Intermediate LaTeX
Coding mathematics

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Dans la section

Math in standard LATEX

By conception, TEX is specially efficient for typesetting math. The basic maths in LATEX are described first.

- Math input defines "mathmode" in two version and four styles:
  - *In-line* mode, with $...$, \(...\), environment `math`.
  - *Display* mode, with \[...\] or environment `displaymath`.
  - \displaystyle, \textstyle, \scriptstyle and \scriptscriptstyle, mostly related to size of symbols.
- In mathmode, each letter is supposed to be single variable, so that abc gives abc and not abc
- Typed spaces are ignored. TEX introduces the required spacing on the basis of the class of symbols, variables, operators, delimiter, binary relations, etc. Tweaking this spacing is sometimes required, with the commands (unit `mu`=1/18`em`):

\quad	\qquad	\␣	\;	\;	\,	\!
18mu	36mu	9mu	5mu	4 mu	3mu	-3mu

Math in standard LaTeX(II)

Basic math constructions

- Indices and exponents:

`$2^3=8$`	$\rightarrow$	$2^3=8$	`$\delta_{ij}=\pm1$`	$\rightarrow \delta_{ij}=\pm1$
`$a^3^2$`	$\rightarrow$	Error	`$a^{3^2}=a^{9}$`	$\rightarrow a^{3^2}=a^9$
`$C_2^4=6$`	$\rightarrow$	$C_2^4=6$	`$\mathrm{H_3O^+}$`	$\rightarrow \mathrm{H_3O^+}$

- Primes :

`$x'=1$` $\rightarrow x'=1$	`$(x^2)'=2x$` $\rightarrow (x^2)'=2x$
`$x''=0$` $\rightarrow x''=0$	`${(x^3)}'=3x$` $\rightarrow (x^3)'=3x$

- Fractions and roots :

`$\frac{a}{b}$`	$\rightarrow$	$\frac{a}{b}$	`$\sqrt{4}=2$`	$\rightarrow \sqrt{4}=2$
`\[\frac{a}{b}\]`	$\rightarrow$	$\dfrac{a}{b}$	`$\sqrt[3]{27}=3$`	$\rightarrow \sqrt[3]{27}=3$

Dans la section

Binary operators

LATEXdistinguishes "Binary operators", "relations"and "(unary) operators".

Binary operators are automatically surrounded by medium space (4 mu).

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

This can be emulated with `\mathbin{`<text>`}`,
Declare a new one with `\newcommand{\`<name>`}{\mathbin{`<name>`}}`.

A few less used binary operators are available with the packages `latexsym`/`amssymb`.

Binary relations

Binary relations are automatically surrounded by small space (3 mu).

`=`	$=$	`\equiv`	$\equiv$	`\prec`	$\prec$	`\succ`	$\succ$
`>`	$>$	`\simeq`	$\simeq$	`\preceq`	$\preceq$	`\succeq`	$\succeq$
`<`	$<$	`\approx`	$\approx$	`\subset`	$\subset$	`\supset`	$\supset$
`\leq`	$\leq$	`\cong`	$\cong$	`\subseteq`	$\subseteq$	`\supseteq`	$\supseteq$
`\geq`	$\geq$	`\asymp`	$\asymp$	`:`	$:$	`\neq`	$\neq$
`\ll`	$\ll$	`\propto`	$\propto$	`\models`	$\models$	`\vdash`	$\vdash$
`\gg`	$\gg$	`\doteq`	$\doteq$	`\mid`	$\mid$	`\dashv`	$\dashv$
`\sim`	$\sim$	`\bowtie`	$\bowtie$	`\perp`	$\perp$	`\parallel`	$\parallel$
`\in`	$\in$	`\ni`	$\ni$	`\smile`	$\smile$	`\frown`	$\frown$

This can be emulated with `\mathrel{<text>}`,
Declare a new one with `\newcommand{\<name>}{\mathrel{<name>}}`.

A few less used binary operators are available with the packages `latexsym`/`amssymb`.

Operators

Log-like operators are automatically preceded by a small space (3 mu).

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

Declare a new one like `\newcommand{\argtanh}{\mathop{argtanh}}`.

Large variable-sized Symbols

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

Delimiters

Delimiters are automatically surrounded by small space (3 mu).

