Introduction to Scientific Typesetting
Lesson 4: Typing Mathematics

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An Overview

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Getting Started

Two Types

There are two types of math (or formulas):

- inline — the formula is part of the current line or paragraph
- displayed — on a separate line (or lines) with spacing that sets it apart

Inline Formulas

Use dollar signs to surround a formula like $2 + 2 = 4$.

```
Use dollar signs to surround
a formula like $2+2=4$.
```

Displayed Formulas

Use the symbols `\[` and `\]` to enclose a formula like

$$2 + 2 = 4.$$

```
...to enclose a formula like \[ 2+2=4. \]
```

Typing `$` or `\[` sends LaTeX into *math mode*. Some of the behavior is different in this mode, so be careful!

An Example

Let f be the function $f(x) = x^2$. This means that $f(2) = 4$ and

$$f(-3) = 9.$$

```
Let $f$ be the function $f(x)=x^2$.
This means that $f(2)=4$ and \[ f(-3)=9. \]
```

Note 1: Remember that formulas are part of your writing, so punctuation rules need to be observed!

Note 2: `\[` and `\]` are shortcuts for `\begin{displaymath}` and `\end{displaymath}`

Working With Math

Spacing in Math Mode

LaTeX treats multiple spaces as one. The following give the same output:

2+2=4

2 + 2 =4

The spacing after a comma is different in math and text. Unless the comma is part of the mathematical notation, you generally want it outside of math mode.

Example: To write $\boxed{x = a, b, \text{ or } c}$ type:

```
$x=a$, $b$, or $c$
```

The amsmath package

Some of what follows requires the `amsmath` package to be loaded in your preamble. So, just to be safe, include

```
\usepackage{amsmath}
```

in your preamble from now on.

Here's a good template for our class at this point:

```
\documentclass{article}
\usepackage[margin=1in]{geometry}
\usepackage{amsmath}
\begin{document}

\end{document}
```

The `equation` environment is the same as the `displaymath` environment except each `equation` environment is numbered.

The quadratic formula is:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}. \tag{1}$$

No blank lines are allowed in an `equation` environment!

The `equation*` environment is the same as `displaymath` or `\[` and `\]`.

(A good rule of thumb—the starred version of an environment suppresses the numbering.)

The Operations of Arithmetic

Here are the ways to type common arithmetic operations:

Type	Display
`$a + b$`	$a + b$
`$a - b$`	$a - b$
`$a \times b$`	$a \times b$
`$a \div b$`	$a \div b$
`$a \cdot b$`	$a \cdot b$
`$a / b$`	a/b

Fractions

Fractions are only slightly different than the other mathematical operators.

To see this: $\dfrac{2+x}{6-y}$, you need to type this: `\frac{2+x}{6-y}`.

Within text this fraction $\frac{2+x}{6-y}$ will look small. We can use `\dfrac` to fix that inline.

You know $\dfrac{2+x}{6-y}$ is my favorite $\ldots$

```
You know $\dfrac{2+x}{6-y}$ is my favorite \ldots
```

If you want the (smaller) inline-sized fraction in display mode, use `\tfrac`.

Subscripts and Superscripts

The “caret” ^ is used for superscripts and the underscore _ is used for subscripts.

Type	Display
`$x^2$`	x^2
`$x_7$`	x_7
`$x^{10}$`	x^{10}
`$x_{17}$`	x_{17}

Note that if your subscript or superscript is more than one character, you’ll need to enclose it in braces.

Ellipses

There are several types of ellipses that LaTeX provides in math mode:

Type	Display
`\ldots`	$1, 2, \ldots$
`\cdots`	$1 + 2 + \cdots + 10$
`\vdots`	$\vdots$
`\ddots`	$\ddots$

The square root sign is made with a command in math mode.

`$\sqrt{51}$` produces $\sqrt{51}$

This is used for all kinds of roots, not just square roots:

`$\sqrt[3]{5}$` produces $\sqrt[3]{5}$

`$\sqrt[10]{44}$` produces $\sqrt[10]{44}$

Text in math is produced with the `\text` command.

$$\text{Area of a rectangle} = l \cdot w \tag{2}$$

```
\begin{equation}
\text{Area of a rectangle} = l\cdot w
\end{equation}
```

Let’s practice!

Open up the first example PDF file from Sakai, and reproduce it.

