Mathematics in LaTeX*

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1. The Basics

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1.2. Displayed Math

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Environment `displaymath`

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\end{displaymath}
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If package `amsmath` is used (highly recommended!), you have another synonym for `displaymath`: `equation*`

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  \begin{equation*}
    f''(x) = \frac{\sin f}{f}
  \end{equation*}
\pause
```

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There are also environments `eqnarray`, `eqnarray*`, and `amsmath` defines a slew of additional environments for numbered and unnumbered displayed math.

In all displayed math empty lines are *forbidden!*

2. Math Fonts & Spacing

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There are special fonts for math: `\mathbf` (for vectors), `\mathsf` (for matrices), `\mathcal` etc.:

```
\begin{displaymath}
  \mathbf{y} = \mathsf{A} \mathbf{x} + \mathcal{G}\mathbf{z}
\end{displaymath}
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There are several commands for spacing: `\,`, `\:`, `\;` for thin spaces, `\␣`, `\quad`, `\qquad` for thick spaces:

```
\begin{displaymath}
  \int f(x)\,dx = y, \qquad y>0
\end{displaymath}
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$$\int f(x)\,dx = y, \qquad y > 0$$

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\end{displaymath}
```

$$\int f(x)\,dx = y, \qquad y > 0$$

There is even a negative spacing: `\!`:

```
\begin{displaymath}
  \int\int f(x)\,dx,\qquad
  \int \! \int f(x)\,dx
\end{displaymath}
```

$$\int\int f(x)\,dx, \qquad \int\!\int f(x)\,dx$$

3. Superscripts and Subscripts

Superscripts: `^`. Subscripts: `_`. If you have multiletter sub- or superscripts, use grouping:

```
\begin{displaymath}
  G_{ij}^a = 1
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$$G_{ij}^{a} = 1$$

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$$G_{ij}^{a} = 1$$

Superscripts and subscripts are allowed only in math mode. This leads to many errors.

Exercise 1. Typeset the file:

superscript.tex

```
\documentclass{article}

\begin{document}

The data in the file new_data.dat are very interesting.

\end{document}
```

Can you explain the result?

4. Math Symbols

4.1. Greek Letters

Greek is very simple in TEX: just type the letter with backslash:

```
\begin{displaymath}
  \alpha + \gamma = \Gamma, \qquad \Delta x =
   \epsilon \zeta + \varepsilon
\end{displaymath}
```

$$\alpha + \gamma = \Gamma, \qquad \Delta x = \epsilon\zeta + \varepsilon$$

See the "Short Introduction"[1] and "Comprehensive List"[2].

[1] Tobias Oetiker et al., The Not So Short Introduction to LATEX 2ε, Or LATEX 2ε in 141 Minutes, May 2008, http://ctan.tug.org/tex-archive/info/lshort.

[2] Scott Pakin, The Comprehensive LATEX Symbol List, September 2008, http://ctan.tug.org/tex-archive/info/symbols/comprehensive.

4.2. Math Accents

Text accents do not work in math mode! But we have many *math accents:*

```
\begin{displaymath}
\tilde{A} = \hat{B} + \vec{\gamma} - \mathring{\zeta}
\end{displaymath}
```

$$\tilde{A} = \hat{B} + \vec{\gamma} - \mathring{\zeta}$$

Again, see the "Short Introduction"[3] and "Comprehensive List"[4].

[3] Oetiker et al., *op. cit.*
[4] Pakin, *op. cit.*


4.3. Math Operators

There is a big difference between `$sin x$` and `$\sin x$`: the first gives $sinx$, the second (the right one!) $\sin x$.

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Other functions include `\cos`, `\tan`, `\log`, etc. (see the familiar sources for the full list).

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Other functions include `\cos`, `\tan`, `\log`, etc. (see the familiar sources for the full list).

4.4. Some Other Symbols

```
\begin{displaymath}
  2\times2 = 4, \qquad
  \vec{a}\cdot\vec{b}=c, \qquad
  T=45^{\circ},\qquad
  \sqrt{2x} = 5
\end{displaymath}
```

$$2 \times 2 = 4, \qquad \vec{a} \cdot \vec{b} = c, \qquad T = 45^{\circ}, \qquad \sqrt{2x} = 5$$

5. Sums, Products, Integrals, Limits

Mathematicians love symbols with super- and subscripts:

```
\begin{displaymath}
\int_0^{\infty} f(x)\,dx, \qquad
\sum_{i=1}^12 a_i,\qquad
\prod_{j=2}^7 u^j,\qquad
\lim_{x\to0} f(x)
\end{displaymath}
```

$$\int_0^{\infty} f(x)\,dx, \qquad \sum_{i=1}^{1} 2a_i, \qquad \prod_{j=2}^{7} u^j, \qquad \lim_{x\to 0} f(x)$$

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\end{displaymath}
```

$$\int_0^{\infty} f(x)\,dx, \qquad \sum_{i=1}^{1} 2a_i, \qquad \prod_{j=2}^{7} u^j, \qquad \lim_{x\to0} f(x)$$

