# LaTeX Math for Undergrads

**Rule One** Any mathematics at all, even a single character, gets a mathematical setting. Thus, for "the value of $x$ is 7" enter `the value of $x$ is $7$`.

**Template** Your document should contain at least this.

```
\documentclass{article}
\usepackage{mathtools,amssymb,amsthm} % imports amsmath

\begin{document}
  --document body here--
\end{document}
```

## Common constructs

| | | | |
|---|---|---|---|
| $x^2$ | `x^2` | $\sqrt{2}$, $\sqrt[n]{3}$ | `\sqrt{2}`, `\sqrt[n]{3}` |
| $x_{i,j}$ | `x_{i,j}` | $\frac{2}{3}$, $2/3$ | `\frac{2}{3}`, `2/3` |

**Calligraphic letters** Use as in `$\mathcal{A}$`.

$$\mathcal{ABCDEFGHIJKLMNOPQRSTUVWXYZ}$$

Get script letters, such as $\mathscr{P}$ from `$\mathscr{P}$`, by putting `\usepackage{mathrsfs}` in the preamble.

## Greek

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

## Sets and logic

| | | | | | |
|---|---|---|---|---|---|
| $\cup$ | `\cup` | $\mathbb{R}$ | `\mathbb{R}` | $\forall$ | `\forall` |
| $\cap$ | `\cap` | $\mathbb{Z}$ | `\mathbb{Z}` | $\exists$ | `\exists` |
| $\subset$ | `\subset` | $\mathbb{Q}$ | `\mathbb{Q}` | $\neg$ | `\neg` |
| $\subseteq$ | `\subseteq` | $\mathbb{N}$ | `\mathbb{N}` | $\vee$ | `\vee` |
| $\supset$ | `\supset` | $\mathbb{C}$ | `\mathbb{C}` | $\wedge$ | `\wedge` |
| $\supseteq$ | `\supseteq` | $\varnothing$ | `\varnothing` | $\vdash$ | `\vdash` |
| $\in$ | `\in` | $\emptyset$ | `\emptyset` | $\models$ | `\models` |
| $\notin$ | `\notin` | $\aleph$ | `\aleph` | $\setminus$ | `\setminus` |

Negate an operator, as in $\not\subset$, with `\not\subset`. Get the set complement $A^{\mathsf{c}}$ with `A^{\mathsf{c}}` (or $A^{\complement}$ with `A^{\complement}`, or $\overline{A}$ with `\overline{A}`).

## Decorations

| | | | | | |
|---|---|---|---|---|---|
| $f'$ | `f'` | $\dot{a}$ | `\dot{a}` | $\tilde{x}$ | `\tilde{x}` |
| $f''$ | `f''` | $\ddot{a}$ | `\ddot{a}` | $\bar{x}$ | `\bar{x}` |
| $\Sigma^*$ | `\Sigma^{*}` | $\hat{x}$ | `\hat{x}` | $\vec{x}$ | `\vec{x}` |

If the decorated letter is $i$ or $j$ then some decorations need `\imath` or `\jmath`, as in `\vec{\imath}`. Some authors use boldface for vectors: `\boldsymbol{x}`.

Entering `\overline{x+y}` produces $\overline{x+y}$, and `\widehat{x+y}` gives $\widehat{x+y}$. Comment on an expression as here (there is also `\overbrace{..}`).

$$\underbrace{x+y}_{|A|} \quad \texttt{\underbrace\{x+y\}\_\{|A|\}}$$

**Dots** Use low dots in a list $\{0, 1, 2, \ldots\}$, entered as `\{0,1,2,\,\ldots\}`. (If you use `\ldots` in plain text as with `London, Paris, \ldots{}\,.` then note the thinspace `\,` before the period.) Use centered dots in a sum or product $1+\cdots+100$, entered as `1+\cdots+100`. You can also get vertical dots `\vdots` and diagonal dots `\ddots`.

