Mathematics (1)

# LaTeX

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# Outlines

# Introduction (Mathematical expressions' modes)

## Inline mode:

```
\( f(x) = x^2 \)
$ f(x) = x^2 $
\begin{math} f(x) = x^2 \end{math}
```

## Display mode:

```
\[ f(x) = x^2 \]
$$ f(x) = x^2 $$
\begin{displaymath} f(x) = x^2 \end{displaymath}
\begin{equation} f(x) = x^2 \end{equation}
```

```
\usepackage{amsmath}
```

## Introduction (Mathematical expressions' modes)

**The well known Pythagorean theorem `\(x^2 + y^2 = z^2\)` was proved to be invalid for other exponents. Meaning the next equation has no integer solutions:**

`\[ x^n + y^n = z^n \]`

The well known Pythagorean theorem $x^2 + y^2 = z^2$ was proved to be invalid for other exponents. Meaning the next equation has no integer solutions:

$$x^n + y^n = z^n$$

# Inline mode

In physics, the mass-energy equivalence is stated by the equation `$E=mc^2$`, discovered in 1905 by Albert Einstein.

In physics, the mass-energy equivalence is stated by the equation $E = mc^2$, discovered in 1905 by Albert Einstein.

## Display mode

```latex
The mass-energy equivalence is described by the famous equation

$$E=mc^2$$

discovered in 1905 by Albert Einstein.
In natural units ($c$ = 1), the formula expresses the identity
\begin{equation}
        E=m
\end{equation}
```

The mass-energy equivalence is described by the famous equation

$$E = mc^2$$

discovered in 1905 by Albert Einstein. In natural units ($c = 1$), the formula expresses the identity

$$E = m \tag{1}$$

# Common math symbols

## Greek letters

\alpha \beta \gamma \rho

\sigma \delta \epsilon

$\alpha\ \beta\ \gamma\ \rho\ \sigma\ \delta\ \epsilon$

## Binary operators

\times \otimes \oplus \cup \cap

$\times\ \otimes\ \oplus\ \cup\ \cap$

## Relation operators

< > \subset \supset \subseteq \supseteq

$<\ >\ \subset\ \supset\ \subseteq\ \supseteq$

## Others

\int \oint \sum \prod

$$\int\ \oint\ \sum\ \prod$$

## Subscripts and superscripts

```
\[ \int\limits_0^1 x^2 + y^2 \ dx \]
```

$$\int\limits_0^1 x^2 + y^2 \ dx$$

```
\[ a_1^2 + a_2^2 = a_3^2 \]
```

$$a_1^2 + a_2^2 = a_3^2$$

```
\[ x^{2\alpha} - 1 = y_{ij} + y_{ij} \]
```

$$x^{2\alpha} - 1 = y_{ij} + y_{ij}$$

```
\[ (a^n)^{r+s} = a^{nr+ns} \]
```

$$(a^n)^{r+s} = a^{nr+ns}$$

```
\[ \sum_{i=1}^{\infty} \frac{1}{n^s}
   = \prod_p \frac{1}{1 - p^{-s}} \]
```

$$\sum_{i=1}^{\infty} \frac{1}{n^s} = \prod_p \frac{1}{1 - p^{-s}}$$

# Subscripts and superscripts

| LaTeX markup | Renders as |
|---|---|
| a_{n_i} | $a_{n_i}$ |
| \int_{i=1}^n | $\int_{i=1}^n$ |
| \sum_{i=1}^{\infty} | $\sum_{i=1}^{\infty}$ |
| \prod_{i=1}^n | $\prod_{i=1}^n$ |
| \cup_{i=1}^n | $\cup_{i=1}^n$ |
| \cap_{i=1}^n | $\cap_{i=1}^n$ |
| \oint_{i=1}^n | $\oint_{i=1}^n$ |
| \coprod_{i=1}^n | $\coprod_{i=1}^n$ |