(	(	)	)	\uparrow	↑	\Uparrow	⇑
[	[	]	]	\downarrow	↓	\Downarrow	⇓
\{	{	\}	}	\updownarrow	↕	\Updownarrow	⇕
|	|	/	/	\lfloor	⌊	\rfloor	⌋
\\|	‖	\\	\	\lceil	⌈	\rceil	⌉
				\langle	⟨	\rangle	⟩

Large delimiters

\rmoustache ⎱ \lmoustache ∫ \rgroup ⎫ \lgroup (

\arrowvert | \Arrowvert ‖ \bracevert |

Big delimiters \Bigg(\bigg(\Big(\big(( ) \big)\Big)\bigg)\Bigg)

gives $\left(\left(\left(\left((())\right)\right)\right)\right)$ but the correct spacing would be obtained with
\Biggl(\biggl(\Bigl(\bigl((
) \bigr)\Bigr)\biggr)\Biggr)

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`	↖
`\leadsto`	⇝ b	`\rightleftharpoons`	⇌		

Note the difference between `\Longleftrightarrow` : $|\!\Longleftrightarrow\!|$, and `\iff` : $|\iff|$
The latter is a relation, with some extra spaces; the same holds for `\to` vs
`\rightarrow`, `\implies` vs `\Longrightarrow` etc.
Many other arrows with `amssymb` / `amsfonts`

Greek letters

\alpha	α	\imath	$\imath$	\rho	ρ	\varepsilon	ε
\beta	β	\kappa	κ	\sigma	σ	\vartheta	ϑ
\gamma	γ	\lambda	λ	\tau	τ	\varkappa	$\varkappa$
\delta	δ	\mu	μ	\upsilon	υ	\varpi	ϖ
\epsilon	ϵ	\nu	ν	\phi	ϕ	\varsigma	ς
\zeta	ζ	\xi	ξ	\chi	χ	\varrho	ϱ
\eta	η	o	o	\psi	ψ	\varphi	φ
\theta	θ	\pi	π	\omega	ω		
\Gamma	Γ	\Lambda	Λ	\Sigma	Σ	\Psi	Ψ
\Delta	Δ	\Xi	Ξ	\Upsilon	Υ	\Omega	Ω
\Theta	Θ	\Pi	Π	\Phi	Φ		
\varGamma	$\varGamma$	\varLambda	$\varLambda$	\varSigma	$\varSigma$	\varPsi	$\varPsi$
\varDelta	$\varDelta$	\varXi	$\varXi$	\varUpsilon	$\varUpsilon$	\varOmega	$\varOmega$
\varTheta	$\varTheta$	\varPi	$\varPi$	\varPhi	$\varPhi$		

Slanted capital are also obtained with \mathnormal{\Gamma} $\rightarrow \varGamma$

More math symbols

`\ldots`	…	`\cdots`	⋯	`\vdots`	⋮	`\ddots`	⋱
`\aleph`	ℵ	`\prime`	′	`\forall`	∀	`\infty`	∞
`\hbar`	ℏ	`\emptyset`	∅	`\exists`	∃	`\Box`	□ ^{b}
`\imath`	ı	`\nabla`	∇	`\neg`	¬	`\Diamond`	◇ ^{b}
`\jmath`	ȷ	`\surd`	√	`\flat`	♭	`\triangle`	△
`\ell`	ℓ	`\top`	⊤	`\natural`	♮	`\clubsuit`	♣
`\wp`	℘	`\bot`	⊥	`\sharp`	♯	`\diamondsuit`	◇
`\Re`	ℜ	`|`	‖	`\backslash`	\	`\heartsuit`	♡
`\Im`	ℑ	`\angle`	∠	`\partial`	∂	`\spadesuit`	♠
`\mho`	℧ ^{b}	`.`	.	`|`				

For a more extended list of symnols look at
The Comprehensive LaTeX Symbol List

Dans la section

1. Basic mathematics in standard LATEX
   - Minimal math notations
   - Math elements by class
   - More math elements

2. $\mathcal{AMS}$-math and mathtools
   - Multi-line display
   - Miscellanea

Decorations

Math mode accents

\hat{a}	$\hat{a}$	\acute{a}	$\acute{a}$	\bar{a}	$\bar{a}$	\dot{a}	$\dot{a}$
\breve{a}	$\breve{a}$	\check{a}	$\check{a}$	\grave{a}	$\grave{a}$	\vec{a}	$\vec{a}$
\ddot{a}	$\ddot{a}$	\tilde{a}	$\tilde{a}$				