Symbols

Greek letters are needed frequently within formulas, like

$$A = \pi r^2.$$

```
...within formulas, like \[ A = \pi r^2. \]
```

You can find a list of the permitted Greek letters in a table on our web site. LaTeX can do some of the Greek capitals, but not all of them.

A lot of these are easy to guess:

Type	Display	Type	Display
`$\alpha$`	α	`$\phi$`	ϕ
`$\beta$`	β	`$\psi$`	ψ
`$\gamma$`	γ	`$\omega$`	ω
`$\delta$`	δ		

This is a mathematics-specific symbol, but it illustrates a larger point. Consider this formula:

$$\int_2^{15} x^2\,dx.$$

```
formula: \[ \int_2^{15} x^2\,dx. \]
```

There are lots of integral symbols available:

Type	Display	Type	Display
`$\int$`	$\int$	`$\iint$`	$\iint$
`$\oint$`	$\oint$	`$\iiint$`	$\iiint$

Delimiters

A *delimiter* is simply a special math symbol to enclose part of a formula. The parentheses in the following formula are an example of delimiters:

$$(x+y)^2.$$

There are all sorts of delimiters available:

Type	Display	Type	Display
`$($`	$($	`$[$`	$[$
`$\{$`	$\{$	`$\|$`	$\vert$
`$\langle$`	$\langle$	`$\rangle$`	$\rangle$
`$\\|$`	$\Vert$		

Stretching Delimiters

Sometimes delimiters do not extend up and down enough to fully enclose what's inside. You can see that here:

$$(\frac{1}{5})^6 \qquad \texttt{(\textbackslash frac\{1\}\{5\})\^{}6.}$$

Instead, we should have

$$\left(\frac{1}{5}\right)^6 \qquad \texttt{\textbackslash left(\textbackslash frac\{1\}\{5\}\textbackslash right)\^{}6.}$$

The `\left` and `\right` commands can be applied to *most* delimiters.

$$\left[\frac{1}{5}\right] \qquad \texttt{\textbackslash left[\textbackslash frac\{1\}\{5\} \textbackslash right]}$$

$$\left\{\frac{1}{5}\right\} \qquad \texttt{\textbackslash left\textbackslash\{ \textbackslash frac\{1\}\{5\} \textbackslash right\textbackslash\}}$$

More on Stretching Delimiters

LaTeX requires a *pair* when stretching delimiters, but they don't have to match.

$$\left(\frac{1}{5} \right\} \qquad \texttt{\textbackslash left(\textbackslash frac\{1\}\{5\} \textbackslash right\textbackslash \}}$$

If you want to stretch just a single delimiter, you need to "fake" the other one.

$$\left[\frac{1}{5} \right. \qquad \texttt{\textbackslash left[\textbackslash frac\{1\}\{5\} \textbackslash right.}$$

`\left.` and `\right.` accomplish this for you.

Specifying Delimiter Height

Instead of trusting LaTeX to give your delimiter the correct size, you can specify it yourself in some cases.

$$(\quad \big(\quad \Big(\quad \bigg(\quad \Bigg($$

`(   \big(   \Big(   \bigg(   \Bigg(`

The analogs for right delimiters exist too, and these can be applied to *most* delimiters.

Example: in integral problems, you need to write $F(x)\Bigr|_a^b$.

`\right|` isn't big enough, so I use `\Bigr|_a^b`.

An *operator* in LaTeX is a log-like function, like $\sin$ or $\ln$.

To get $\sin x$ you cannot type `$sin x$` or `sin $x$`. You must type `$\sin x$`.

Another kind of operator is $\lim$. This is called an *operator with limits* because it is frequently used like this:

$$\lim_{x \to 1} f(x) \qquad \texttt{\textbackslash lim\_\{x \textbackslash to 1\} f(x)}$$

For this reason, operators like $\sin$ are called *operators without limits*.

You need to be in display mode for the $x \to 1$ to go *under* the symbol; otherwise you'll get $\lim_{x \to 1} f(x)$.

You can fake display mode with `\displaystyle`.
Type: `$\displaystyle \lim_{x \to 1} f(x)$`

Tables of Operators

Operators without limits:

Type	Display	Type	Display
`$\sin$`	$\sin$	`$\cos$`	$\cos$
`$\tan$`	$\tan$	`$\cot$`	$\cot$
`$\arcsin$`	$\arcsin$	`$\arctan$`	$\arctan$
`$\deg$`	$\deg$	`$\dim$`	$\dim$

Operators with limits:

Type	Display	Type	Display
`$\lim$`	$\lim$	`$\det$`	$\det$
`$\max$`	$\max$	`$\min$`	$\min$

There are lots more of both of these; see resources linked from our class web page if necessary.