# Brackets and Parentheses

```
\[
\left \{
\begin{tabular}{ccc}
        1 & 5 & 8 \\
        0 & 2 & 4 \\
        3 & 3 & -8
\end{tabular}
\right \}
\]
```

$$\left\{ \begin{array}{ccc} 1 & 5 & 8 \\ 0 & 2 & 4 \\ 3 & 3 & \text{-8} \end{array} \right\}$$

**Manually sized brackets**

```
\[
\Bigg \langle 3x+7 \bigg \rangle
\]
```

Manually sized brackets

$$\Bigg\langle 3x+7 \bigg\rangle$$

# Brackets and Parentheses

| LaTeX markup | Renders as |
|---|---|
| \big( \Big( \bigg( \Bigg( | $\big( \Big( \bigg( \Bigg($ |
| \big] \Big] \bigg] \Bigg] | $\big] \Big] \bigg] \Bigg]$ |
| \big\{ \Big\{ \bigg\{ \Bigg\{ | $\big\{ \Big\{ \bigg\{ \Bigg\{$ |
| \big \langle \Big \langle \bigg \langle \Bigg \langle | $\big\langle \Big\langle \bigg\langle \Bigg\langle$ |
| \big \rangle \Big \rangle \bigg \rangle \Bigg \rangle | $\big\rangle \Big\rangle \bigg\rangle \Bigg\rangle$ |

## Fractions and Binomials

The binomial coefficient is defined by the next expression:

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

The binomial coefficient is difined by the next expression:

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

```
\usepackage{amsmath}
```

## Binomial coefficients

The binomial coefficient is defined by the next expression:

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

And of course this command can be included in the normal text flow `\(\binom{n}{k}\)`.

The binomial coefficient is defined by the next expression:

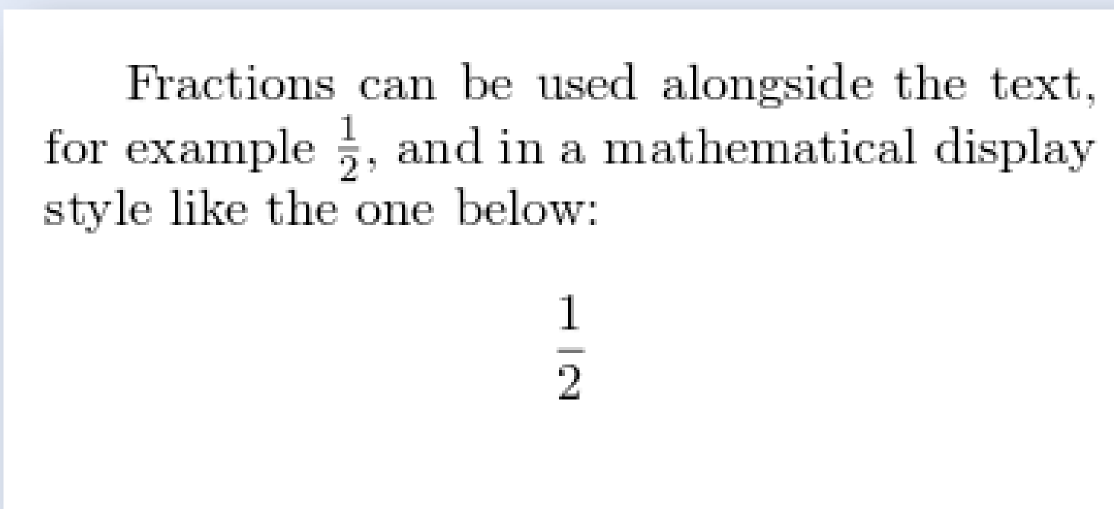
$$\binom{n}{k} = \frac{n!}{k!(n-k)!}$$

And of course this command can be included in the normal text flow $\binom{n}{k}$.

