Typesetting mathematics with LaTeX

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LaTeX for Technical and Scientific Documents
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Day II

Outline

In this workshop:

- Day 1: Introduction to LaTeX
- **Day 2: Typesetting Mathematics**
- Day 3: Writing your thesis / technical report
- Day 4: Make your presentations
- Day 5: Basics of science communication

Outline

1. What did we learn about typesetting Math
2. Mathematics Symbology
3. Advanced equations
4. Greek Letters

Playing with mathematics text

Inline and display math

There are two kinds of math used in LaTeX.

- Inline math (surrounded by $ signs)
- Display math (surrounded by square brackets \[and \] or $$

About any point x in a metric space M we define the open ball of radius $r > 0$ about x as the set

$$B(x;r) = \{y \in M : d(x,y) < r\}.$$

```
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open ball of radius $r > 0$ about $x$ as the set
\[
B(x;r) = \{y \in M : d(x,y) < r\}.
\]
```

Typesetting equations

Numbered equations

Numbered equations can be typeset by using

```
\begin{equation}
R(x,y) = \frac{Ax^3+Bx^2+Cx+D}{Ey^3 + Fy + G}
\end{equation}
```

$$R(x,y) = \frac{Ax^3+Bx^2+Cx+D}{Ey^3 + Fy + G} \tag{1}$$

Outline

1. What did we learn about typesetting Math
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4. Greek Letters

Definition symbols

An example of a Cauchy sequence

A sequence of numbers $\left\langle x_i \right\rangle_{i=1}^n$, is called a Cauchy sequence, if $\exists\,\epsilon > 0$, $\forall N\in\mathbb{N}$, such that for all $m,n\in\mathbb{N}$,

$$\left\vert x_m - x_n \right\vert < \epsilon$$

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  $m,n\in\mathbb{N}$,
\[
\left\vert x_m - x_n \right\vert < \epsilon
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```

Definition symbols

Continuous function example

We can say that

$$\lim\limits_{x\rightarrow c} f(x) = L$$

if $\forall\,\varepsilon > 0$, $\exists\, \delta > 0$ such that $\forall x\in D$ that satisfy $0 < | x - c | < \delta$, the inequality $|f(x) - L| < \varepsilon$ holds.

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    \delta$ ,
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```

Outline

Multiline equations

... and alignment

If $h \leq \frac{1}{2}|\zeta - z|$ then

$$|\zeta - z - h| \geq \frac{1}{2}|\zeta - z|$$

and hence

$$\begin{aligned}\left|\frac{1}{\zeta - z - h} - \frac{1}{\zeta - z}\right| &= \left|\frac{(\zeta - z) - (\zeta - z - h)}{(\zeta - z - h)(\zeta - z)}\right| \\ &= \left|\frac{h}{(\zeta - z - h)(\zeta - z)}\right| \\ &\leq \frac{2|h|}{|\zeta - z|^2}. \qquad (2)\end{aligned}$$

```
If $h \leq \frac{1}{2} |\zeta - z|$ then
\[ |\zeta - z - h| \geq \frac{1}{2}
    |\zeta - z|\]
and hence
\begin{eqnarray}
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\frac{1}{\zeta - z} \right|
& = & \left|
\frac{(\zeta - z) -
(\zeta - z - h)}{(\zeta - z - h)(\zeta -
    z)}
\right| \nonumber \\  & = &
\left| \frac{h}{(\zeta - z - h)(\zeta -
    z)}
 \right| \nonumber \\
  & \leq & \frac{2 |h|}{|\zeta - z|^2}.
\end{eqnarray}
```

Case based definitions

An example of a continuous, nowhere differential function is given as

$$f(x) = \begin{cases} 0 & x \mathrm{\ is\ irrational} \\ 1 & x \mathrm{\ is\ rational} \end{cases}$$

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\begin{cases}
0 &{x\ \mathrm{\ is\ irrational}} \\
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\end{cases}
\]
```

Case based definitions

... a more professional one

An example of a continuous, nowhere differential function is given as

$$f(x) = \begin{cases} 1 & x \in \mathbb{Q} \\ 0 & x \in \mathbb{R} - \mathbb{Q} \end{cases}$$

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An example of a continuous, nowhere differential function
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\[
f(x) =
\begin{cases}
1 &{x\in\mathbb{Q}} \\
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\end{cases}
\]
```

Fractions and binomials

To typeset:

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

Use

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

For the computation of a permutation ${}^nP_k$, we would use the following formula:

$${}^n P_k = \underbrace{(n-1)(n-2)\dotsc(n-k+1)}_{\mbox{Exactly k factors}}$$

```
\[
{}^n P_k = \underbrace{(n-1)(n-2)
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\]
```

What about a continued fraction?

Any idea?

