well in the normal text size:

| | | |
|---|---|---|
| $[\![$ `\lbrack\!\lbrack` | $\langle\!\langle$ `\langle\!\langle` | $(($ `(\!(` |

*12. Closings.* The corresponding right delimiters are present too:

| | | |
|---|---|---|
| $]$ `\rbrack` | $\rfloor$ `\rfloor` | $\rceil$ `\rceil` |
| $\}$ `\rbrace` | $\rangle$ `\rangle` | |

Everything that works for openings works also for closings, but reversed.

notin
arrows
leftarrow
longleftarrow
uparrow
Leftarrow
Longleftarrow
Uparrow
rightarrow
longrightarrow
downarrow
Rightarrow
Longrightarrow
Downarrow
leftrightarrow
longleftrightarrow
updownarrow
Leftrightarrow
Longleftrightarrow
Updownarrow
mapsto
longmapsto
nearrow
hookleftarrow
hookrightarrow
searrow
leftharpoonup
rightharpoonup
swarrow
leftharpoondown
rightharpoondown
nwarrow
rightleftharpoons
buildrel
over
left delimiters
lbrack
lbrace
langle
lfloor
lceil
bigl
Bigl
biggl
Biggl
left
lgroup
lmoustache
rbrack
rbrace
rangle
rfloor
rceil

colon
colon
ldotp
cdotp
ldots
cdots
ne
neq
le
ge
to
gets
owns
land
lor
lnot
vert
iff

*13. Punctuation.* TEX puts a thin space after commas and semicolons that appear in mathematical formulas, and it does the same for a colon that is called `\colon`. (Otherwise a colon is considered to be a relation, as in '$x := y$' and '$a : b :: c : d$', which you type by saying '`$x:=y$`' and '`$a:b::c:d$`'.) Examples of `\colon` are

| | |
|---|---|
| $f\colon A \rightarrow B$ | `$f\colon A\rightarrow B$` |
| $L(a,b;c\colon x,y;z)$ | `$L(a,b;c\colon x,y;z)$` |

Plain TEX also defines `\ldotp` and `\cdotp` to be '.' and '$\cdot$' with the spacing of commas and semicolons. These symbols don't occur directly in formulas, but they are useful in the definition of `\ldots` and `\cdots`.

*14. Alternate names.* If you don't like plain TEX's name for some math symbol—for example, if there's another name that looks better or that you can remember more easily—the remedy is simple: You just say, e.g., '`\let\cupcap=\asymp`'. Then you can type '`f(n)\cupcap n`' instead of '`f(n)\asymp n`'.

Some symbols have alternate names that are so commonly used that plain TEX provides two or more equivalent control sequences:

| | | |
|---|---|---|
| $\neq$ | `\ne` or `\neq` | (same as `\not=`) |
| $\leq$ | `\le` | (same as `\leq`) |
| $\geq$ | `\ge` | (same as `\geq`) |
| { | `\{` | (same as `\lbrace`) |
| } | `\}` | (same as `\rbrace`) |
| $\rightarrow$ | `\to` | (same as `\rightarrow`) |
| $\leftarrow$ | `\gets` | (same as `\leftarrow`) |
| $\ni$ | `\owns` | (same as `\ni`) |
| $\wedge$ | `\land` | (same as `\wedge`) |
| $\vee$ | `\lor` | (same as `\vee`) |
| $\neg$ | `\lnot` | (same as `\neg`) |
| \| | `\vert` | (same as `\|`) |
| $\|$ | `\Vert` | (same as `\\|`) |

There's also `\iff` ( $\iff$ ), which is just like `\Longleftrightarrow` except that it puts an extra thick space at each side.

*15. Non-math symbols.* Plain TEX makes four special symbols available outside of math mode, although the characters themselves are actually typeset from the math symbols font:

| | |
|---|---|
| § | `\S` |
| ¶ | `\P` |
| † | `\dag` |
| ‡ | `\ddag` |

These control sequences do not act like ordinary math symbols; they don't change their size when they appear in subscripts or superscripts, and you must say, e.g.,