## Displaying fractions

**Fractions can be used alongside the text, for example `\( \frac{1}{2} \)`, and in a mathematical display style like the one below:**

**`\[\frac{1}{2}\]`**


Fractions can be used alongside the text, for example $\frac{1}{2}$, and in a mathematical display style like the one below:

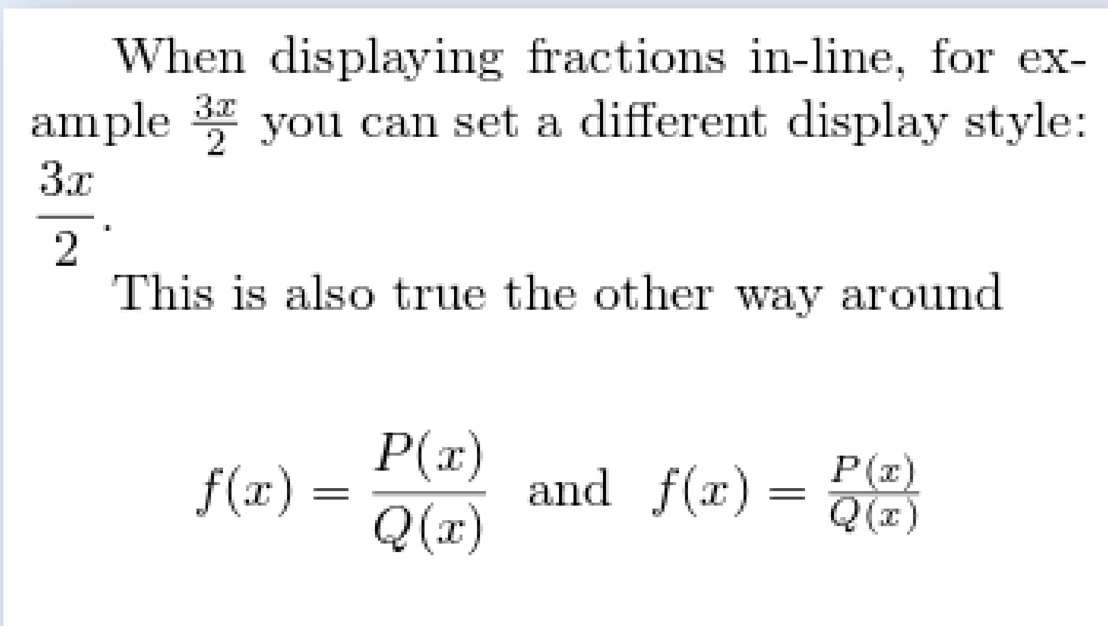
$$\frac{1}{2}$$

## Displaying fractions

When displaying fractions in-line, for example \(\frac{3x}{2}\) you can set a different display style: \(\displaystyle \frac{3x}{2} \)

This is also true the other way around

\[ f(x)=\frac{P(x)}{Q(x)} \ \ \textrm{and} \ \ f(x)=\textstyle\frac{P(x)}{Q(x)} \]


When displaying fractions in-line, for example $\frac{3x}{2}$ you can set a different display style: $\displaystyle\frac{3x}{2}$.

This is also true the other way around

$$f(x)=\frac{P(x)}{Q(x)} \ \ \textrm{and} \ \ f(x)=\textstyle\frac{P(x)}{Q(x)}$$

## Continued fractions

**The fractions can be nested**

```
\[ \frac{1+\frac{a}{b}}{1+\frac{1}{1+\frac{1}{a}}} \]
```

**Now a wild example**

```
\[ a_0+\cfrac{1}{a_1+\cfrac{1}{a_2+\cfrac{1}{a_3+\cdots}}} \]
```

The fractions can be nested

$$\frac{1+\frac{a}{b}}{1+\frac{1}{1+\frac{1}{a}}}$$

Now a wild example

$$a_0+\cfrac{1}{a_1+\cfrac{1}{a_2+\cfrac{1}{a_3+\cdots}}}$$

# Continued fractions

**Final example**

```
\newcommand*{\contfrac}[2]{
{ \rlap{$\dfrac{1}{\phantom{#1}}$}
\genfrac{}{}{0pt}{0}{}{#1+#2}
}}
\[
a_0 + \contfrac{a_1}{
\contfrac{a_2}{
\contfrac{a_3}{
\genfrac{}{}{0pt}{0}{}{\ddots}
}}}
\]
```

