Typesetting Mathematics

LaTeX: A Professional Document Preparation System

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Agenda

1. Mathematical Expression
2. Mathematics Symbols
3. Equations
4. Brackets and Parentheses
5. Matrices
6. Adding text to equations
7. Formatting mathematics symbols
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Mathematical Expression

```
Let $x_0 = x_1 = 2^0 = 1$, define
\[ x_{n+2} = x_{n+1}^2 + x_{n}^{2n} \]
such that $n \leq 100$.
```

Let $x_0 = x_1 = 2^0 = 1$, define

$$x_{n+2} = x_{n+1}^2 + x_n^{2n}$$

such that $n \leq 100$.

Mathematics Packages

Typesetting mathematics is one of LaTeX's greatest strengths. It is also a large topic due to the existence of so much mathematical notation.

```
\usepackage{mathtools}
\usepackage{amssymb}
\usepackage{amsthm}
```

```
\usepackage{mathtools, amssymb, amsthm}
```

These packages introduces several new commands that are more powerful and flexible than the ones provided by basic LaTeX.

Math Mode: In-Line Style

```
Let $x\in\mathbb{R}$
 ↪  be a distance
 ↪  between points
 ↪  $a$ and $b$.
```

Let $x \in \mathbb{R}$ be a distance between points a and b.

```
Let
 ↪  \(x\in\mathbb{R}\)
 ↪  be a distance
 ↪  between points
 ↪  \(a\) and \(b\).
```

Let $x \in \mathbb{R}$ be a distance between points a and b.

Math Mode: Display Style

```
Let $x\in\mathbb{R}$ be
↪  a distance between
↪  points $a$ and $b$.
↪  Therefore,
$$ x = \sqrt{a^2+b^2}
↪  $$
```

Let $x \in \mathbb{R}$ be a distance between points a and b. Therefore,

$$x = \sqrt{a^2 + b^2}$$

```
Let $x\in\mathbb{R}$ be
↪  a distance between
↪  points $a$ and $b$.
↪  Therefore,
\[ x = \sqrt{a^2+b^2}
↪  \]
```

Let $x \in \mathbb{R}$ be a distance between points a and b. Therefore,

$$x = \sqrt{a^2 + b^2}$$

Avoid using the $$ ... $$, as it may cause problems.

Symbols

The following is a set of symbols that can be accessed directly from the keyboard:

```
+ - = ! / ( ) [ ] < > | ' : *
```

Beyond those listed above, distinct commands must be issued in order to display the desired symbols, e.g.,

```
\forall x \in X, \quad \exists y \leq \epsilon
```

$$\forall x \in X, \quad \exists y \leq \epsilon$$

Greek Letters

```
\alpha, \beta, \gamma, \Gamma, \pi, \Pi, \phi, \varphi
```

$$\alpha, \beta, \gamma, \Gamma, \pi, \Pi, \phi, \varphi$$

Symbol	Script	Symbol	Script
A and α	`A` and `\alpha`	N and ν	`N` and `\nu`
B and β	`B` and `\beta`	Ξ and ξ	`\Xi` and `\xi`
Γ and γ	`\Gamma` and `\gamma`	O and o	`O` and `o`
Δ and δ	`\Delta` and `\delta`	Π, π and ϖ	`\Pi`, `\pi` and `\varpi`
E, ϵ and ε	`E`, `\epsilon` and `\varepsilon`	P, ρ and ϱ	`P`, `\rho` and `\varrho`
Z and ζ	`Z` and `\zeta`	Σ, σ and ς	`\Sigma`, `\sigma` and `\varsigma`
H and η	`H` and `\eta`	T and τ	`T` and `\tau`
Θ, θ and ϑ	`\Theta`, `\theta` and `\vartheta`	Y, Υ and υ	`Y`, `\Upsilon` and `\upsilon`
I and ι	`I` and `\iota`	Φ, ϕ, and φ	`\Phi`, `\phi` and `\varphi`
K, κ and $\varkappa$	`K`, `\kappa` and `\varkappa`	X and χ	`X` and `\chi`
Λ and λ	`\Lambda` and `\lambda`	Ψ and ψ	`\Psi` and `\psi`
M and μ	`M` and `\mu`	Ω and ω	`\Omega` and `\omega`