Other constructions

\widetilde{abc}	$\widetilde{abc}$	\widehat{abc}	$\widehat{abc}$
\overleftarrow{abc}	$\overleftarrow{abc}$	\overrightarrow{abc}	$\overrightarrow{abc}$
\overline{abc}	$\overline{abc}$	\underline{abc}	$\underline{abc}$
\overbrace{abc}^d	$\overbrace{abc}^d$	\underbrace{efg}_h	$\underbrace{efg}_h$

Extensible delimiters The \Bigg\bigg\Big\big delimiters are
sometimes to small. Get larger delimiters as shown here with:

    \left<delim1> content\right<delim2>

\left and \right must be paired <delim1>and <delim2> can
differ. Use **.** for no printed delimiter.

$$\left(\begin{matrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \\ j \\ k \\ l \\ m \\ n \end{matrix} \right.$$
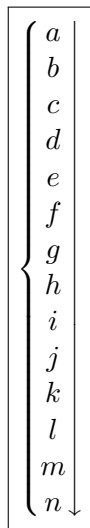
Integrals, sums and limits

The Euler-Mascheroni constant γ

• In `textstyle` (in-line math) $\gamma = \lim_{n\to\infty}(\sum_{k=1}^n \frac{1}{k} - \int_1^n \frac{dx}{x})$
is produced by the command :
`\lim_{n\to\infty}(\sum_{k=1}^n \frac{1}{k}-\int_1^n \frac{dx}{x})`

• Better result obtained in `displaystyle` : $\displaystyle\lim_{n\to\infty}(\sum_{k=1}^n \frac{1}{k} - \int_1^n \frac{dx}{x})$
  – With the `displaymath` environment `\[`$\cdots$`\]`
  – By adding the command `\displaystyle` in front of the formula:
     `\displaystyle\lim_{n\to\infty}(\sum_{k=1}^n \frac{1}{k}`$\cdots$

• The limits position is controlled by `\limits` or `\nolimits`:
  – in `textstyle` `$\lim\limits_{n\to\infty}(\sum_{k=1}^n`$\cdots$`$`
    gives $\lim\limits_{n\to\infty}(\sum\nolimits_{k=1}^n \frac{1}{k} \cdots$
  – in `displaystyle` `\[\lim_{n\to\infty}(\sum\nolimits_{k=1}^n`$\cdots$`\]`
    gives $\lim_{n\to\infty}(\sum\nolimits_{k=1}^n \frac{1}{k} \cdots$

Math Fonts

Regular math is in "$mathematical\ italic$" (`lmmi` for `latinmodern`)

Styles and families work like in text, but with `\math<style>`:
mathrm, `mathtt`, mathsf, **mathbf**, $mathit$

Symbols are not embolden by `\mathbf`:
`$\mathbf{\sum\int\beta}$` $\rightarrow \sum \int \beta \leftarrow$ `$\sum\int\beta$`
Use instead `$\bm{\sum\int\beta}$` $\rightarrow \boldsymbol{\sum \int \beta}$ of package `bm`

Other styles (with packages)
- `\mathcal{ABCDEFGH}` $\rightarrow \mathcal{ACDEFGH}$ (uppercase only, `latex`)
- `\mathbbm{ABCNR12abc}` $\rightarrow \mathbb{ABCNR}12\mathrm{abc}$ (`bbm`)
- `\upalpha\upbeta\upmu`$\cdots \rightarrow \alpha\beta\mu \cdots$ (`upgreek`)
- `\mathfrak{ABCNR12abc}` $\rightarrow \mathfrak{ABCNR}12\mathfrak{abc}$ (`amssymns`)
- `\mathscr{ABCD}` $\rightarrow \mathscr{ABCD}$ (uppercase only, `mathrsfs`)
- etc.