**Roman names** Enter `\tan(x)`, with a backslash, instead of `tan(x)`. These get the same treatment.

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

## Other symbols

| | | | | | |
|---|---|---|---|---|---|
| $<$ | `<` | $\angle$ | `\angle` | $\cdot$ | `\cdot` |
| $\leq$ | `\leq` | $\measuredangle$ | `\measuredangle` | $\pm$ | `\pm` |
| $>$ | `>` | $\ell$ | `\ell` | $\mp$ | `\mp` |
| $\geq$ | `\geq` | $\parallel$ | `\parallel` | $\times$ | `\times` |
| $\neq$ | `\neq` | $45°$ | `45^{\circ}` | $\div$ | `\div` |
| $\ll$ | `\ll` | $\cong$ | `\cong` | $*$ | `\ast` |
| $\gg$ | `\gg` | $\ncong$ | `\ncong` | $\mid$ | `\mid` |
| $\approx$ | `\approx` | $\sim$ | `\sim` | $\nmid$ | `\nmid` |
| $\asymp$ | `\asymp` | $\simeq$ | `\simeq` | $n!$ | `n!` |
| $\equiv$ | `\equiv` | $\nsim$ | `\nsim` | $\partial$ | `\partial` |
| $\prec$ | `\prec` | $\oplus$ | `\oplus` | $\nabla$ | `\nabla` |
| $\preceq$ | `\preceq` | $\ominus$ | `\ominus` | $\hbar$ | `\hbar` |
| $\succ$ | `\succ` | $\odot$ | `\odot` | $\circ$ | `\circ` |
| $\succeq$ | `\succeq` | $\otimes$ | `\otimes` | $\star$ | `\star` |
| $\propto$ | `\propto` | $\oslash$ | `\oslash` | $\surd$ | `\surd` |
| $\doteq$ | `\doteq` | $\upharpoonright$ | `\upharpoonright` | ✓ | `\checkmark` |

Use `a\mid b` for the divides relation, $a \mid b$, and `a\nmid b` for the negation, $a \nmid b$. Also use `\mid` to get set builder notation $\{a \in S \mid a \text{ is odd}\}$, with `\{a\in S\mid\text{$a$ is odd}\}`.

## Arrows

| | | | |
|---|---|---|---|
| $\to$ | `\rightarrow`, `\to` | $\mapsto$ | `\mapsto` |
| $\nrightarrow$ | `\nrightarrow` | $\longmapsto$ | `\longmapsto` |
| $\longrightarrow$ | `\longrightarrow` | $\leftarrow$ | `\leftarrow` |
| $\Rightarrow$ | `\Rightarrow` | $\leftrightarrow$ | `\leftrightarrow` |
| $\nRightarrow$ | `\nRightarrow` | $\downarrow$ | `\downarrow` |
| $\Longrightarrow$ | `\Longrightarrow` | $\uparrow$ | `\uparrow` |
| $\leadsto$ | `\leadsto` | $\updownarrow$ | `\updownarrow` |

The right arrows in the first column have matching left arrows, such as `\nleftarrow`, and there are some other matches for down arrows, etc.

**Variable-sized operators** The summation $\sum_{j=0}^{3} j^2$ `\sum_{j=0}^3 j^2` and the integral $\int_{x=0}^{3} x^2\,dx$ `\int_{x=0}^3 x^2\,dx` expand when displayed.

$$\sum_{j=0}^{3} j^2 \qquad \int_{x=0}^{3} x^2\,dx$$

These do the same.

| | | | | | |
|---|---|---|---|---|---|
| $\int$ | `\int` | $\iiint$ | `\iiint` | $\bigcup$ | `\bigcup` |
| $\iint$ | `\iint` | $\oint$ | `\oint` | $\bigcap$ | `\bigcap` |

**Fences**

| | | | | | |
|---|---|---|---|---|---|
| $(\,)$ | `()` | $\langle\,\rangle$ | `\langle\rangle` | $\vert\,\vert$ | `\| \|` |
| $[\,]$ | `[]` | $\lfloor\,\rfloor$ | `\lfloor\rfloor` | $\Vert\,\Vert$ | `\\| \\|` |
| $\{\,\}$ | `\{\}` | $\lceil\,\rceil$ | `\lceil\rceil` | | |

Fix the size with `\big`, `\Big`, `\bigg`, or `\Bigg`.

$$\Big[\sum_{k=0}^{n} e^{k^2}\Big] \quad \texttt{\textbackslash Big[\textbackslash sum\_\{k=0\}\textasciicircum n e\textasciicircum\{k\textasciicircum 2\}\textbackslash Big]}$$

To have them grow with the enclosed formula, use `\left` and `\right` (although sometimes `\big`, etc., are necessary).

$$\left\langle i, 2^{2^i} \right\rangle \quad \texttt{\textbackslash left\textbackslash langle i,2\textasciicircum\{2\textasciicircum i\}\textbackslash right\textbackslash rangle}$$

Every `\left` must match a `\right` and they must end on the same line in the output. For a one-sided fence, put a `\left.` or `\right.` on the other side.

$$\left.\frac{df}{dx}\right|_{x_0} \quad \texttt{\textbackslash left.\textbackslash frac\{df\}\{dx\}\textbackslash right|\_\{x\_0\}}$$