Operators

An operator is a function that is written as a word: e.g. trigonometric functions (**sin, cos, tan, . . .**), logarithms (**log/ln**), exponentials (**exp**), limits (**lim**), as well as trace (**tr**) and determinant (**det**).

```
\cos (2\theta) = \cos^2
↪  \theta - \sin^2
↪  \theta
```

$$\cos(2\theta) = \cos^2\theta - \sin^2\theta$$

For certain operators such as limits, the subscript is placed underneath the operator:

```
\lim\limits_{x \to
↪  \infty} \exp(-x) =
↪  0
```

$$\lim_{x\to\infty} \exp(-x) = 0$$

Modular Operator

For the modular operator there are two commands:

```
a \bmod b
```

$$a \bmod b$$

```
x \equiv a \pmod{b}
```

$$x \equiv a \pmod{b}$$

Powers and indices

Powers and indices are equivalent to superscripts and subscripts in normal text mode.

- The caret (^) character is used to raise something.
- The underscore (_) is for lowering.

```
k_{n+1} = n^2 + k_n^2 -
↪  k_{n-1}
```

$$k_{n+1} = n^2 + k_n^2 - k_{n-1}$$

```
n^{22}
```

$$n^{22}$$

```
f(n) = n^5 +
↪  kn^2|_{k=17}
```

$$f(n) = n^5 + kn^2|_{k=17}$$

Fractions and Binomials

A fraction is created using the `\frac{numerator}{denominator}` command. Likewise, the binomial coefficient may be written using the `\binom` command.

```
\frac{n!}{k!(n-k)!} =
↪  \binom{n}{k}
```

$$\frac{n!}{k!(n-k)!} = \binom{n}{k}$$

You can embed fractions within fractions:

```
\frac{ \frac{1}{x} +
↪  \frac{1}{y} }{y-z}
```

$$\frac{\frac{1}{x} + \frac{1}{y}}{y - z}$$

Continued Fractions

A continued fraction is created using the `\cfrac{numerator}{denominator}` command.

```
x = a_0 + \cfrac{1}{a_1
        + \cfrac{1}{a_2
        + \cfrac{1}{a_3 +
        ↪  \cfrac{1}{a_4}
        ↪  } } }
```

$$x = a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3 + \cfrac{1}{a_4}}}}$$

Roots

The `\sqrt` command creates a square root surrounding an expression.

```
\sqrt{\frac{a}{b}}
```

$$\sqrt{\frac{a}{b}}$$

You can embed fractions within fractions:

```
\sqrt[n]{1+x+x^2+\dots+x^n}
```

$$\sqrt[n]{1+x+x^2+\cdots+x^n}$$

Sums and Integrals

The \sum and \int commands insert the sum and integral symbols respectively.

```
\sum_{i=1}^{10} t_i
```

$$\sum_{i=1}^{10} t_i$$

```
\displaystyle\sum_{i=1}^{10} t_i
```

$$\displaystyle\sum_{i=1}^{10} t_i$$

```
\int_0^\infty
↪  \mathrm{e}^{-x}\,\mathrm{d}x
```

$$\int_0^\infty \mathrm{e}^{-x}\,\mathrm{d}x$$

```
\int\limits_a^b
```

$$\int\limits_a^b$$

Substacks

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

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

`\sum`	$\sum$	`\prod`	$\prod$	`\coprod`	$\coprod$
`\bigoplus`	$\bigoplus$	`\bigotimes`	$\bigotimes$	`\bigodot`	$\bigodot$
`\bigcup`	$\bigcup$	`\bigcap`	$\bigcap$	`\biguplus`	$\biguplus$
`\bigsqcup`	$\bigsqcup$	`\bigvee`	$\bigvee$	`\bigwedge`	$\bigwedge$
`\int`	$\int$	`\oint`	$\oint$	`\iint` [3]	$\iint$
`\iiint` [3]	$\iiint$	`\iiiint` [3]	$\iiiint$	`\idotsint` [3]	$\int\cdots\int$

Numbering Equations

```
Let $x\in\mathbb{R}$ be a distance between
 ↪  points $a$ and $b$. Therefore,
\begin{equation}
 x = \sqrt{a^2+b^2}
\end{equation}
```