To get,

$$x = a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3 + \cfrac{1}{a_4}}}}$$

```
\[
  x = a_0 + \cfrac{1}{a_1
          + \cfrac{1}{a_2
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Square roots

... and other roots too!

$$A = \sqrt{4x^3 + 3x^2 - 5x + 1}$$

$$B = \sqrt[3]{4x^3 + 3x^2 - 5x + 1}$$

```
\[
A = \sqrt{4x^3 + 3x^2 - 5x + 1}
\]
\[
B = \sqrt[3]{4x^3 + 3x^2 - 5x + 1}
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Square roots

...use in mathematical expressions

Given a quadratic equation $ax^2 + bx + c = 0$, the roots of the equation are given by the following formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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Sums and Products

$$\sum_{i=0}^n a_i = a_1 + a_2 + a_3 + \dots + a_n$$

```
\[
\sum_{i=0}^n a_i = a_1 + a_2 + a_3 + \dots + a_n
\]
```

$$\prod_{i=0}^n a_i = a_1 \cdot a_2 \cdot a_3 \cdot \dots \cdot a_n$$

```
\[
\prod_{i=0}^n a_i = a_1 \cdot a_2 \cdot a_3
\cdot \dots \cdot a_n
\]
```

Integrals and Differentials

$$\int_0^\infty e^{-x^2} dx=\frac{\sqrt{\pi}}{2}$$

```
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\int_0^\infty e^{-x^2} dx=\frac{\sqrt{\pi}}{2}
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If $f(x,y) = x^2 + y^2$, then:

$$\frac{\partial f}{\partial x} = 2x$$

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Mathematical operators

Integration examples

In the field of integral calculus, it is known that

$$\int \sin x = -\cos x$$

and

$$\int \cos x = \sin x$$

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Mathematical operators and notation

Fourier transform

The Fourier transform, for a function $f(x)$, is given as

$$\hat{f}(\xi) = \int_{-\infty}^{\infty} f(x)\ e^{-2 \pi i x \xi}\, dx, \qquad \forall \xi\in\mathbb{R}$$

and the inverse Fourier transform is given as,

$$f(x) = \int_{-\infty}^{\infty} \hat{f}(\xi)\ e^{2 \pi i x \xi}\, d\xi \qquad \forall x \in\mathbb{R}$$

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Mathematical Operators

Continuity equation ... and vector notation

Mathematically, the integral form of the continuity equation is:

$$\frac{dq}{dt} + \oiint_S \mathbf{j} \cdot d\mathbf{S} = \Sigma$$

which in vector notation can also be written as

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Typesetting Matrices
... and determinants

The determinant of the matrix A, where

$$A = \begin{vmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{vmatrix}$$

is zero.

```
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A =
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Typesetting Matrices
Typically some long ones

The Gaussian Elimination Method can be used to find the solution of the following system of equations, represented in the matrix form:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{bmatrix}$$

```
\[
\begin{bmatrix}
a_{11} & a_{12} &a_{13} &\dots &a_{1n} \\ a_{21} & a_{22}
    &a_{23} &\dots &a_{2n} \\
\vdots &\vdots &\vdots &\ddots &\vdots \\ a_{n1} & a_{n2}
    &a_{n3} &\dots &a_{nn} \\
\end{bmatrix}
\begin{bmatrix}
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Array based typesetting of equations

Least squares example

The least squares method is used to find the solution of a system of n equations, with m variables where $m > n$. The system of equations is given as follows:

$$\begin{array}{llllll}
a_{11} x_1 &+a_{12} x_2 &+\dots &+a_{1m} x_m &= &b_1 \\
a_{21} x_1 &+a_{22} x_2 &+\dots &+a_{2m} x_m &= &b_2 \\
\dots &\dots &\dots &\dots &\dots &\dots \\
a_{n1} x_1 &+a_{n2} x_2 &+\dots &+a_{nm} x_m &= &b_m
\end{array} \tag{3}$$

```
The least squares method is used to find the solution of
a system of $n$ equations, with $m$ variables where
$m > n$. The system of equations is given as follows:
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\dots &\dots &\dots &\dots &\dots &\dots \\
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Array based typesetting of equations
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Array based typesetting of equations

Least squares example ... with a twist

The least squares method is used to find the solution of a system of n equations, with m variables where $m > n$. The system of equations is given as follows:

$$\rotatebox{90}{Solve} \left\{ \begin{array}{llllll}
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\end{array}\right. \tag{4}$$

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Array based typesetting of equations

Least squares example ... with a twist

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Greek letters

The small greek letters are
$\alpha, \beta, \gamma, \delta, \epsilon, \varepsilon, \zeta, \eta, \theta, \vartheta, \kappa, \varkappa, \lambda, \mu, \nu, \xi, \pi, \varpi, \rho, \varrho, \sigma, \varsigma, \tau, \upsilon, \phi, \varphi, \chi, \psi, \omega$,
and the capital greek letters are given as
$A, B, \Gamma, \Delta, E, Z, H, \Theta, K, \Lambda, M, N, \Xi, \Pi, P, \Sigma, T, \Upsilon, \Phi, X, \Psi, \Omega$


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\delta, \epsilon, \varepsilon, \zeta, \eta, \theta,
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\upsilon, \phi, \varphi, \chi, \psi, \omega$, and
the capital greek letters are given as $ A, B, \Gamma,
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\Sigma, T, \Upsilon, \Phi, X, \Psi, \Omega $
```

Example with greek letters

... and something more

If $Z_1, \dots, Z_k$ are independent, standard normal random variables, then the sum of their squares,

$$Q = \sum_{i=1}^k Z_i^2 ,$$

is distributed according to the ξ^2 distribution with k degrees of freedom. This is usually denoted as

$$Q \sim \chi^2(k) \ \text{or} \ Q \sim \chi^2_k .$$

The chi-squared distribution has one parameter: k – a positive integer that specifies the number of degrees of freedom (i.e. the number of Z_i's)

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