COMP516 Practical 8
(non-assessed)
11 November 2008

This is the final LaTeX practical. In this session we want to investigate one of the strength of LaTeX, namely *typesetting of mathematical formulae*. This document can be found at

`http://www.csc.liv.ac.uk/~ullrich/COMP516/notes/practical8.pdf`

As you might expect, LaTeX uses markup to describe mathematical formulae. The amount of markup required is by far not as extensive as for MathML (`http://www.w3.org/Math/`).

1. In order to describe a mathematical formula using LaTeX, you must enter *mathematics mode* before the formula and leave it afterwards. If you want to embed a mathematical formula into text, then LaTeX uses `\(` and `\)` to mark the beginning and the end of a mathematical formula. Alternatively, you can enclose a mathematical formula in pair of $ signs.

   Add the following text to the file `small.tex` **before** the line `\bibliography{mysources}`:

   ```
   Let f be the function defined by \(f(x,y)=3xy+7\), and let \(flow\) be a positive
   real number. Let \(f\) be the function defined by \(f(x, y) = 3xy + 7\), and let
   \(\mathit{flow}\) be a positive real number.
   ```

   Save the file, run `latex small` once, and have a look at the DVI file. The new text that you've added should have been typeset as follows:

   > Let f be the function defined by $f(x, y) = 3xy + 7$, and let $flow$ be a positive real number. Let f be the function defined by $f(x, y) = 3xy + 7$, and let flow be a positive real number.

   LaTeX uses a different character set, called *math italic*, to typeset mathematical formulae. This is the reason why the first 'f' in the first sentence doesn't look like the 'f' in $f(x, y)$. Since both refer to the same 'object', this is a mistake. We should have used '`\(f\)`' for the first 'f' to ensure that they look the same; as is done in the second sentence.

   Also, compare the occurrence of $flow$ in the first sentence with flow in the second sentence. In the first sentence, the characters 'f', 'l', 'o', 'w' are further apart than in the second sentence. This is because in mathematics mode, LaTeX interprets a sequence of characters as a their *mathematical product*, like in xy which is the product of x and y. However, we've obviously intended flow to be a the name/identifier of a *constant* or *variable*. For this we need the use the markup `\mathit{flow}`, as is done in the second sentence.

   Finally, note that in the first sentence we have used `\(f(x,y)=3xy+7\)`, without any spaces, while in the second sentence we have used `\(f(x, y) = 3xy + 7\)`. However, the typeset text for both looks absolutely identical. In mathematics mode, LaTeX ignores the spaces you type and puts in the spacing that it thinks is best.

2. In order to obtain a mathematical formula or equation which is displayed on a line by itself, one places `\[` before and `\]` after the formula. Alternatively, the formula can be enclosed in a pair of $$ signs.

   Add the following text to the file `small.tex` **before** the line `\bibliography{mysources}`:

   ```
   If $f(x_1) = 3x_1 + 7$ and $g(x_1) = x_1 + 4$ then \[f(x_1) + g(x_1) = 4x_1 + 11.\]
   ```

Save the file, run `latex small` once, and have a look at the DVI file. The new text that you've added should have been typeset as follows:

If $f(x_1) = 3x_1 + 7$ and $g(x_1) = x_1 + 4$ then
$$f(x_1) + g(x_1) = 4x_1 + 11.$$

Note that `x_1` produces 'x' with a subscript '1' and that the formula enclosed in `\[...\]` is centered on a line on its own.

3. LaTeX provides facilities for the automatic numbering of equations. If you want a numbered equation then you use `\begin{equation}` and `\end{equation}` instead of `\[` and `\]`. This becomes even more useful if you label those equations (using a `\label` macro) so that you can late refer to them (using a `\ref` or `\pageref` macro).

   Add the following text to the file `small.tex` **before** the line `\bibliography{mysources}`:

```
If $f(x) = 3x + 7$ and $g(x) = x + 4$ then
\begin{equation}
  f(x) + g(x) = 4x + 11\label{eq1}
\end{equation}
and
\begin{equation}
  f(x)g(x) = 3x^2 + 19x +28.\label{eq2}
\end{equation}
Are equations \ref{eq1} and \ref{eq2} on page \pageref{eq1} correct?
```

   Save the file, run `latex small` twice, and have a look at the DVI file. The new text that you've added should have been typeset as follows (the page number might be different):

   If $f(x) = 3x + 7$ and $g(x) = x + 4$ then
$$f(x) + g(x) = 4x + 11 \tag{1}$$
   and
$$f(x)g(x) = 3x^2 + 19x + 28. \tag{2}$$
   Are equations 1 and 2 on page 3 correct?

   Note that `x^2` produces 'x' with a superscript '2'.

4. Often we want to align related equations together, or to align each line of a multi-line derivation. The `eqnarray` mathematics environment does this.

   Add the following text to the file `small.tex` **before** the line `\bibliography{mysources}`:

```
\begin{eqnarray}
  \cos 2\theta & = & \cos^2 \theta - \sin^2 \theta \label{eq3}\\
             & = & 2 \cos^2 \theta - 1.\label{eq4}
\end{eqnarray}
These equations will get labels \ref{eq3} and \ref{eq4}.
```

   Save the file, run `latex small` once, and have a look at the DVI file. The new text that you've added should have been typeset as follows:

$$\cos 2\theta = \cos^2\theta - \sin^2\theta \tag{3}$$
$$= 2\cos^2\theta - 1. \tag{4}$$

   These equations will get labels 3 and 4.