Let $x \in \mathbb{R}$ be a distance between points a and b. Therefore,

$$x = \sqrt{a^2 + b^2}. \tag{1}$$

Align Equations

```
\begin{align}
(x+y)^2 &= 2xy, \\
2(x+y)^2 &= 4xy, \\
2x^2+2y^2 &= 0.
\end{align}
```

$$(x+y)^2 = 2xy, \quad (2)$$
$$2(x+y)^2 = 4xy, \quad (3)$$
$$2x^2 + 2y^2 = 0. \quad (4)$$

Align Equations (No Numbering)

```
\begin{align*}
(x+y)^2 & = 2xy,  \\
2(x+y)^2 & = 4xy, \\
2x^2+2y^2 & = 0.
\end{align*}
```

$$
\begin{aligned}
(x+y)^2 &= 2xy, \\
2(x+y)^2 &= 4xy, \\
2x^2+2y^2 &= 0.
\end{aligned}
$$

Align Equations (Some Numbering)

```
\begin{align}
(x+y)^2 &= 2xy,  \\
\nonumber
2(x+y)^2 &= 4xy, \\
2x^2+2y^2 &= 0.
\end{align}
```

$$(x+y)^2 = 2xy, \tag{5}$$
$$2(x+y)^2 = 4xy,$$
$$2x^2+2y^2 = 0. \tag{6}$$

An Aligned Equation

```
1 \begin{equation}
2 \begin{aligned}
3 x_{n+2} &= x_{n+1} +
  ↪  x_{n}, \\
4 x_0 &= 0, \\
5 x_1 &= 1.
6 \end{aligned}^^I
7 \end{equation}
```

$$\begin{aligned} x_{n+2} &= x_{n+1} + x_{n}, \\ x_0 &= 0, \\ x_1 &= 1. \end{aligned} \tag{7}$$

Brackets and Parentheses

Types	Commands	Results
Parentheses	`(x+y)`	$(x+y)$
Brackets	`[x+y]`	$[x+y]$
Braces	`\{x+y\}`	$\{x+y\}$
Angle Brackets	`\langle x+y \rangle`	$\langle x+y \rangle$
Pipes	`|x+y|`	$\|x+y\|$
Double Pipes	`\\|x+y\\|`	$\|\|x+y\|\|$

Brackets and Parentheses

```
F = G   \left(
            \frac{m_1
            ↪  m_2}{r^2}
        \right)
```

$$F = G\left(\frac{m_1 m_2}{r^2}\right)$$

```
\left[
    \frac{N}{\left(
    ↪  \frac{L}{p}
    ↪  \right) - (m+n)}
\right]
```

$$\left[\frac{N}{\left(\frac{L}{p}\right) - (m+n)}\right]$$

Matrices

```
\begin{matrix}
1 & 2 & 3\\
a & b & c
\end{matrix}
```

$$\begin{matrix}
1 & 2 & 3\\
a & b & c
\end{matrix}$$

```
\begin{pmatrix}
1 & 2 & 3\\
a & b & c
\end{pmatrix}
```

$$\begin{pmatrix}
1 & 2 & 3\\
a & b & c
\end{pmatrix}$$

Matrices

```
\begin{bmatrix}
1 & 2 & 3\\
a & b & c
\end{bmatrix}
```

$$\begin{bmatrix} 1 & 2 & 3 \\ a & b & c \end{bmatrix}$$

```
\begin{Bmatrix}
1 & 2 & 3\\
a & b & c
\end{Bmatrix}
```

$$\begin{Bmatrix} 1 & 2 & 3 \\ a & b & c \end{Bmatrix}$$

Matrices

```
\begin{vmatrix}
1 & 2 & 3\\
a & b & c
\end{vmatrix}
```

$$\begin{vmatrix} 1 & 2 & 3 \\ a & b & c \end{vmatrix}$$

```
\begin{Vmatrix}
1 & 2 & 3\\
a & b & c
\end{Vmatrix}
```

$$\begin{Vmatrix} 1 & 2 & 3 \\ a & b & c \end{Vmatrix}$$

Matrices

```
\left\langle
\begin{matrix}
1 & 2 & 3\\
a & b & c
\end{matrix}
\right\rvert
```

$$\left\langle \begin{matrix} 1 & 2 & 3 \\ a & b & c \end{matrix} \right\rvert$$

```
\left\lVert
\begin{matrix}
1 & 2 & 3\\
a & b & c
\end{matrix}
\right\rangle
```

