LaTeX, A Short Course

Typesetting Mathematics

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January 31, 2017

Mathematical Formulas

- Math formulas may appear *inline* or *displayed*.
- Inline formulas appear in the body of the text. Example:

  The equation $f(x) = x^2 + 3$ is a parabola translated upwards by 3.

Mathematical Formulas

- Displayed equations are "showcased" on their own line, centered, and separated vertically by from the surrounding text. Example:

  The Pythagorean Theorem is very important in trigonometry. This theorem asserts that the equation

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

  where z is the length of the hypotenuse of a right-angle triangle, and x and y are the lengths of the remaining sides, always holds true.

Mathematical Formulas

- Displayed equations are generally used for emphasis of important formulae and can be automatically numbered by LaTeX.
- For the moment we will concentrate on how to typeset various mathematical notations.

Typing Inline Mathematics

- In order to typeset mathematics, one must tell LaTeX to enter *math mode*.
- For inline formula, this is done simply by enclosing the commands to typeset the formula within a pair of $'s:

  ```
  $f(x) = x^2$ is a parabola.
  ```

  typesets as

  $f(x) = x^2$ is a parabola.

Basic arithmetic

- Constants and variables are just numbers and single letters.
- Mathematical symbols that are available on the keyboard are:

Keyboard	Typesets as...	Keyboard	Typesets as...
+	$+$	-	$-$
=	$=$	<	$<$
>	$>$	/	$/$
:	$:$	'	$'$
|	$\vert$	[	$[$
]	$]$	(	$($
)	$]$		

Exponents and Indices

- Superscript and subscripts (exponents and indices) can be added to any symbol using ^ and _.
- Example: `$x^2$` produces x^2, `$x_2$` produces x_2.
- Both super- and sub-scripts can be attached to the same symbol.
- Example: `$x_2^2$` produces x_2^2.

Exponents and Indices

- If the exponent or index contains more than one character (in the source) then it must be enclosed in braces.
- Example:

```
$x^2n$
```

produces x^2n, while

```
$x^{2n}$
```

produces x^{2n}.

Exponents and Indices

- Unlimited nesting of exponents and indices is permitted:
  - `$x^{y^2}$`

    produces x^{y^2}.
  - `$A^{x_i^2}_{j^{2n}_{n,m}}$`

    produces $A^{x_i^2}_{j^{2n}_{n,m}}$.
- Note that `^` and `_` are only permitted in math mode.

Fractions

- Short, inline fractions are best typeset using the / character, for example,

```
$(a+b)/4$
```

  for $(a+b)/4$.

- For complicated fractions use the command:

```
\frac{numerator}{denominator}
```

Fraction Examples

- `$\frac{1}{2}$`

  produces: $\frac{1}{2}$

- `$\frac{a^2+b^2}{a+b} = a-b$`

  produces: $\frac{a^2+b^2}{a+b} = a - b$

```
$\frac{\frac{a}{x-y}+\frac{b}{x+y}}{1+\frac{a-b}{a+b}}$
```

produces: $\frac{\frac{a}{x-y}+\frac{b}{x+y}}{1+\frac{a-b}{a+b}}$ (Note nesting of fractions!).

Roots

- Roots are typeset using the command:

```
\sqrt[n]{arg}
```

- Example (cube root):

```
$\sqrt[3]{8} = 2$
```

typesets as $\sqrt[3]{8} = 2$.

- Omitting the optional argument `n` produces the square root.

```
$\sqrt{16} = 4$
```

typesets as $\sqrt{16} = 4$.

- Size and shape of the root sign are automatically fitted to the argument.
- Roots may be nested inside one another to any depth.

Exercise

- Making a copy of your `blank.tex` workfile (call it `math.tex`), try to reproduce the following formula:

$$\frac{\sqrt[3]{-q+\sqrt{a^2+b_2}}}{(n+1)^2}$$

Sums and Integrals

- Integrals are made with the command `\int`.
- Summations are typeset with the command `\sum`.
- Sums and integrals usually possess upper and lower limits, specified with the exponent and index commands. For example, the summation

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$$

is typeset by

```
$\sum_{i=1}^n i = \frac{n(n+1)}{2}$
```

Exercise

- Using your `math.tex` practice file, try to typeset the following:

  $2\sum_{i=1}^{n} a_i \left(\int_a^b f_i(x)g_i(x)\mathrm{d}x\right)$

- Notice how the exact same formula looks a bit different if set as a displayed equation:

$$2\sum_{i=1}^{n} a_i \left(\int_a^b f_i(x)g_i(x)\mathrm{d}x\right)$$

Displayed Formula

- Displayed equations are typeset by placing them in one of the following environments:
  - `equation` - numbered displayed formula
  - `equation*` - unnumbered displayed formula
- Enclosing an equation in double $'s (ie `$$...$$`) is a synonym for the `displaymath` environment.