Making larger or smaller symbols

- Some symbols sometimes need to be enlarged.
- But the fonts `cmex` or `lmex` are defined as non-scalable !
  Fix this by loading package `exscale` (sample in `\Huge`):

$$\langle X \rangle = \underset{i}{\Sigma}\underset{j}{\Sigma}\, p_{ij}x_i = \frac{\Sigma_j\, n_j x_j}{\Sigma_j\, n_j} \quad \rightarrow \quad \langle X \rangle = \sum_i \sum_j p_{ij}x_i = \frac{\sum_j n_j x_j}{\sum_j n_j}$$

- For a finer control use the package `relsize` and do for example:

```
1 \def\Sum{\mathop{\mathlarger{\sum}}}
2 \def\sums{\mathop{\mathsmaller{\sum}}}
```

To get :

$$\langle X \rangle = \sum_i \sum_j p_{ij}x_i = \frac{\sum_j n_j x_j}{\sum_j n_j}$$

Sommaire

$\mathcal{A}\mathcal{M}\mathcal{S}$-math & mathtools

- **Never** use the awful `\eqalign` to align equations.
- For this purpose you should load the package `amsmath`, with is companion `mathtools`.
- **Warning**: `amsmath` package and not `ams(la)tex` class, and its documentation is named `amsldoc.pdf`.
- `amsmath` & `mathtools` define (namely) :
  - Many multi-line displayed equation environments.
  - Better `matrices`, root, fractions, limits and integrals.
  - $\boxed{\ }$ formulas, and ... in math mode.
  - Stacking of subscript (`\substack`) or relations (`\stackrel`).
  - `\DeclareMathOperator{\xxx}{xxx}` (starred for limit position).
  - Content of null vertical space (`\smash`, `\smashoperator`) or horizontal width (`\mathllap`,`\mathclap`,`\mathrlap`).
  - Extensible arrows like `\xLeftarrow[<sub>]{<sup>}` for $A \xLeftarrow[under]{over} B$
  - Left indices and exponents, etc.

Dans la section

Aligned equations : `align` and `aligned`

By default, all lines are numbered. Use $*$ to suppress all numbers, or
`\nonumber` on specific lines.

```latex
1  \begin{align*}
2  aa  &=bbbbbbb\\
3  cccccc&=dd
4  \end{align*}
```

$$aa = bbbbbbb$$
$$cccccc = dd$$

```latex
1  \begin{align*}
2  aa  &=bbbbbbb & ee&=ff\\
3  cccc&=dd & hhhh&=gg
4  \end{align*}
```

$$aa = bbbbbbb \qquad ee = ff$$
$$cccccc = dd \qquad hhhh = gg$$

```latex
1  \begin{equation}
2  \left\{
3  \begin{aligned}
4  aaa&=bbb\\
5  w&= u \text{ ou }v
6  \end{aligned}
7  \right.
8  \end{equation}
```

$$\begin{cases} aaa = bbb \\ w = u \text{ ou } v \end{cases} \tag{1}$$

More aligned equations

- alignat reduces the inter equations space (use number of columns)

```latex
\begin{align*}
 aa  &=bbbbbb & eee &=vvvv\\
 cccc &=dd & fff &= zzz
\end{align*}
\smallskip
\begin{alignat*}{2}
 aa  &=bbbbbb & eee &=vvvv\\
 cccc &=dd & fff &= zzz
\end{alignat*}
```

$$aa = bbbbbb \qquad eee = vvvv$$
$$cccc = dd \qquad\quad fff = zzz$$

$$aa = bbbbbb\ eee = vvvv$$
$$cccc = dd \quad\ fff = zzz$$

- split is used to display a single equation with multiline aligned terms

```latex
\begin{equation}
\begin{split}
a & =b+c-d\\
  & \qquad +e-f\\
  & =g+h
\end{split}
\end{equation}
```

$$
\begin{split}
a &= b + c - d \\
  &\qquad + e - f \\
  &= g + h
\end{split}
\tag{2}
$$