5. Both the `equation` and `eqnarray` have a variant `equation*` and `eqnarray*`, respectively, which suppress the numbering of equations. See the effect by modifying the previous example to

```
\begin{eqnarray*}
  \cos 2\theta & = & \cos^2 \theta - \sin^2 \theta \label{eq3}\\
               & = & 2 \cos^2 \theta - 1.\label{eq4}
\end{eqnarray*}
These equations will get labels \ref{eq3} and \ref{eq4}.
```

6. Mathematicians and computer scientists love to use greek letters. The previous example already shows you how this is done in LaTeX. Greek letters are produced in mathematics mode by preceding the name of the letter by a backslash `\`, e.g. `\alpha`, `\beta`, ..., `\omega`. There are also uppercase greek letters, e.g. `\Pi`, `\Omega`. Note that these macros will only work in mathematics mode. Test those macros by adding them to your text in mathematics mode and see how they are typeset.

7. There is a whole raft of other symbols for which LaTeX provides macros, for example, `\forall` for $\forall$, `\exists` for $\exists$, `\land` for $\land$, `\lor` for $\lor$, `\neg` for $\neg$, `\times` for $\times$, `\cap` for $\cap$, `\cup` for $\cup$, etc. For a more complete list see

   `http://www.maths.tcd.ie/~dwilkins/LaTeXPrimer/MathSymb.html`

8. Besides `\mathit` there are three more macros which allow you to change fonts in mathematics mode: `\mathrm` for roman/regular font, `\mathbf` for bold font, and `\mathcal` for a calligraphic font (only available for uppercase letters). Add the following text to the file `small.tex` **before** the line `\bibliography{mysources}`:

```
According to Hamilton's principle, the true evolution $\mathbf{q}_{\mathrm{true}}(t)$
is an evolution for which the action $\mathcal{S}[\mathbf{q}(t)]$ is stationary.
```

   Save the file, run `latex small` once, and have a look at the DVI file.

9. *Fractions* are obtained in LaTeX using the `\frac` macro, which takes two arguments, numerator and denominator (in that order). To obtain *square roots* one uses the macro `\sqrt` which has a single argument, while the nth root is produced using `\sqrt[n]{expression}`. Add the following text to the file `small.tex` **before** the line `\bibliography{mysources}`:

```
The function $f$ is given by \[ f(x) = 2x + \frac{x - 7}{x^2 + 4}\] for all real
numbers $x$. The roots of a quadratic polynomial $a x^2 + bx + c$ with $a \neq 0$
are given by the formula \[ \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}. \]
The roots of a cubic polynomial of the form $x^3 - 3px - 2q$ are given by the
formula \[ \sqrt[3]{q + \sqrt{ q^2 - p^3 }} + \sqrt[3]{q - \sqrt{ q^2 - p^3 }} \]
where the values of the two cube roots must are chosen so as to ensure that their
product is equal to $p$.
```

   Save the file, run `latex small` once, and have a look at the DVI file.

10. To obtain mathematical expressions such as

$$\lim_{x \to +\infty}, \quad \inf_{x > s} \quad \text{and} \quad \sup_K$$

   we use `\lim_{x \to +\infty}`, `\inf_{x > s}` and `\sup_K`, respectively.

To obtain a *summation sign* such as $\sum_{i=1}^{2n}$ type `\sum_{i=1}^{2n}`.

Integrals are a bit more complicated. An integral sign $\int$ is produced by `\int` and limits a and b are added as sub- and superscripts, i.e. `\int_a^b`. Most integrals occurring in mathematical documents begin with an integral sign and contain one or more instances of d followed by another (Latin or Greek) letter, as in dx, dy and $d\theta$. To obtain the correct appearance one should put extra space before the d, using `\,`. As an example try

```
\[ \int_0^{+\infty} x^n e^{-x} \,dx = n!.\]
```

11. Topics we won't have time to explore are the typesetting of matrices and other arrays in mathematics mode and the typesetting of tabular material in general. For details on how this is done in LaTeX see

    `http://www.giss.nasa.gov/tools/latex/ltx-202.html`

12. As a final exercise, try to reproduce the following equations in LaTeX:

$$\lim_{n\to\infty}\sum_{k=1}^{n}\frac{1}{k^2} = \int_1^n \cos^2 k \times \sin^2 k \tag{5}$$

$$= \begin{cases} -\pi^2 k, & \text{if } k \leq 0 \\ \pi^2 k, & \text{otherwise} \end{cases} \tag{6}$$

This concludes our consideration of LaTeX. In our four practicals we have only been able to scratch the surface of what LaTeX is capable of. For a more comprehensive overview see, for example, Tobias Oetiker et al.'s 'Not So Short Introduction to LaTeX 2_ε' at

`http://www.ctan.org/tex-archive/info/lshort/english/lshort.pdf`