Final example

$$a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3 + \ddots}}}$$

# Aligning equations with amsmath

```
\begin{equation}
\label{eq1}
\begin{split}
A & = \frac{\pi r^2}{2} \\
  & = \frac{1}{2} \pi r^2
\end{split}
\end{equation}
```

$$\begin{split} A &= \frac{\pi r^2}{2} \\ &= \frac{1}{2} \pi r^2 \end{split} \qquad (1)$$

# Aligning equations with amsmath

```
\begin{equation}
\label{eu_eqn}
e^{\pi i} + 1 = 0
\end{equation}
```

**The beautiful equation \ref{eu_eqn} is known as the Euler equation**

$$e^{\pi i} - 1 = 0 \qquad (1)$$

The beautiful equation 1 is known as the Euler equation

## Displaying long equations

```
\begin{multline*}
p(x) = 3x^6 + 14x^5y + 590x^4y^2 + 19x^3y^3\\
- 12x^2y^4 - 12xy^5 + 2y^6 - a^3b^3
\end{multline*}
```

$$\begin{multline*}
p(x) = 3x^6 + 14x^5y + 590x^4y^2 + 19x^3y^3\\
- 12x^2y^4 - 12xy^5 + 2y^6 - a^3b^3
\end{multline*}$$

# Aligning several equations

```
\begin{align*}
2x - 5y & = 8 \\
3x + 9y & = -12
\end{align*}
```

$$\begin{aligned} 2x - 5y &= 8 \\ 3x + 9y &= -12 \end{aligned}$$

```
\begin{align*}
x&=y & w &=z & a&=b+c\\
2x&=-y & 3w&=\frac{1}{2}z & a&=b\\
-4 + 5x&=2+y & w+2&=-1+w & ab&=cb
\end{align*}
```

$$\begin{aligned} x&=y & w &=z & a&=b+c\\ 2x&=-y & 3w&=\frac{1}{2}z & a&=b\\ -4 + 5x&=2+y & w+2&=-1+w & ab&=cb \end{aligned}$$

# Grouping and centering equations

```
\begin{gather*}
2x - 5y = 8 \\
3x^2 + 9y = 3a + c
\end{gather*}
```

$$2x - 5y = 8$$
$$3x^2 + 9y = 3a + c$$

# Operators

Examples of mathematical operators

```
\[
\sin(a + b ) = \sin(a)\cos(b) + \cos(b)\sin(a)
\]
```

Examples of mathematical operators

$$\sin(a+b) = \sin(a)\cos(b) + \cos(b)\sin(a)$$

# Operators in different contexts

Testing notation for limits

```
\[
\lim_{h \rightarrow 0 } \frac{f(x+h)-f(x)}{h}
\]
```

This operator changes when used alongside text
```
\( \lim_{x \rightarrow h} (x-h) \).
```

Testing notation for limits

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

This operator changes when used alongside text $\lim_{x \to h}(x-h)$.

## Defining your own operators

```
\documentclass{article}
\usepackage{amssymb}
\usepackage{amsmath}
\DeclareMathOperator{\Mr}{M_{\mathbb{R}}}
\begin{document}
User-defined operator for matrices with Real entries
\[ x \in \Mr \]
\end{document}
```

User-defined operator for matrices with Real entries

$$x \in \mathrm{M}_{\mathbb{R}}$$

# Operators

| Operator | Renders as | Operator | Renders as | Operator | Renders as |
|---|---|---|---|---|---|
| \cos | $\cos$ | \gcd | $\gcd$ | \log | $\log$ |
| \csc | $\csc$ | \lg | $\lg$ | \sec | $\sec$ |
| \exp | $\exp$ | \ln | $\ln$ | \tan | $\tan$ |
| \ker | $\ker$ | \Pr | $\Pr$ | \arg | $\arg$ |
| \limsup | $\limsup$ | \sup | $\sup$ | \coth | $\coth$ |
| \min | $\min$ | \arctan | $\arctan$ | \dim | $\dim$ |
| \sinh | $\sinh$ | \cot | $\cot$ | \liminf | $\liminf$ |
| \arcsin | $\arcsin$ | \det | $\det$ | \max | $\max$ |
| \cosh | $\cosh$ | \hom | $\hom$ | \sin | $\sin$ |
| \deg | $\deg$ | \lim | $\lim$ | \tanh | $\tanh$ |