$$\left\lVert \begin{matrix} 1 & 2 & 3 \\ a & b & c \end{matrix} \right\rangle$$

Matrices

```
A_{m,n} =
 \begin{pmatrix}
  a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\
  a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\
  \vdots  & \vdots  & \ddots & \vdots  \\
  a_{m,1} & a_{m,2} & \cdots & a_{m,n}
 \end{pmatrix}
```

$$A_{m,n} = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m,1} & a_{m,2} & \cdots & a_{m,n} \end{pmatrix}$$

Adding text to equations

Unformatted Text:

```
50 \text{ apples} \times 100 \text{ apples}
 = \text{lots of apples}^2
```

$$50 \text{ apples} \times 100 \text{ apples} = \text{lots of apples}^2$$

Formatted Text:

```
50 \textrm{ apples} \times 100
 \textbf{ apples} = \textit{lots of apples}^2
```

$$50 \textrm{ apples} \times 100 \textbf{ apples} = \textit{lots of apples}^2$$

Formatting mathematics symbols

Command	Sample
`\mathnormal{ ... }`	$\mathnormal{ABCDEF\ abcdef\ 123456}$
`\mathrm{ ... }`	$\mathrm{ABCDEF\ abcdef\ 123456}$
`\mathit{ ... }`	$\mathit{ABCDEF\ abcdef\ 123456}$
`\mathbf{ ... }`	$\mathbf{ABCDEF\ abcdef\ 123456}$
`\mathsf{ ... }`	$\mathsf{ABCDEF\ abcdef\ 123456}$
`\mathtt{ ... }`	$\mathtt{ABCDEF\ abcdef\ 123456}$
`\mathfrak{ ... }`	$\mathfrak{ABCDEF\ abcdef\ 123456}$
`\mathcal{ ... }`	$\mathcal{ABCDEF}$
`\mathbb{ ... }`	$\mathbb{ABCDEF}$

Accents

`a'` or `a^{\prime}`	a'	`a''`	a''
`\hat{a}`	$\hat{a}$	`\bar{a}`	$\bar{a}$
`\grave{a}`	$\grave{a}$	`\acute{a}`	$\acute{a}$
`\dot{a}`	$\dot{a}$	`\ddot{a}`	$\ddot{a}$
`\not{a}`	$\not{a}$	`\mathring{a}`	$\mathring{a}$
`\overrightarrow{AB}`	$\overrightarrow{AB}$	`\overleftarrow{AB}`	$\overleftarrow{AB}$
`a'''`	a'''	`a''''`	a''''
`\overline{aaa}`	$\overline{aaa}$	`\check{a}`	$\check{a}$
`\breve{a}`	$\breve{a}$	`\vec{a}`	$\vec{a}$
`\dddot{a}` [3]		`\ddddot{a}` [3]	
`\widehat{AAA}`	$\widehat{AAA}$	`\widetilde{AAA}`	$\widetilde{AAA}$
`\stackrel\frown{AAA}`	$A\stackrel{\frown}{A}A$		
`\tilde{a}`	$\tilde{a}$	`\underline{a}`	$\underline{a}$

Controlling horizontal spacing

```
f(n) =
  \begin{cases}
    n/2         & \quad \text{if } n \text{ is even}\\
    -(n+1)/2    & \quad \text{if } n \text{ is odd}
  \end{cases}
```

$$f(n) = \begin{cases} n/2 & \text{if } n \text{ is even} \\ -(n+1)/2 & \text{if } n \text{ is odd} \end{cases}$$

Command	Space Size
\quad	11pt
\qquad	22pt
\,	3/18 of quad
\:	4/18 of quad
\;	5/18 of quad
\!	-3/18 of quad