**Arrays, Matrices** Make an array of mathematical text as you make a table of plain text.

$$\begin{array}{rcl} 0 & \leftrightarrow & 0 \\ 1 & \leftrightarrow & 1 \\ 2 & \leftrightarrow & 4 \\ \vdots & & \vdots \end{array}$$

```
\begin{array}{rcl}
  0 &\leftrightarrow &0 \\
  1 &\leftrightarrow &1 \\
  2 &\leftrightarrow &4 \\
  \vdots &  &\vdots
\end{array}
```

Definition by cases is an array with two columns.

$$f_n = \begin{cases} a & \text{if } n=0 \\ r\cdot f_{n-1} & \text{else} \end{cases}$$

```
f_n=
\begin{cases}
 a     &\text{if $n=0$} \\
 r\cdot f_{n-1} &\text{else}
\end{cases}
```

A matrix is an array with fences. With a `pmatrix` environment, you need not specify column alignments.

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}$$

```
\begin{pmatrix}
  a  &b \\
  c  &d
\end{pmatrix}
```

For the determinant use `|A|` inline and `vmatrix` in display.

**Spacing in mathematics** Improve $\sqrt{2}x$ to $\sqrt{2}\,x$ with a thin space, as in `\sqrt{2}\,x`. Slightly wider are `\:` and `\;` (the three are in ratio $3:4:5$). Get the improvement of $n/\log n$ instead of $n/\log n$ by using a negative thin space, as in `n/\!\log n`. Bigger spaces are: `\quad` for $\rightarrow\quad\leftarrow$, and `\qquad` for $\rightarrow\qquad\leftarrow$, which are useful between parts of a display. Get arbitrary space as in `\hspace*{0.5cm}`.

**Displayed equations** The `equation*` environment puts an equation on a separate line.

$$S = k\cdot\lg W$$

```
\begin{equation*}
  S=k\cdot\lg W
\end{equation*}
```

You can break into multiple lines.

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \cdots$$

```
\begin{multline*}
  \sin (x)=x-\frac{x^3}{3!} \\
      +\frac{x^5}{5!}-\cdots
\end{multline*}
```

Align equations using `align*`

$$\begin{aligned} \nabla\cdot\boldsymbol{D} &= \rho \\ \nabla\cdot\boldsymbol{B} &= 0 \end{aligned}$$

```
\begin{align*}
  \nabla\cdot\boldsymbol{D} &= \rho \\
  \nabla\cdot\boldsymbol{B} &= 0
\end{align*}
```

(the left or right side of an alignment can be empty). For each environment, get a numbered version by dropping the asterisk from the name.

**Calculus examples** The last three here are display style.

$f\colon \mathbb{R}\to\mathbb{R}$ `f\colon\mathbb{R}\to\mathbb{R}`

$9.8\ \mathrm{m/s^2}$ `9.8~\text{m}/\text{s}^2`

$\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}$ `\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}`

$\int x^2\,dx = x^3/3+C$ `\int x^2\,dx=x^3/3+C`

$\nabla = \boldsymbol{i}\frac{d}{dx}+\boldsymbol{j}\frac{d}{dy}+\boldsymbol{k}\frac{d}{dz}$ `\nabla=\boldsymbol{i}\frac{d}{dx}+\cdots`

**Discrete mathematics examples** There are four modulo forms: $m \bmod n$ is from `m\bmod n`, and $a \equiv b \pmod m$ is from `a\equiv b\pmod m`, and $a \equiv b \mod m$ is from `a\equiv b\mod m`, and $a \equiv b\ (m)$ is from `a\equiv b\pod m`.

For combinations the binomial symbol $\binom{n}{k}$ is from `\binom{n}{k}`. This resizes to be bigger in a display (to require the display version use `\dbinom{n}{k}` and require the inline version with `\tbinom{n}{k}`).

For permutations use $n^{\underline{r}}$ from `n^{\underline{r}}` (some authors use $P(n,r)$, or ${}_nP_r$ from `{}_nP_r`).

**Statistics examples**

$\sigma^2 = \sqrt{\sum(x_i-\mu)^2/N}$ `\sigma^2=\sqrt{\,\sum (x_i-\mu)^2/N}`

$E(X) = \mu_X = \sum(x_i - P(x_i))$ `E(X)=\mu_X=\sum (x_i-P(x_i))`

The probability density of the normal distribution

$$\frac{1}{\sqrt{2\sigma^2\pi}}\,e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

comes from this.

```
\frac{1}{sqrt{2\sigma^2\pi}}
   \,e^{-\frac{(x-\mu)^2}{2\sigma^2}}!.
```

**For more** See also the Comprehensive LaTeX Symbols List at `mirror.ctan.org/info/symbols/comprehensive` and DeTeXify at `detexify.kirelabs.org/classify.html`.

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