LaTeX Course 2011

Part 4: Typesetting mathematics

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Typesetting mathematics

Inlined equations are written inside `$$` characters:
E.g., `$\sum_{k=1}^\infty a_k$` produces $\sum_{k=1}^\infty a_k$.

Equations on their own line are put into a separate environment `\begin{equation}..\end{equation}`[1],

$$\sum_{k=1}^\infty a_k, \tag{1}$$

or `\[..\]`[2],

$$\sum_{k=1}^\infty a_k.$$

[1] This produces a number.
[2] This doesn't.

Typesetting mathematics...

Observe the differences in style when writing the equations within the text, or separately (e.g. the limits of the sum were written differently)

The style can also be forced with the commands,

- `\textstyle`
- `\displaystyle`

if needed.

Typesetting mathematics...

In the math mode, letters (the variables or constants) are typeset with slanted typeface and extra spaces are ignored:

```
\begin{equation}
I(x) := a_1^2 b_{1,2} c x .
\end{equation}
```

$$I(x) := a_1^2 b_{1,2} c x. \tag{2}$$

If the equations are part ot the sentence, commas should be written such that the formulas become a natural part of the sentence.

Typesetting mathematics...

The characters

```
# $ % & ~ _ ^ \ { }
```

have a special meaning in LaTeX. If they are needed in the equations, one must write

```
\#   \$   \%   \&   \_   \{   \}
```

For example,

```
\[ \mathcal{L}\{f\}(s) :=
   \int_0^\infty f(t) e^{-st} dt \]
```

$$\mathcal{L}\{f\}(s) := \int_0^\infty f(t)e^{-st}dt$$

Typesetting mathematics...

- Because ordinary keyboards are lacking most of the mathematical symbols, there are quite a number of special commands – in addition to the greek letters
  $\alpha, \beta, \gamma, \delta,\ \epsilon, \zeta, \eta, \theta, \iota,\ \kappa, \lambda, \mu, \nu, \xi, o, \pi, \rho, \sigma, \tau, \upsilon, \phi, \chi, \psi$ and ω
- The commands for mathematical typesetting are best learned by heart. Editors (including Eclipse) also help in remembering the commands.

Upper and lower indices

The upper and lower indices can be produced with ^ and _.

```
\[ V^2_1 \ge V_{21} \]
```

$$V^2_1 \ge V_{21}$$

If there are more than one index, they need to be grouped with curly braces.

Rational expressions

```
\[ \frac{a}{b} \]
\[ \sqrt{2} \approx 1.4142 \]
```

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

$$\sqrt{2} \approx 1.4142$$

Rational expressions...

```
\[ \left(
   \frac{\sqrt[3]{z-1}}{2}
   \right)^2 \]
```

$$\left(\frac{\sqrt[3]{z-1}}{2}\right)^2$$

Rational expressions...

Revision:

- Fraction: `\frac{numerator}{denominator}`
- Root: `\sqrt{}` ja `\sqrt[n]{}` (!)
- The size of the parenthesis can be automatically adjusted with the command pair `\left(` and `\right)`
  - Also `\left[, \left\{` and `\left|` work
  - One can mix $|, (, [, \{$ and .
  - The dot shows nothing. Example: $\left\{ \frac{\frac{a}{b}}{C} \right.$

Rational expressions...

Chain fractions (or continuous fractions):

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

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

Differential operators

```
\[ \frac{dy}{dt} = f(y;\lambda) \]
\[ \frac{\partial u}{\partial t} = \kappa^2
   \left( \frac{\partial^2 u}{\partial x^2}
        + \frac{\partial^2 u}{\partial y^2}
        + \frac{\partial^2 u}{\partial z^2}
     \right) \]
```

$$\frac{dy}{dt} = f(y;\lambda)$$

$$\frac{\partial u}{\partial t} = \kappa^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right)$$

Limits, sums, integrals

```
\[ \lim_{x \to 0}
   \frac{3x^2 +7x^3}{x^2 +5x^4} = 3.\]
```

$$\lim_{x \to 0} \frac{3x^2 + 7x^3}{x^2 + 5x^4} = 3.$$

```
\[ \sum_{k=1}^\infty \frac{1}{2^k} =
   \frac{\pi^2}{6} \]
```

$$\sum_{k=1}^{\infty} \frac{1}{2^k} = \frac{\pi^2}{6}$$

Limits, sums, integrals...

```
\[ \int_{-\infty}^\infty \sin(x)\ dx = \pi \]
```

$$\int_{-\infty}^{\infty} \sin(x)\, dx = \pi$$

```
\[ \oint_{\partial C} h(z)\ dz = 0 \]
```

$$\oint_{\partial C} h(z)\, dz = 0$$

Limits, sums, integrals...

```
\[ \int\limits_{-\infty}^\infty
   \sin(x)\ dx = \pi \]
```

$$\int_{-\infty}^{\infty} \sin(x)\, dx = \pi$$

```
\[ \oint\limits_{\partial C} h(z)\ dz = 0 \]
```

$$\oint_{\partial C} h(z)\, dz = 0$$

Revision and some trivia

- The upper and lower indices are obtained with `^` ja `_`
- Spaces in equations can be enforced with `\` (backslash and space)
- The command `\limits` puts more emphasis on the upper and lower indices

