AMTH250 Lecture 2

LaTeX – Formatting Mathematics

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2 Formatting Mathematics

2.1 Mathematics Modes

There are two mathematics modes in LaTeX:

1. Mathematics within text is enclosed between `$` and `$` (most commonly), or between `\(` and `\)`, or between `\begin{math}` and `\end{math}`. This is often referred to as paragraph mode.

2. Mathematics displayed on a separate line is enclosed between `\[` and `\]`, or between `$$` and `$$` or between `\begin{displaymath}` and `\end{displaymath}`. This is often referred to as display mode.

Example:

```
Here is a formula
$x^2 + y^2 = z^2$
within a paragraph.
Here is the same formula
$$x^2 + y^2 = z^2$$
in display mode.
```

Here is a formula $x^2 + y^2 = z^2$ within a paragraph. Here is the same formula

$$x^2 + y^2 = z^2$$

in display mode.

Whitespace

There are some important differences between mathematics mode and text:

1. Most spaces and line breaks have no significance in mathematics mode.

2. Blank lines are not allowed in mathematics mode.

Example:

```
You can type a formula in a way that is almost most unreadable,
but as long as there are no blank lines it is OK to \LaTeX{}
$$          x       ^
            2  +   y
            ^
                   2=z
    ^                              2 $$
```

You can type a formula in a way that is almost most unreadable, but as long as there are no blank lines it is OK to LaTeX

$$x^2 + y^2 = z^2$$

2.1.1 Numbered Equations

The pair `\begin{equation}` and `\end{equation}` are used to obtain numbered equations. When equations are numbered, that numbering can be used to refer to particular equations. LaTeX has simple a mechanism for handling this: equations can be labelled with `\label{XXX}` and then referred to with `\ref{XXX}`. Notice, that the number tags are usually in parentheses, but `\ref{XXX}` does not produce them automatically. Therefore type `(\ref{XXX})` instead of `\ref{XXX}` to get the reference in parentheses.

Example:

```
Here is a numbered equation
\begin{equation}
  x^2 + y^2 = z^2 .
\end{equation}
When an equation has been labelled
\begin{equation} \label{eq:pythag}
  \sin^2 \theta + \cos^2 \theta = 1
\end{equation}
it can be referred to in the text, in this case as Equation
(\ref{eq:pythag}).
```

Here is a numbered equation

$$x^2 + y^2 = z^2. \tag{1}$$

When an equation has been labelled

$$\sin^2 \theta + \cos^2 \theta = 1 \tag{2}$$

it can be referred to in the text, in this case as Equation (2).

2.2 Basics

2.2.1 Mathematics Fonts

Mathematical symbols are generally printed in italics[1]. The dollar signs around mathematics takes care of this automatically so use `$x$` rather that

[1] More precisely, variables are printed in italics whereas constants and names of standard functions or operators are printed in romans. This can be achieved with the command \operatorname{}.

`\textit{x}`. The `\mathbf` command is used to produce bold maths symbols which are often used for vector and matrices. These are identical to bold roman text letters produced by `\textbf` and are not italicized.

Example:

```
Mathematical symbols like $A$, $x$ and $b$ are the same as
italic letters \textit{A}, \textit{x} and \textit{b}, but obey
different spacing rules as in $A x = b$ and \textit{A x = b}.
Numbers look the same whether in maths mode or not,
e.g $123.456$ is the same as 123.456.
```

Mathematical symbols like A, x and b are the same as italic letters A, x and b, but obey different spacing rules as in $Ax = b$ and $A\ x = b$. Numbers look the same whether in maths mode or not, e.g 123.456 is the same as 123.456.

2.2.2 Greek Letters

1. Lowercase Greek letters are referred to by their name, e.g. `\alpha`, `\beta`, `\gamma` ...
2. Uppercase Greek letters are referred to by their name with the first letter capitalized, e.g. `\Gamma`, `\Delta`, `\Lambda` ...
3. Greek letters can only be used in mathematics mode, not in ordinary text.

Example:

```
$$ V = \frac{4}{3} \pi r^3 $$
To use a Greek letter like $\Sigma$ in ordinary text we have
to be in mathematics mode.
```

$$V = \frac{4}{3}\pi r^3$$

To use a Greek letter like Σ in ordinary text we have to be in mathematics mode.

