\LaTeX, A Short Course

Typesetting Mathematics

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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.

- 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.
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.
In order to typeset mathematics, one must tell \LaTeX\ to enter \textit{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:

<table>
<thead>
<tr>
<th>Keyboard Symbol</th>
<th>Typesets as...</th>
<th>Keyboard symbol</th>
<th>Typesets as...</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
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</tbody>
</table>
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 \( x^{2n} \).
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

<table>
<thead>
<tr>
<th>Source</th>
<th>Typeset Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{1}{2})</td>
<td>(\frac{1}{2})</td>
</tr>
<tr>
<td>(\frac{a^2+b^2}{a+b} = a-b)</td>
<td>(\frac{a^2+b^2}{a+b} = a-b)</td>
</tr>
<tr>
<td>(\frac{\frac{a}{x-y}+\frac{b}{x+y}}{1+\frac{a-b}{a+b}})</td>
<td>(\frac{\frac{a}{x-y}+\frac{b}{x+y}}{1+\frac{a-b}{a+b}})</td>
</tr>
</tbody>
</table>

- Note nesting of fractions in the third example.
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.
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:

\[ \sqrt[3]{-q + \sqrt{a^2 + b^2}} \]
\[ \frac{1}{(n+1)^2} \]
Integrals are made with the command \texttt{\textbackslash int}.

Summations are typeset with the command \texttt{\textbackslash 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:

\[ 2 \sum_{i=1}^{n} a_i \left( \int_a^b f_i(x) g_i(x) \, dx \right) \]

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

\[
2 \sum_{i=1}^{n} a_i \left( \int_a^b f_i(x) g_i(x) \, dx \right)
\]
Displayed equations are typeset by placing them in one of the following environments:

- **displaymath** - unnumbered displayed formula
- **equation** - numbered displayed formula
- **eqnarray** - numbered multi-line equation
- **eqnarray** - unnumbered multi-line equation

Enclosing an equation in double $’s (ie $$\ldots$$) is a synonym for the displaymath environment.

Similarly for \[\ldots\].
Exercise

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

- `displaymath`
- `equation`

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.

(Don’t try `eqnarray` yet)
Multiline Equations

- The \texttt{eqnarray} and \texttt{eqnarray*} environments work slightly differently.
- The formats are
  \[
  \begin{eqnarray}
  \text{line}_1 \backslash \text{line}_2 \backslash \ldots \backslash \text{line}_n \\
  \end{eqnarray}
  \]
  \[
  \begin{eqnarray*}
  \text{line}_1 \backslash \text{line}_2 \backslash \ldots \backslash \text{line}_n \\
  \end{eqnarray*}
  \]
- Each line has the form:
  \[
  \text{left\_formula} \quad & \quad \text{middle\_formula} \quad & \quad \text{right\_formula} \\
  \]
- Left formulas appear right-justified in their column, middle formulas are centered, and right formulas are left-justified.
- This allows for nice alignment of equations when used properly.
Exercise

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

\[
(x + 3)(x + 2)(x + 1) = (x^2 + 5x + 6)(x + 1) \\
= x^3 + 6x^2 + 11x + 6
\] (1)

(2)

- Remember that columns may be left empty. You do not need to give a left/middle/right formula for every line.

- Auto-numbering can be suppressed for a given line by putting `\nonumber` at the end of the line before the double-backslash (try this with the first line).

- The `eqnarray*` environment is identical but does no automatic numbering.
You can create a reference to a numbered equation using the `\label{string}` command.

For multi-line equations (eqnarray) 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 obtain the number of the automatically numbered 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)

■ Follow the \texttt{eqnarray} environment with 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 \texttt{\nonumber} at the end of the first equation (always before the double backslash) and re-typeset to see how the label number in the sentence following the equation changes.
Greek letters are typeset by commands with the name of the letter:

- \( \alpha \) typesets \( \alpha \)
- \( \lambda \) typesets \( \lambda \)
- \( \sigma \) typesets \( \sigma \)

Uppercase Greek letters are distinguished by capitalizing the first letter of the command:

- \( \delta \) typesets \( \delta \)
- \( \Delta \) typesets \( \Delta \)
Mathematical Symbols

- **Other common mathematical symbols:**
  
  \( \times \) \( \cap \) \( \cap \) \( \cup \) \( \leq \) \( \geq \)
  
  \( \cdot \) \( \leq \) \( \geq \)
  
  \( \subset \) \( \subseteq \) \( \supset \)
  
  \( \neg \) \( \in \) \( \notin \)
  
  \( \leftarrow \) \( \rightarrow \) \( \not\subseteq \)
  
  \( \emptyset \) \( \infty \)

- **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.
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 \texttt{\textbackslash \mathrm{}}. For common function names, \LaTeX{} has built-in commands, for example:

\begin{align*}
\sin x & \quad \cos x \\
\tan x & \quad \log x \\
\lim_{n \to \infty} & \quad \lim_{n \to \infty}
\end{align*}

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

Complete lists are available in the references.
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...