Spaces in equations

```
\[ a\, b \]
\[ a\: b \]
\[ a\  b \]
\[ a\! b \]
```

$$a\, b$$

$$a\: b$$

$$a\ b$$

$$a\! b$$

- The last command `\!` is a negative space.
- Use these fine-tunings sparingly!

Math fonts

Math mode is not for writing text. Nevertheless, there are some commands to change the appearance of the fonts.

`A`	A
`\mathrm{A}`	A
`\mathbf{A}`	$\mathbf{A}$
`\mathbb{A}`	$\mathbb{A}$
`\mathcal{A}`	$\mathcal{A}$,

The last two commands only work for capital letters.

Font style, examples

```
\[ \dot{M}_{\mathrm{CO_2}} \]
```

$$\dot{M}_{\mathrm{CO_2}}$$

```
\[ \alpha \in \mathbb{C}, \mathbf{v} \in X
    \Rightarrow \alpha \mathbf{v} \in X \]
```

$$\alpha \in \mathbb{C}, \mathbf{v} \in X \Rightarrow \alpha \mathbf{v} \in X$$

- Chemical formulas are written with capital letter.
- (In modern literature, vectors are typically written just as $v \in X$, without any additional decorations.

Font size

The size of the font is also controlled differently:

`{\scriptscriptstyle \sum}`	$\scriptscriptstyle \sum$
`{\scriptstyle \sum}`	$\scriptstyle \sum$
`{\textstyle \sum}`	$\textstyle \sum$
`{\displaystyle \sum}`	$\displaystyle \sum$

Function names

LaTeXknows the most conventional function names:

```
\[ \cos (\pi) = -1 \]
```

$$\cos(\pi) = -1$$

```
\[ \sin (0) = 0 \]
```

$$\sin(0) = 0$$

Function names...

Known names include

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

Function names...

Own functions can be **declared** as operators with the command `\operatorname`.

```
\[ \operatorname{arg min}_
   \Theta f(\Theta) \]
```

$$\operatorname{arg\,min}_{\Theta} f(\Theta)$$

Function names...

The previous example still needs some tuning:

```
\[ \operatorname{arg\ min}_
   \Theta f(\Theta) \]
```

$$\operatorname{arg\,min}_{\Theta} f(\Theta)$$

```
\[ \underset{\Theta}
   {\operatorname{arg\ min}} f(\Theta) \]
```

$$\underset{\Theta}{\operatorname{arg\,min}} f(\Theta)$$

Mixing text and formulas

LaTeX :

```
\[ S := \{ x\in \Omega | f(x) = c
          \ \mathrm{and}\ g(x) < 0 \} \]
```

$$S := \{x \in \Omega | f(x) = c, \text{ and } g(x) < 0\}$$

AMS-LaTeX:

```
\[ S := \{ x\in \Omega | f(x) = c
          \text{ and } g(x) < 0 \} \]
```

$$S := \{x \in \Omega | f(x) = c, \text{ and } g(x) < 0\}$$

Three dots(...)

Three dots:

```
\[ a_0 + a_2 + \cdots + a_n \]
\[ \ldots, \cdots, \ddots, \vdots \]
```

$$a_0 + a_2 + \cdots + a_n$$

$$\ldots, \cdots, \ddots, \vdots$$

Mathematical accents

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

Norm and absolute value

Norm:

```
\[ \|a x\| = |a| \|x\| \]
```

$$\|ax\| = |a|\|x\|$$

Parentheses

Dot produces an invisible parenthesis:

```
\[ \left( \frac{1+z}{1-z} \right. \]
\[ \left. \frac{du}{dx} \right|_{x=0} \]
```

$$\left(\frac{1+z}{1-z} \right.$$

$$\left. \frac{du}{dx} \right|_{x=0}$$

Multiline equations

```
\begin{eqnarray}
F(x) &= & \int_a^b I(u,x) du  \nonumber \\
     &= & \frac{1}{\sqrt{\pi}}G(x)
\end{eqnarray}
```

$$
\begin{aligned}
F(x) &= \int_a^b I(u,x)du \\
&= \frac{1}{\sqrt{\pi}}G(x)
\end{aligned} \tag{3}
$$

Multiline equations...