2.2.3 Exponents and Subscripts

1. Exponents and superscripts are specified by a caret `^`.
2. Subscripts are specified by an underscore `_`.
3. Exponents and subscripts are usually enclosed in braces `{...}`. However when the exponent or subscript is a single character the braces are not necessary.
4. Exponents and subscripts may be mixed and/or nested.

Example:

```
If you forget the braces you can get unintended results.
For example compare
$$ X_{ab} = y^{12}  \qquad X_ab = y^12 $$
Here are the right and wrong ways to nest exponents and
subscripts.
$$ e^{x^{2}} \qquad {e^{x}}^{2}  $$
$$ P_{a_{0}} \qquad {P_{a}}_{0}  $$
Here are some examples of mixed exponents and subscripts:
$$ A_{ij}^{3} \qquad A^{3}_{ij} \qquad 3^{- P_{0}}
     \qquad P_{x^{3}} $$
```

If you forget the braces you can get unintended results. For example compare

$$X_{ab} = y^{12} \qquad X_ab = y^12$$

Here are the right and wrong ways to nest exponents and subscripts.

$$e^{x^{2}} \qquad e^{x2}$$

$$P_{a_{0}} \qquad P_{a0}$$

Here are some examples of mixed exponents and subscripts:

$$A_{ij}^{3} \qquad A^{3}_{ij} \qquad 3^{- P_{0}} \qquad P_{x^{3}}$$

2.2.4 Fractions and Roots

Example:

```
Fractions are written with the \verb+\frac{...}{...}+
command. Here are some examples:
$$ \frac{n!}{(n-k)! k!} \qquad 2^{\frac{1}{2}}
     \qquad \frac{3^5}{4^5} $$
Sometimes it is preferable to use the slash form, e.g $1/2$,
as it can be easier to read in some contexts.
Compare
$$ x^{\frac{3}{4}} \qquad \text{to} \qquad x^{3/4} $$
and compare $\frac{3}{4}$ hour to $3/4$ hour.
```

Fractions are written with the `\frac{...}{...}` command. Here are some examples:

$$\frac{n!}{(n-k)!k!} \qquad 2^{\frac{1}{2}} \qquad \frac{3^5}{4^5}$$

Sometimes it is preferable to use the slash form, e.g 1/2, as it can be easier to read in some contexts. Compare

$$x^{\frac{3}{4}} \qquad \text{to} \qquad x^{3/4}$$

and compare $\frac{3}{4}$ hour to 3/4 hour.

Example:

```
Here is how we write square roots $\sqrt{b^2 - 4ac}$
and other roots $\sqrt[127]{2}$.
```

Here is how we write square roots $\sqrt{b^2 - 4ac}$ and other roots $\sqrt[127]{2}$.

2.2.5 Standard Functions

The names of certain standard mathematical functions and abbreviations are obtained by putting a backslash \ before their name. See the list on page 51 of NSSI.

Example:

```
$$ \lim_{x \rightarrow 0} \frac{\sin x}{x} = 1 $$
but if we forget the backslash we get
$$ \lim_{x \rightarrow 0} \frac{sin x}{x} = 1 $$
```

$$\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1$$

but if we forget the backslash we get

$$\lim_{x \rightarrow 0} \frac{sinx}{x} = 1$$

2.2.6 Integrals, Sums, Products

1. Integrals are generated by `\int`
2. Sums are generated by `\sum`
3. Products are generated by `\prod`
4. Limits of integration etc. are generated by superscripts and subscripts.

Example:

```
$$ \int \sin x dx = - \cos x \qquad
     \int_{0}^{\infty} e^{-x} dx = 1 $$

$$ \sum_{k=1}^n k =  \frac{1}{2} n (n + 1) \qquad
     \prod_{\text{$k$ even}} P_k = 1 $$

Integrals, $\int \sin x dx = - \cos x$, sums,
$\sum_{k=1}^n k =  \frac{1}{2} n (n + 1)$, and products
look different within paragraph mode.
```

$$\int \sin x dx = -\cos x \qquad \int_0^\infty e^{-x} dx = 1$$

$$\sum_{k=1}^{n} k = \frac{1}{2} n(n+1) \qquad \prod_{k \text{ even}} P_k = 1$$

Integrals, $\int \sin x dx = -\cos x$, sums, $\sum_{k=1}^{n} k = \frac{1}{2} n(n+1)$, and products look different within paragraph mode.