Relational Symbols

Symbol	Script	Symbol	Script	Symbol	Script	Symbol	Script	Symbol	Script
$<$	`<`	$>$	`>`	$=$	`=`	$\parallel$	`\parallel`	$\nparallel$	`\nparallel`
$\leq$	`\leq`	$\geq$	`\geq`	$\doteq$	`\doteq`	$\asymp$	`\asymp`	$\bowtie$	`\bowtie`
$\ll$	`\ll`	$\gg$	`\gg`	$\equiv$	`\equiv`	$\vdash$	`\vdash`	$\dashv$	`\dashv`
$\subset$	`\subset`	$\supset$	`\supset`	$\approx$	`\approx`	$\in$	`\in`	$\ni$	`\ni`
$\subseteq$	`\subseteq`	$\supseteq$	`\supseteq`	$\cong$	`\cong`	$\smile$	`\smile`	$\frown$	`\frown`
$\nsubseteq$	`\nsubseteq`	$\nsupseteq$	`\nsupseteq`	$\simeq$	`\simeq`	$\models$	`\models`	$\notin$	`\notin`
$\sqsubset$	`\sqsubset`	$\sqsupset$	`\sqsupset`	$\sim$	`\sim`	$\perp$	`\perp`	$\mid$	`\mid`
$\sqsubseteq$	`\sqsubseteq`	$\sqsupseteq$	`\sqsupseteq`	$\propto$	`\propto`	$\prec$	`\prec`	$\succ$	`\succ`
$\preceq$	`\preceq`	$\succeq$	`\succeq`	$\neq$	`\neq`	$\sphericalangle$	`\sphericalangle`	$\measuredangle$	`\measuredangle`
$\therefore$	`\therefore`	$\because$	`\because`						

Binary Operations

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

Set/Logic Notations

Symbol	Script	Symbol	Script
$\exists$	`\exists`	$\rightarrow$	`\rightarrow` or `\to`
$\nexists$	`\nexists`	$\leftarrow$	`\leftarrow` or `\gets`
$\forall$	`\forall`	$\mapsto$	`\mapsto`
$\neg$	`\neg`	$\implies$	`\implies`
$\cap$	`\cap`		
$\cup$	`\cup`		
$\subset$	`\subset`	$\impliedby$	`\impliedby`
$\supset$	`\supset`	$\Rightarrow$	`\Rightarrow` or `\implies`
$\in$	`\in`	$\leftrightarrow$	`\leftrightarrow`
$\notin$	`\notin`	$\iff$	`\iff`
$\ni$	`\ni`	$\Leftrightarrow$	`\Leftrightarrow` (preferred for equivalence (iff))
$\land$	`\land`	$\top$	`\top`
$\lor$	`\lor`	$\bot$	`\bot`
$\angle$	`\angle`	$\emptyset$ and $\varnothing$	`\emptyset` and `\varnothing` [1]
		$\rightleftharpoons$	`\rightleftharpoons`

Delimiters and Other Symbols

Symbol	Script	Symbol	Script	Symbol	Script	Symbol	Script
$\vert$	`|` or `\mid` (difference in spacing)	$\Vert$	`\\|`	$/$	`/`	$\backslash$	`\backslash`
$\{$	`\{`	$\}$	`\}`	$\langle$	`\langle`	$\rangle$	`\rangle`
$\uparrow$	`\uparrow`	$\Uparrow$	`\Uparrow`	$\lceil$	`\lceil`	$\rceil$	`\rceil`
$\downarrow$	`\downarrow`	$\Downarrow$	`\Downarrow`	$\lfloor$	`\lfloor`	$\rfloor$	`\rfloor`

Symbol	Script	Symbol	Script	Symbol	Script	Symbol	Script	Symbol	Script
∂	`\partial`	$\imath$	`\imath`	$\Re$	`\Re`	∇	`\nabla`	$\aleph$	`\aleph`
$\eth$	`\eth`	$\jmath$	`\jmath`	$\Im$	`\Im`	$\Box$	`\Box`	$\beth$	`\beth`
$\hbar$	`\hbar`	ℓ	`\ell`	$\wp$	`\wp`	∞	`\infty`	$\gimel$	`\gimel`

Symbol	Script	Symbol	Script	Symbol	Script	Symbol	Script
$\sin$	`\sin`	$\arcsin$	`\arcsin`	$\sinh$	`\sinh`	$\sec$	`\sec`
$\cos$	`\cos`	$\arccos$	`\arccos`	$\cosh$	`\cosh`	$\csc$	`\csc`
$\tan$	`\tan`	$\arctan$	`\arctan`	$\tanh$	`\tanh`		
$\cot$	`\cot`	arccot	`\arccot`	$\coth$	`\coth`		

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