- `eqnarray` works like a table, but it has three columns fixed.
- The numbering can be suppressed with `\nonumber`
- If the numbering is not needed at all, one can use the form `\begin{eqnarray*}...\end{eqnarray*}`

Matrices

Like the table,

```
\[ \left[\begin{array}{ccc}
    1 & 0 & 2  \\
    0 & 2 & 0  \\
    0 & 0 & a \end{array}\right] \]
```

$$\left[\begin{array}{ccc}
1 & 0 & 2 \\
0 & 2 & 0 \\
0 & 0 & a
\end{array}\right]$$

Matrices...

Using the AMS-package:

```
\[ \begin{bmatrix}
  1 & 0 & 2  \\
  0 & 2 & 0  \\
  0 & 0 & a \end{bmatrix} \]
```

$$\begin{bmatrix} 1 & 0 & 2 \\ 0 & 2 & 0 \\ 0 & 0 & a \end{bmatrix}$$

Matrices...

...or ...

```
\[ \begin{pmatrix}
  1 & 0 & 2  \\
  0 & 2 & 0  \\
  0 & 0 & a \end{pmatrix} \]
```

$$\begin{pmatrix} 1 & 0 & 2 \\ 0 & 2 & 0 \\ 0 & 0 & a \end{pmatrix}$$

Functions defined in parts

Like with tables,

```
\[ |x| = \left\{ \begin{array}{rl}
    x & \mbox{if $x \geq 0$};\\
   -x & \mbox{if $x < 0$}.\end{array}
   \right. \]
```

$$|x| = \left\{ \begin{array}{rl} x & \text{if } x \geq 0; \\ -x & \text{if } x < 0. \end{array} \right.$$

Functions defined in parts...

Or using the AMS-package:

```
\[ |x| = \left\{ \begin{aligned}
    x & \text{ if } x \geq 0;\\
   -x & \text{ if } x < 0.\end{aligned}
   \right. \]
```

$$|x| = \begin{cases} x \text{ if } x \geq 0; \\ -x \text{ if } x < 0. \end{cases}$$

Grouping with curly braces

Equations can be annotated to help the reader:

```
\[ \underbrace{A}_{\star} \]
```

$$\underbrace{A}_{\star}$$

```
\[ \overbrace{B}^{\dag} \]
```

$$\overbrace{B}^{\dagger}$$

Grouping with curly braces...

Example:

```
\[ y' = \overbrace{
   \underbrace{Ay}_{\text{linear part}} +
   \underbrace{By^R}_{\text{nonlinear part}}
   }^{\text{the driving force}} \]
```

$$y' = \overbrace{\underbrace{Ay}_{\text{linear part}} + \underbrace{By^R}_{\text{nonlinear part}}}^{\text{the driving force}}$$

Boxes

Adding a box around an equation

```
\[ \boxed{\frac{1}{1+x}} \]
```

$$\boxed{\frac{1}{1+x}}$$

- may simplify the presentation
- . . . or make it even more complicated

Boxes...

Example:

```
\begin{eqnarray*}
\| x - z \| &= &\| x\ \boxed{-y+y} - z \|\\
          &\leq &\| x - y \| + \| y - z \|
\end{eqnarray*}
```

$$\begin{aligned} \|x - z\| &= \|x \boxed{-y + y} - z\| \\ &\leq \|x - y\| + \|y - z\| \end{aligned}$$

The AMS package

In this course, we use the commands from the AMS package without separate notification (as they have become standard over the years). The following commands are especially from the AMS package `amsmath`:

`\iint`	$\iint$
`\iiint`	$\iiint$
`\iiiint`	$\iiiint$
`\idotsint`	$\int\cdots\int$

The AMS package...

```
\[ \sum_{\substack{k=1\dots n\\
                   l=1\dots m\\
                   k\neq l}}
    a_{k,l} \]
```

$$\sum_{\substack{k=1\dots n\\ l=1\dots m\\ k\neq l}} a_{k,l}$$

The AMS package...

```
\[ \overset{*}{A}, \underset{*}{B} \]
```

$$\overset{*}{A}, \underset{*}{B}$$

```
\[ \sideset{_a^b}{_c^d}\prod \]
```

$$\sideset{_a^b}{_c^d}\prod$$

Greek letters

\alpha	α	\beta	β	\gamma	γ
\delta	δ	\epsilon	ϵ	\varepsilon	ε
\zeta	ζ	\eta	η	\theta	θ
\vartheta	ϑ	\iota	ι	\kappa	κ
\lambda	λ	\mu	μ	\nu	ν
\xi	ξ	\pi	π	\varpi	ϖ
\rho	ρ	\varrho	ϱ	\sigma	σ
\varsigma	ς	\tau	τ	\upsilon	υ
\phi	ϕ	\varphi	φ	\chi	χ
\psi	ψ	\omega	ω		

Greek capital letters

Only those letters are having a separate command, which do not have a key in the ordinary keyboard.