Note that the same symbols *inline* have different appearance $\int_0^{\infty} f(x)\,dx$, $\sum_{i=1}^{1} 2a_i$ $\prod_{j=2}^{7} u^j$, $\lim_{x\to0} f(x)$

6. Fractions

The command to enter fractions is `\frac{...}{...}`:

```
\begin{displaymath}
  \frac{12}{4} = 3,\qquad
  \frac{1}{\sum_{i=1}^5 x_i} = \sum_{i=1}^{10} y_i
\end{displaymath}
```

$$\frac{12}{4} = 3, \qquad \frac{1}{\sum_{i=1}^{5} x_i} = \sum_{i=1}^{10} y_i$$

Note the difference between sum in the denominator and in the right hand side.

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Note the difference between sum in the denominator and in the right hand side.

Inline fractions are very ugly: $\frac{12}{3} = 4$. Avoid them: $12/3 = 4$.

7. Delimiters

Mathematicians love big brackets. TEX can make them:

```
\begin{displaymath}
  \Biggl( \Bigl[ \bigl\{  \dots \bigr\} \Bigr] \Biggr)
\end{displaymath}
```

$$\left(\left[\{ \dots \} \right] \right)$$

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\end{displaymath}
```

$$\left(\left[\{\dots\}\right]\right)$$

TEX also knows how to adjust delimiters *automatically:*

```
  \begin{displaymath}
    \right( \frac{12}{3}+1 \right) = 5
  \end{displaymath}
```

$$\left(\frac{12}{3}+1\right)=5$$

The right and left delimiters might be different:

```
\begin{displaymath}
  \left[ \frac{3}{4}, \infty \right)
\end{displaymath}
```

$$\left[\frac{3}{4}, \infty\right)$$

The right and left delimiters might be different:

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\end{displaymath}
```

$$\left[\frac{3}{4}, \infty\right)$$

Limitation: each `\left` must correspond to `\right`.

Exercise 3. Typeset the file:

delimiters.tex

```
\documentclass{article}

\begin{document}

\begin{displaymath}
  \frac{df}{dx} \right| = 0
\end{displaymath}

\end{document}
```

Can you explain the result?

Sometimes you need just left or right brace. For these cases there is *empty delimiter* `\right.` or `\left.`:

```
\begin{displaymath}
  \left.  \frac{df}{dx} \right|_{x=0} = 0
\end{displaymath}
```

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

8. Matrices & Arrays

Mathematicians love matrices. Standard LaTeX has an environment *array*. Rows are separated by \\, columns by &. You need to tell how many columns do you have, and how to align them (usually centering):

```
\begin{displaymath}
  \left(
    \begin{array}{ccc}
      a   & b  & c \\
      g^2 & 12 & d
    \end{array}
  \right)
\end{displaymath}
```

$$\left(\begin{array}{ccc} a & b & c \\ g^2 & 12 & d \end{array} \right)$$

Package `amsmath` has a simpler version:

```
\begin{pmatrix}
    a   & b  & c \\
    g^2 & 12 & d
\end{pmatrix}
```

$$\begin{pmatrix} a & b & c \\ g^2 & 12 & d \end{pmatrix}$$

Sometimes you need equations aligned:

```
\begin{eqnarray}
  x + y & = & 2\\
  x - y & = & 4
\end{eqnarray}
```

$$x + y = 2 \tag{2}$$
$$x - y = 4 \tag{3}$$

Sometimes you need equations aligned:

```
\begin{eqnarray}
  x + y & = & 2\\
  x - y & = & 4
\end{eqnarray}
```

$$x + y = 2 \tag{2}$$
$$x - y = 4 \tag{3}$$

Again, it is better with `amsmath`

```
\begin{align}
  x + y & =  2\\
  x - y & =  4
\end{align}
```

$$x + y = 2 \tag{4}$$
$$x - y = 4 \tag{5}$$

9. AMS Packages

For serious mathematics the package `amsmath` is very useful. You should use it (and forget about ugly spacing of `eqnarray`!).

One of the best descriptions of this package is in the Gräetzer book[5]. The first part of this book is available online[6].

Another important package is `amssymb`. It defines many strange symbols.

[5] George Gräetzer, *More Math Math into LaTeX*, fourth edition (New York: Springer, 2007).
[6] http://ctan.tug.org/tex-archive/info/Math_into_LaTeX-4/

References

Gräetzer, George. *More Math Math into LaTeX*. Fourth edition. New York: Springer, 2007.

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