2.2.7 Derivatives

1. Derivatives are easily constructed using `\frac`
2. Alternatively, they can be written using the prime symbol `'`.
3. The partial derivative symbol is `\partial`

Example:

```
$$ \frac{d^2 y}{d x^2} + y(x) = 0 \qquad
     y'' + y = 0 \qquad
     \frac{\partial^2 \phi}{\partial x^2} +
     \frac{\partial^2 \phi}{\partial y^2} = 0 $$

Again, the slash form, $d\sin x/ dx = \cos x$, is
is sometimes preferable to the fraction form,
$\frac{d\sin x}{dx} = \cos x$, in paragraph mode.
```

$$\frac{d^2 y}{dx^2} + y(x) = 0 \qquad y'' + y = 0 \qquad \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$$

Again, the slash form, $d\sin x/dx = \cos x$, is is sometimes preferable to the fraction form, $\frac{d\sin x}{dx} = \cos x$, in paragraph mode.

2.2.8 Accents

There are a lot of these so make sure you use the right one for your particular need.

1. $\overline{x}$ `$\overline{x}$`
2. $\hat{x}$ `$\hat{x}$`
3. $\check{x}$ `$\check{x}$`
4. $\tilde{x}$ `$\tilde{x}$`
5. $\acute{x}$ `$\acute{x}$`

6. $\grave{x}$ `$\grave{x}$`
7. $\dot{x}$ `$\dot{x}$`
8. $\ddot{x}$ `$\ddot{x}$`
9. $\breve{x}$ `$\breve{x}$`
10. $\bar{x}$ `$\bar{x}$`
11. $\vec{x}$ `$\vec{x}$`
12. $\mathring{x}$ `$\mathring{x}$`
13. $\underline{x}$ `$\underline{x}$`

2.2.9 Brackets

For mathematical formulas to look right brackets must be the correct size. LaTeX will determine the correct size bracket if the opening bracket of a pair is preceded by `\left` and the closing bracket is preceded by `\right`. Curly brackets are written `\{` and `\}`.

Example:

```
$$ \left[\sum_{k=0}^n \left(x_k -
     \bar{x} \right)^2 \right]^{\frac{1}{2}} \qquad
     [\sum_{k=0}^n (x_k - \bar{x})^2]^{\frac{1}{2}} $$
```

$$\left[\sum_{k=0}^{n} (x_k - \bar{x})^2 \right]^{\frac{1}{2}} \qquad [\sum_{k=0}^{n} (x_k - \bar{x})^2]^{\frac{1}{2}}$$

2.2.10 Spacing

A number of examples have already used `\qquad` to separate formulas on one line. A `\qquad` is double the space of a `\quad`.

Another use of spacing is to adjust the position of symbols in formulas; sometimes small changes can make a big improvement. These are most often needed with integrals. The spacings available are:

1. `\!` – negative thinspace
2. `\,` – thinspace
3. `\:` – medspace
4. `\;` – thickspace

Example:

```
$$ \int_a^b f(x) \, dx  \qquad \qquad \int_a^b f(x) dx $$

$$ \int \!\!\!\! \int f(x,y) \, dx \, dy \qquad \qquad
     \int \int f(x,y) dx dy  $$
```

$$\int_a^b f(x)\,dx \qquad \int_a^b f(x)dx$$

$$\iint f(x,y)\,dx\,dy \qquad \int\int f(x,y)dxdy$$

2.2.11 Mathematical Symbols

There is a huge array of mathematical symbols available in LaTeX. See the tables on pages 60–66 of NSSI or `symbols.pdf` in the directory for this lecture. You should at least have a glance at these to see what is available.

2.2.12 Including Text

Text can be included in mathematical formulas by using the `\text{...}` command. This is part of the `amsmath` package and is preferable to the `\mbox` of standard LaTeX.

Example:

```
$$ f(x) > 0 \quad \text{for all $x \in X$} $$

$$ \epsilon_{\text{mach}} \approx 2.2 \times 10^{-16} $$
```

$$f(x) > 0 \quad \text{for all } x \in X$$

$$\varepsilon_{\text{mach}} \approx 2.2 \times 10^{-16}$$

2.3 The `amsmath` Package

This package makes available a number of features including:

1. A large number of additional mathematical symbols.
2. Easy to use matrix facility.
3. A variety of methods for aligning equations.

4. An easy way of adding new function names.

To access the package include

```
\usepackage{amsmath}
```

in the preamble.