# Spacing in math mode

**Assume we have the next sets**

```
\[ S = \{ z \in \mathbb{C}\, |\, |z| < 1 \} \quad
 \textrm{and} \quad S_2=\partial{S}
\]
```

Assume we have the next sets

$$S = \{ z \in \mathbb{C}\, |\, |z| < 1 \} \quad \textrm{and} \quad S_2=\partial{S}$$

# Spacing in math mode

**Spaces in mathematical mode.**

```
\begin{align*}
f(x) =& x^2\! +3x\! +2 \\
f(x) =& x^2+3x+2 \\
f(x) =& x^2\, +3x\, +2 \\
f(x) =& x^2\: +3x\: +2 \\
f(x) =& x^2\; +3x\; +2 \\
f(x) =& x^2\ +3x\ +2 \\
f(x) =& x^2\quad +3x\quad +2 \\
f(x) =& x^2\qquad +3x\qquad +2
\end{align*}
```

Spaces in mathematical mode.

$$
\begin{align*}
f(x) =& x^2\! +3x\! +2 \\
f(x) =& x^2+3x+2 \\
f(x) =& x^2\, +3x\, +2 \\
f(x) =& x^2\: +3x\: +2 \\
f(x) =& x^2\; +3x\; +2 \\
f(x) =& x^2\ +3x\ +2 \\
f(x) =& x^2\quad +3x\quad +2 \\
f(x) =& x^2\qquad +3x\qquad +2
\end{align*}
$$

# Spacing in math mode

| LaTeX code | Description |
|---|---|
| \quad | space equal to the current font size (= 18 mu) |
| \, | 3/18 of \quad (= 3 mu) |
| \: | 4/18 of \quad (= 4 mu) |
| \; | 5/18 of \quad (= 5 mu) |
| \! | -3/18 of \quad (= -3 mu) |
| \ (space after backslash!) | equivalent of space in normal text |
| \qquad | twice of \quad (= 36 mu) |

# Integrals, sums, products and limits

**Integral**

\int_{lower}^{upper}

**Sum**

\sum_{lower}^{upper}

**Product**

\prod_{lower}^{upper}

**Limit**

\lim_{lower}

# Integrals

| LaTeX code | Output |
|---|---|
| `Integral $\int_{a}^{b} x^2 dx$ inside text` | Integral $\int_{a}^{b} x^2 dx$ inside text |
| `$$\int_{a}^{b} x^2 dx$$` | $$\int_{a}^{b} x^2 dx$$ |

# Multiple integrals

| LaTeX code | Output |
|---|---|
| `$\iint_V \mu(u,v) \,du\,dv$$`<br>`$$\iiint_V \mu(u,v,w) \,du\,dv\,dw$$`<br>`$$\iiiint_V \mu(t,u,v,w) \,dt\,du\,dv\,dw$$`<br>`$$\idotsint_V \mu(u_1,\dots,u_k) \,du_1 \dots du_k$$` | $\iint_V \mu(u,v) \,du\,dv$<br>$\iiint_V \mu(u,v,w) \,du\,dv\,dw$<br>$\iiiint_V \mu(t,u,v,w) \,dt\,du\,dv\,dw$<br>$\idotsint_V \mu(u_1,\dots,u_k) \,du_1 \dots du_k$ |
| `$$\oint_V f(s) \,ds$$`<br>`$$\oiint_V f(s,t) \,ds\,dt$$` | $\oint_V f(s) \,ds$<br>$\oiint_V f(s,t) \,ds\,dt$ |