The symbols for sums and products are examples of symbols which have different sizes depending on whether they are typeset inline or in a displayed environment.

Here is the sum symbol $\sum_{i=i}^n i$ typeset inline, and here it is displayed:

$$\sum_{i=1}^n i.$$

```
\sum_{i=1}^n i
```

Though there are lots of other symbols which have this property, the other most common one is the symbol for a product:

$$\prod_{i<4} i^2$$

```
\prod_{i < 4} i^2
```

Let’s practice!

Open up the second example PDF file from Sakai, and reproduce it.

Multiline Mathematics

Aligned Formulas

When you want to consider multiple formulas or equations at once, you need a nice way to put math on multiple lines. The simplest setup here is when you have a point to line up in the equations.

$$a^2 + b^2 = c^2 \tag{3}$$
$$a + b = c + 2 \tag{4}$$

```
\begin{align}
a^2 + b^2 &= c^2 \\
a+b &= c + 2
\end{align}
```

Use & as your alignment point and `\\` as the line separator.

The `align*` environment will align without equation numbers.

Multiple Aligned Columns

The `align` environment aligned things in one column. The `alignat` environment allows alignment of multiple columns and control over the intercolumn space.

$$f(x) = x^2 \qquad g(x) = 2x - 1 \tag{5}$$
$$f(2) = 4 \qquad g(2) = 3 \tag{6}$$

```
\begin{alignat}{2}
f(x) &= x^2  \qquad & g(x) &= 2x-1 \\
f(2) &= 4 & g(2) &= 3
\end{alignat}
```

The mandatory argument is the number of aligned columns.

In this example, the first and third & give the alignment points, the second & begins the second column. In general, even-numbered &'s are column separators, and odd-numbered &'s are alignment points.

Matrices function like tables, except everything is in math mode. Consequently, you must enter math mode before entering a `matrix` environment.

$$\begin{matrix} a-2 & b & x+y-z \\ 4 & e+f & 0 \end{matrix}$$

```
\[
  \begin{matrix}
  a-2 & b & x+y-z \\
  4 & e+f & 0
  \end{matrix}
\]
```

Within the `matrix` environment, all columns are centered. Also, there are no delimiters on either side of the matrix.

More Matrices

We can enclose a matrix in delimiters in the expected way:

$$\left(\begin{matrix} a & b+c \\ d-e & 2 \end{matrix}\right)$$

```
\[
  \left(
    \begin{matrix}
    a & b+c \\
    d-e & 2
    \end{matrix}
  \right)
\]
```

The delimiters do not have to match: $\left\{\begin{matrix} a & b+c \\ d-e & 2 \end{matrix}\right]$

Variant Matrix Environments

LaTeX provides environments for matrices with the most common delimiters:

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad \texttt{pmatrix}$$

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \quad \texttt{bmatrix}$$

$$\begin{vmatrix} a & b \\ c & d \end{vmatrix} \quad \texttt{vmatrix}$$

$$\begin{Vmatrix} a & b \\ c & d \end{Vmatrix} \quad \texttt{Vmatrix}$$

$$\begin{Bmatrix} a & b \\ c & d \end{Bmatrix} \quad \texttt{Bmatrix}$$

The major difference between the various `matrix` environments and the `array` environment is that you have a lot more control within `array`.

$$
\begin{array}{|l|r|} \hline
a+b & d \\ \hline
e & f+2 \\ \hline
\end{array}
$$

```
\[
  \begin{array}{|l|r|} \hline
  a+b & d \\ \hline
  e & f+2 \\ \hline
  \end{array}
\]
```

`array` is just like `tabular` except in math mode. If you want any `\multicolumns`, you must use `array` instead of `matrix`. You can put delimiters around `array` environments too.

Cases

The `cases` environment is the way to denote a piecewise-defined function. It is really a special type of matrix.

$$|x| = \begin{cases} -x & x<0 \\ x & x \ge 0 \end{cases}$$

```
\[
  |x| =
  \begin{cases}
    -x & x<0 \\
    x & x \ge 0
  \end{cases}
\]
```

The `cases` environment can appear inline or displayed.

Let’s practice!

Open up the third example PDF file from Sakai, and reproduce it.