Non aligned equations

- `multiline` environment is a variation of the equation environment used for equations that don't fit on a single line. It add some space at the beginning and the end of the lines to emphasize the continuation.

```
1 \begin{multline}
2 s = a+b+c+d+e+f\\
3 +i+j+k+l+m
4 \end{multline}
```

$$s = a + b + c + d + e + f$$
$$+ i + j + k + l + m \quad (3)$$

- `gather` environment allows to put several non aligned equation in the same display, without any alignment.

```
1 \begin{gather}
2 s_1 = a+b+c+d+e+f+g+h\\
3 k+l+m+n=s_2
4 \end{gather}
```

$$s_1 = a + b + c + d + e + f \quad (4)$$
$$k + l + m + n = s_2 \quad (5)$$

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Text in math mode

- To produce text in mayhmode the most basic is `\mbox{the text}` (in `\mbox{the text}` the mode is LR).
- But `amsmath` provides the command `\text{the text}`, which oppositely to `\mbox{the text}` scales according to the mode like:
$$\texttt{\textbackslash mbox} \rightarrow \frac{\text{the text}}{\text{the text}} \neq \frac{\text{the text}}{\text{the text}} \leftarrow \texttt{\textbackslash text}$$
and also restart the style of the surrounding text.
- For text between equations `\intertext{}` which produces left aligned text without breaking the alignment.
  And with `mathtools` `\shortintertext` reduces the white (wasted) space produced by `\intertext{}`.
- Text *on the same line* as displaymath is obtained with the trick:

```
1 \begin{flalign*}
2 &\text{Hence} & E &=mc^2 &\\
3 &\text{and}
  & E &=\hbar\omega &
4 \end{flalign*}
```

Hence $E = mc^2$

and $E = \hbar\omega$

Equations numbering

- Equations are automatically numbered (each line, as above))
- This can be disabled on a given line with `\nonumber` or globally with the starred version like `\begin{align*}`.
- The number format can be modified with the `\numberwithin` command and the usual `\renewcommand{\theequation}{...}`.
- In the environment `subequations` a letter is added instead incrementing equation:

```
1  \begin{subequations}
2  \begin{align}
3  E & = mc^2 \\
4  E & = \hbar\omega
5  \end{align}
6  \end{subequations}
```

$$E = mc^2 \qquad (6a)$$

$$E = \hbar\omega \qquad (6b)$$

- In principle, only equations explicitly referred to in the text must be numbered : use `\mathtoolsset{showonlyrefs}` and `\eqref` instead of `\ref` or `\refeq`.

\DeclarePairedDelimiter & variants

- mathtools features a command \DeclarePairedDelimiter defining paired delimiters at the proper size acording to contents. As an example \DeclarePairedDelimiter\abs{\lvert}{\rvert} producing with the starred \abs*:

```
1  \[ \abs*{c}= \abs*{\tfrac{a}{b}} =
   \abs*{\dfrac{a}{b}} \]
```

$$|c| = \left|\frac{a}{b}\right| = \left|\dfrac{a}{b}\right|$$

- If needed the * can ve replaced by an optional arguiment like [\Big] which prepend the prefix\Big on both delimiters.

- In \DeclarePairedDelimiterX one has the size of the delimiters in \delimsize, so that on can use :

```
\DeclarePairedDelimiterX\braket[3]{\langle}{\rangle}%
{#1\delimsize\vert#2\delimsize\vert#3}
```

or with an improved spacing

```
\DeclarePairedDelimiterX\braket[3]{\langle}{\rangle}%
{#1\,\delimsize\vert\,\mathopen{}#2\,\delimsize\vert\,\mathopen{}#3}
```

yielding: $\langle \phi \,|\, A \,|\, \psi \rangle \neq \langle \Phi \,|\, B^{\dagger} \,|\, \Psi \rangle$

Theorems

- If you do real mathematical works you will need to define structured and numbered environments like definition, proposition, theorems, lemma, proofs and so on.

- There ara plainty of package to do that, but the basic and general one is `amsthm`

- We won't describe the multiple possibilities, bui provide an example, built with `ntheorem`, (more powerful than `amsthm` but much more complex), using `\savebox`, and combined with `\shadowbox` (provided by the package `fancybox`).

Propriété III.10 (Théorème de la moyenne) :
Si f est une fonction continue sur $[a,b]$, et m(f) la moyenne» de f sur $[a,b]$, il existe un réel $c \in]a,b[$ tel que m(f) = $f(c)$.

Preuve : Cette propriété résulte simplement du théorème de accroissements finis (Propriété I.7 p. 23) appliqué à une primitive F de f selon lequel $\exists\, c \in]a,b[/\quad F(b) - F(a) = F'(c)(b - a)$. $\qquad\square$