# Sums, products and limits

| LaTeX code | Output |
| --- | --- |
| `Sum $\sum_{n=1}^{\infty} 2^{-n} = 1$ inside text` | Sum $\sum_{n=1}^{\infty} 2^{-n} = 1$ inside text |
| `$$\sum_{n=1}^{\infty} 2^{-n} = 1$$` | $$\sum_{n=1}^{\infty} 2^{-n} = 1$$ |
| `Product $\prod_{i=a}^{b} f(i)$ inside text` | Product $\prod_{i=a}^{b} f(i)$ inside text |
| `$$\prod_{i=a}^{b} f(i)$$` | $$\prod_{i=a}^{b} f(i)$$ |
| `Limit $\lim_{x\to\infty} f(x)$ inside text` | Limit $\lim_{x\to\infty} f(x)$ inside text |
| `$$\lim_{x\to\infty} f(x)$$` | $$\lim_{x\to\infty} f(x)$$ |

# Integer and sum limits improvement

| LaTeX code | Output |
|---|---|
| `Integral $\int_{a}^{b} x^2 dx$ inside text` | Integral $\int_{a}^{b} x^2 dx$ inside text |
| `Improved integral $\int\limits_{a}^{b} x^2 dx$ inside text` | Improved integral $\int\limits_{a}^{b} x^2 dx$ inside text |
| `Sum $\sum_{n=1}^{\infty} 2^{-n} = 1$ inside text` | Sum $\sum_{n=1}^{\infty} 2^{-n} = 1$ inside text |
| `Improved sum $\sum\limits_{n=1}^{\infty} 2^{-n} = 1$ inside text` | Improved sum $\sum\limits_{n=1}^{\infty} 2^{-n} = 1$ inside text |

## Bigger integral symbol in display

```
$\int\frac{1}{2}dx - \mathlarger{\int\frac{1}{2}dx}$
```

```
\usepackage{relsize}
```

$$\textstyle\int\frac{1}{2}dx - \displaystyle\int\frac{1}{2}dx$$

## Display style in math mode

```
Depending on the value of $x$ the equation
\( f(x) = \sum_{i=0}^{n} \frac{a_i}{1+x} \) may diverge or
converge.

\[ f(x) = \sum_{i=0}^{n} \frac{a_i}{1+x} \]
```

Depending on the value of $x$ the equation $f(x) = \sum_{i=0}^{n} \frac{a_i}{1+x}$ may diverge or converge.

$$f(x) = \sum_{i=0}^{n} \frac{a_i}{1+x}$$

# Setting mathematical styles

In-line maths elements can be set with a different style:

```
\( f(x) = \displaystyle \frac{1}{1+x} \).
The same is true the other way around:


\begin{eqnarray*}
f(x) = \sum_{i=0}^{n} \frac{a_i}{1+x} \\
\textstyle f(x) = \textstyle
\sum_{i=0}^{n} \frac{a_i}{1+x} \\
\scriptstyle f(x) = \scriptstyle
\sum_{i=0}^{n} \frac{a_i}{1+x} \\
\scriptscriptstyle f(x) =
\scriptscriptstyle \sum_{i=0}^{n}
\frac{a_i}{1+x}
\end{eqnarray*}
```

In-line maths elements can be set with a different style: $f(x) = \displaystyle \frac{1}{1+x}$. The same is true the other way around:

$$f(x) = \sum_{i=0}^{n} \frac{a_i}{1+x}$$

$$\textstyle f(x) = \textstyle \sum_{i=0}^{n} \frac{a_i}{1+x}$$

$$\scriptstyle f(x) = \scriptstyle \sum_{i=0}^{n} \frac{a_i}{1+x}$$

$$\scriptscriptstyle f(x) = \scriptscriptstyle \sum_{i=0}^{n} \frac{a_i}{1+x}$$

# Greek letters

| | | | |
|---|---|---|---|
| $\alpha A$ | \alpha A | $\nu N$ | \nu N |
| $\beta B$ | \beta B | $\xi\Xi$ | \xi\Xi |
| $\gamma\Gamma$ | \gamma \Gamma | $o O$ | o O |
| $\delta\Delta$ | \delta \Delta | $\pi\Pi$ | \pi \Pi |
| $\epsilon\varepsilon E$ | \epsilon \varepsilon E | $\rho\varrho P$ | \rho\varrho P |
| $\zeta Z$ | \zeta Z | $\sigma\Sigma$ | \sigma \Sigma |
| $\eta H$ | \eta H | $\tau T$ | \tau T |
| $\theta\vartheta\Theta$ | \theta \vartheta \Theta | $\upsilon\Upsilon$ | \upsilon \Upsilon |
| $\iota I$ | \iota I | $\phi\varphi\Phi$ | \phi \varphi \Phi |
| $\kappa K$ | \kappa K | $\chi X$ | \chi X |
| $\lambda\Lambda$ | \lambda \Lambda | $\psi\Psi$ | \psi \Psi |
| $\mu M$ | \mu M | $\omega\Omega$ | \omega \Omega |

# Arrows

| | | | |
|---|---|---|---|
| $\leftarrow$ | \leftarrow | $\Leftarrow$ | \Leftarrow |
| $\rightarrow$ | \rightarrow | $\Rightarrow$ | \Rightarrow |
| $\leftrightarrow$ | \leftrightarrow | $\rightleftharpoons$ | \rightleftharpoons |
| $\uparrow$ | \uparrow | $\downarrow$ | \downarrow |
| $\Uparrow$ | \Uparrow | $\Downarrow$ | \Downarrow |
| $\Leftrightarrow$ | \Leftrightarrow | $\Updownarrow$ | \Updownarrow |
| $\mapsto$ | \mapsto | $\longmapsto$ | \longmapsto |
| $\nearrow$ | \nearrow | $\searrow$ | \searrow |
| $\swarrow$ | \swarrow | $\nwarrow$ | \nwarrow |
| $\leftharpoonup$ | \leftharpoonup | $\rightharpoonup$ | \rightharpoonup |
| $\leftharpoondown$ | \leftharpoondown | $\rightharpoondown$ | \rightharpoondown |
| $\rightleftharpoons$ | \rightleftharpoons | | |

# Miscellaneous symbols

| | | | |
|---|---|---|---|
| $\infty$ | \infty | $\forall$ | \forall |
| $\Re$ | \Re | $\Im$ | \Im |
| $\nabla$ | \nabla | $\exists$ | \exists |
| $\partial$ | \partial | $\nexists$ | \nexists |
| $\emptyset$ | \emptyset | $\varnothing$ | \varnothing |
| $\wp$ | \wp | $\complement$ | \complement |
| $\neg$ | \neg | $\cdots$ | \cdots |
| $\square$ | \square | $\surd$ | \surd |
| $\blacksquare$ | \blacksquare | $\triangle$ | \triangle |