Exercise

- Using the equations you have already typeset in `math.tex`, try enclosing them with different displayed equation environments:
  - `equation`
  - `displaymath`

  You may want to place some text before and after your displayed equations to really get a sense of where the displayed equation will appear.

Multiline Equations

- Vanilla LaTeX does not have good support for multiline equations.
- The `amsmath` package is superior for this purpose.
- To use the package we must put the following command in our document preamble:

```
\usepackage{amsmath}
```

Aligning a List of Equations

- A common need is to list a few equations, one per line, and have them horizontally aligned.
- This can be done with the `align` environment.
- A typical (but not the only) form of usage is:

```
\begin{align}
eq1ls &= eqn1rs \\
eq2ls &= eqn2rs \\
eq3ls &= eqn3rs
\end{align}
```

Ampersands are alignment points, \\ to end a line is mandatory. Do not use \\ on last line.

Aligning a List of Equations

- Example:

```
\begin{equation}
\begin{align}
x &= y\\
f(x) &= 2n^2 + 5n + 1\\
&= O(n^2)
\end{align}
\end{equation}
```

produces:

$$x = y \tag{1}$$
$$f(x) = 2n^2 + 5n + 1 \tag{2}$$
$$= O(n^2) \tag{3}$$

Working with the `align` environment.

- The `\nonumber` command can be placed at the end of a line, before the `\\` to suppress the equation number on that line.
- The starred variant, `align*`, turns off all equation numbering.
- Other variants are possible such as multiple columns of aligned equations.
- For further possibilities, and other multiline equation environments see the `amsmath` package documentation.

Exercise

- Adding again to `math.tex`, try typesetting the following using the `align` environment:

$$(x+3)(x+2)(x+1) = (x^2+5x+6)(x+1) \tag{4}$$
$$= x^3+6x^2+11x+6 \tag{5}$$

- Try suppressing one of the equation numbers with `\nonumber`

Referencing Equations

- You can create a reference to a numbered equation using the

  ```
  \label{string}
  ```

  command.
- For multi-line equations (`align`) the label should go at the end of the line before the double-backslash.
- For `equation` environments, the label can go anywhere within the environment.
- You can typeset the number labeled equation using

  ```
  \ref{string}
  ```

- The string argument is a unique symbolic name for the equation number.

Exercise

- Try labeling the second line of your multi-line equation with:

  `\label{mystring}`.

  (Remember to put it just before the double backslash)

- Following your `align` environment, typeset the sentence:

```
Please refer to equation \ref{mystring}.
```

  Re-run LaTeX and view – you may have to run LaTeX twice for the number to appear.

- Put a `\nonumber` at the end of the first equation (before the double backslash) and re-typeset to see how the label number in the sentence following the equation changes.

Mathematical Symbols

- All mathematical symbols must be typeset in math mode.
- Greek letters are typeset by commands with the name of the letter:
  - `$\alpha$` typesets α
  - `$\lambda$` typesets λ
  - `$\sigma$` typesets σ
- Uppercase Greek letters are distinguished by capitalizing the first letter of the command:
  - `$\delta$` typesets δ
  - `$\Delta$` typesets Δ

Mathematical Symbols

- Other common mathematical symbols:

\times	$\times$	\cap	$\cap$	\cup	$\cup$
\cdot	$\cdot$	\leq	$\leq$	\geq	$\geq$
\subset	$\subset$	\subseteq	$\subseteq$	\supset	$\supset$
\neq	$\neq$	\in	$\in$	\not\in	$\notin$
\leftarrow	$\leftarrow$	\rightarrow	$\rightarrow$	\not\subseteq	$\not\subseteq$
\emptyset	$\emptyset$	\infty	∞		

- LaTeX reference books can give you the commands for dozens more symbols. If you can think of a symbol, there is probably a LaTeX command for it.
- Most symbols that represent relations can have `\not` prepended to get the negated version.

Function Names

- The standard way to typeset math is to put symbols in italics and function names in Roman. For example:

$$\sin x$$

- We have seen how to do this with `\mathrm`.
- For common function names, LaTeX has built-in commands, for example:

`\sin x`	$\sin x$	`\cos x`	$\cos x$
`\tan x`	$\tan x$	`\log x`	$\log x$
`\lim_{n\rightarrow\infty}`	$\lim_{n\to\infty}$		

- It is preferable to use built-in function names because LaTeX is able to achieve more attractive spacing.

Advanced Mathematics

- There are many ways to fine-tune the typesetting of formula and additional features such as:
  - Theorem environments
  - Fine-tuning spacing
  - Overlines and underlines (bars and braces)
  - Stacking of symbols to form new symbols
  - Math accents
  - Many more...