`\Gamma`	Γ	`\Delta`	Δ	`\Theta`	Θ
`\Lambda`	Λ	`\Xi`	Ξ	`\Pi`	Π
`\Sigma`	Σ	`\Upsilon`	Υ	`\Phi`	Φ
`\Psi`	Ψ	`\Omega`	Ω		

Symbols: relations

`\approx`	$\approx$	`\asymp`	$\asymp$	`\bowtie`	$\bowtie$
`\cong`	$\cong$	`\dashv`	$\dashv$	`\doteq`	$\doteq$
`\equiv`	$\equiv$	`\frown`	$\frown$	`\ge` or `\geq`	$\geq$
`\gg`	$\gg$	`\in`	$\in$	`\le` or `\leq`	$\leq$
`\ll`	$\ll$	`\mid` or `|`	$\mid$	`\models`	$\models$
`\neq`	$\neq$	`\ni`	$\ni$	`\notin`	$\notin$

Symbols: relations...

`\parallel`	$\parallel$	`\prec`	$\prec$	`\preceq`	$\preceq$
`\perp`	$\perp$	`\propto`	$\propto$	`\sim`	$\sim$
`\simeq`	$\simeq$	`\smile`	$\smile$	`\sqsubseteq`	$\sqsubseteq$
`\sqsupseteq`	$\sqsupseteq$	`\subset`	$\subset$	`\subseteq`	$\subseteq$
`\succ`	$\succ$	`\succeq`	$\succeq$	`\supset`	$\supset$
`\supseteq`	$\supseteq$	`\vdash`	$\vdash$		

Symbols: binary operators

`\amalg`	$\amalg$	`\ast`	$\ast$
`\bullet`	$\bullet$	`\bigcirc`	$\bigcirc$
`\bigtriangledown`	$\bigtriangledown$	`\bigtriangleup`	$\bigtriangleup$
`\cap`	$\cap$	`\cdot`	$\cdot$
`\circ`	$\circ$	`\cup`	$\cup$
`\dagger`	$\dagger$	`\ddagger`	$\ddagger$
`\diamond`	$\diamond$	`\div`	$\div$
`\mp`	$\mp$	`\odot`	$\odot$

Symbols: binary operators...

`\ominus`	$\ominus$	`\oplus`	$\oplus$
`\oslash`	$\oslash$	`\otimes`	$\otimes$
`\pm`	$\pm$	`\setminus`	$\setminus$
`\sqcap`	$\sqcap$	`\sqcup`	$\sqcup$
`\star`	$\star$	`\times`	$\times$
`\triangleleft`	$\triangleleft$	`\triangleright`	$\triangleright$
`\uplus`	$\uplus$	`\vee`	$\vee$
`\wedge`	$\wedge$	`\wr`	$\wr$

Symbols: arrows

`\downarrow`	$\downarrow$
`\Downarrow`	$\Downarrow$
`\hookleftarrow`	$\hookleftarrow$
`\hookrightarrow`	$\hookrightarrow$
`\leftarrow` or `\gets`	$\leftarrow$
`\Leftarrow`	$\Leftarrow$
`\leftharpoondown`	$\leftharpoondown$
`\leftharpoonup`	$\leftharpoonup$
`\leftrightarrow`	$\leftrightarrow$
`\Leftrightarrow`	$\Leftrightarrow$

Symbols: arrows...

`\longleftarrow`	$\longleftarrow$
`\Longleftarrow`	$\Longleftarrow$
`\longleftrightarrow`	$\longleftrightarrow$
`\Longleftrightarrow`	$\Longleftrightarrow$
`\longmapsto`	$\longmapsto$
`\longrightarrow`	$\longrightarrow$
`\Longrightarrow`	$\Longrightarrow$
`\mapsto`	$\mapsto$
`\nearrow`	$\nearrow$
`\nwarrow`	$\nwarrow$

Symbols: arrows...

`\rightarrow` or `\to`	$\rightarrow$
`\Rightarrow`	$\Rightarrow$
`\rightharpoondown`	$\rightharpoondown$
`\rightharpoonup`	$\rightharpoonup$
`\rightleftharpoons`	$\rightleftharpoons$
`\searrow`	$\searrow$
`\swarrow`	$\swarrow$
`\uparrow`	$\uparrow$
`\Uparrow`	$\Uparrow$
`\updownarrow`	$\updownarrow$
`\Updownarrow`	$\Updownarrow$

Symbols: big symbols

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