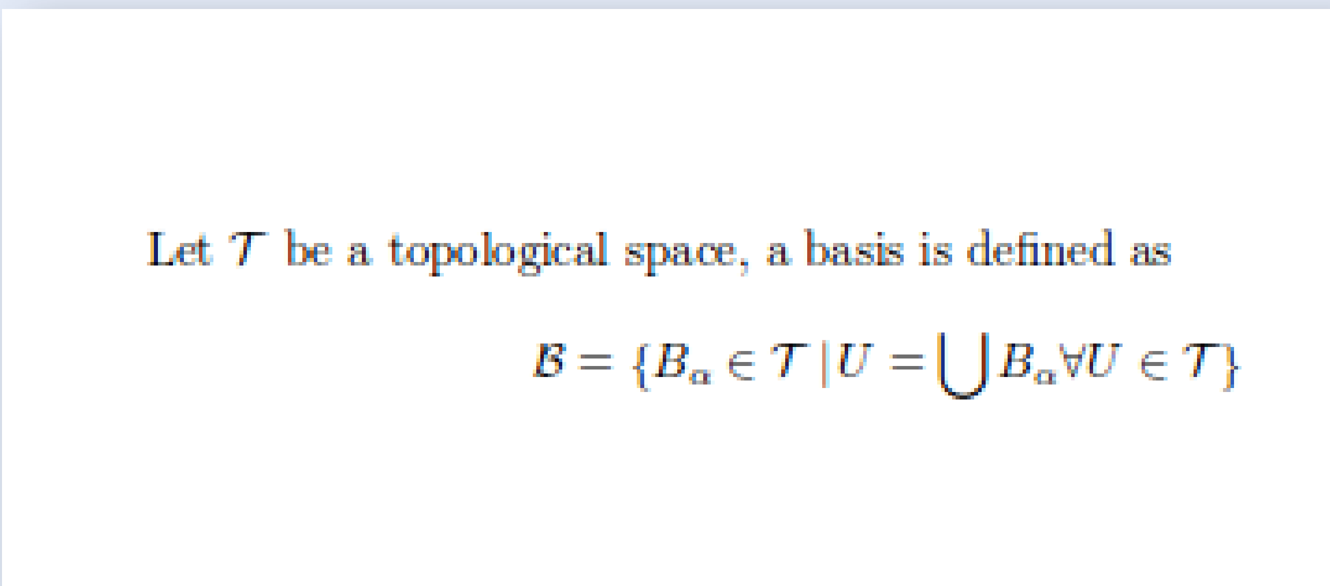
# Binary Operation/Relation Symbols

| | | | |
|---|---|---|---|
| $\times$ | \times | $\otimes$ | \otimes |
| $\div$ | \div | $\cap$ | \cap |
| $\cup$ | \cup | $\neq$ | \neq |
| $\leq$ | \leq | $\geq$ | \geq |
| $\in$ | \in | $\perp$ | \perp |
| $\notin$ | \notin | $\subset$ | \subset |
| $\simeq$ | \simeq | $\approx$ | \approx |
| $\wedge$ | \wedge | $\vee$ | \vee |
| $\oplus$ | \oplus | $\otimes$ | \otimes |
| $\Box$ | \Box | $\boxtimes$ | \boxtimes |
| $\equiv$ | \equiv | $\cong$ | \cong |

## Mathematical fonts

```
Let \( \mathcal{T} \) be a topological space, a basis is
defined as

\[
\mathcal{B} = \{ B_{\alpha} \in \mathcal{T}\,
|\, U = \bigcup B_{\alpha} \forall U \in \mathcal{T} \ }
\]
```



Let $\mathcal{T}$ be a topological space, a basis is defined as

$$\mathcal{B} = \{ B_{\alpha} \in \mathcal{T}\, |\, U = \bigcup B_{\alpha} \forall U \in \mathcal{T} \}$$

# Mathematical fonts

```
\begin{align*}
RQSZ \\
\mathcal{RQSZ} \\
\mathfrak{RQSZ} \\
\mathbb{RQSZ}
\end{align*}
```

## Mathematical fonts

```
\begin{align*}
3x^2 \in R \subset Q \\
\mathnormal{3x^2 \in R \subset Q} \\
\mathrm{3x^2 \in R \subset Q} \\
\mathit{3x^2 \in R \subset Q} \\
\mathbf{3x^2 \in R \subset Q} \\
\mathsf{3x^2 \in R \subset Q} \\
\mathtt{3x^2 \in R \subset Q}
\end{align*}
```

$$
\begin{aligned}
3x^2 \in R \subset Q \\
\mathnormal{3x^2 \in R \subset Q} \\
\mathrm{3x^2 \in R \subset Q} \\
\mathit{3x^2 \in R \subset Q} \\
\mathbf{3x^2 \in R \subset Q} \\
\mathsf{3x^2 \in R \subset Q} \\
\mathtt{3x^2 \in R \subset Q}
\end{aligned}
$$

## The END

Thank you!