CHAPTER 8: MORE MATH

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Abstract. We will review

- Spacing of symbols
- Building new symbols
- Math alphabets and symbols
- Vertical spacing
- Tagging and grouping
- Miscellaneous

To insert a thin space, we type `\,`. Compare this

$$A = \{x \in X \mid x\beta \geq xy > (x+1)^2 - \alpha\}$$

with this

$$A = \{\, x \in X \mid x\beta \geq xy > (x+1)^2 - \alpha \,\}$$

We see that there is more space between the brackets and what lies inside. Also something important to note is the difference between the `\mid` command and the use of a `|`, which is a midline character. Using the `\mid` command inserts a `|` character which acts as a binary operator, so spacing is automatic. Using the `|` character by itself does not act as a binary operator, so there is no implicit spacing. Compare the following:

$X \mid x$	uses the `\mid` command
$X\|x$	uses the | character

LaTeX implicitly creates spacing for binary operators, such as the + and - operators. If you intend for a that can be binary or unary to be treated as a binary operator, place empty brackets { } one one side of the operator. Compare $+a$ and $+\,a$.

There are many different spacing commands, and spacing commands may either be positive or negative. In order of increasing width, the positive spaces are: `\,` or `\thinspace`; `\:` or `\medspace`; `\;` or `\thickspace`; or `\ ` which is an interword space. Also there is `\quad`, which is 1 em long and `\qquad`, which is 2 em long.

$$\begin{array}{c} \mathrm{thinspace} \\ \mathrm{medspace} \\ \mathrm{thickspace} \\ \mathrm{interword\ space} \end{array}$$

To use negative spaces, generally the long command must be used. Here are the options: `\!` or `\negthinspace`, `\negmedspace`, and `\negthickspace`.

$$\begin{array}{c} \mathrm{X\!x} \\ \mathrm{X\!\!x} \\ \mathrm{X\!\!\!x} \end{array}$$

Compare the following

$$\begin{aligned} \sqrt{5}\text{side} &\quad \text{to} \quad \sqrt{5}\,\text{side} \\ \sin x/\log n &\quad \text{to} \quad \sin x/\log n \\ f(1/\sqrt{n}) &\quad \text{to} \quad f(1/\sqrt{n}\,) \\ f : A \to B &\quad \text{to} \quad f\colon A \to B \end{aligned}$$

The `\phantom` command is very useful but examples won't be developed here.

The `\overset` and `\underset` commands allow new symbols to be made from extant ones. There are two arguments; the first is the variable to be displayed above or below the second argument. For underset, second argument and for overset, first argument second argument. We can get creative with this command

$$\overset{l}{+} \quad \underset{\alpha}{x} \quad \overset{\alpha}{\underset{x}{}} \quad \lim_{x\to\infty} x \quad \underset{j\,\text{even}}{A_j}$$

Generally with a large operator, we can place subscripts or superscripts

$$\sum_{i=0}^{j} i = \frac{j(j+1)}{2}$$

However, in the event that we would like to get more creative with where we may place symbols around a large operator, we may use the four corners by use of the `\sideset` command, which has the form
`\sideset{ _{ll}^{ul} }{ _{lr}^{ur} }{large_op}` and from this we get constructions such as

$$\sideset{^{ul}_{ll}}{^{ur}_{lr}}\prod_{b}^{t}$$

If we want to use a symbol as a binary operator, we can tell LaTeX of our intentions so it spaces accordingly. This is done with the `\mathbin{operator}` or `\mathrel{operator}` commands. The first treats the symbol as a binary operator, the second treats the symbol as a binary relation.

$$A\alpha B \quad \text{compare to} \quad A\,\alpha\,B$$

When you type letters in a math formula you are using a *math alphabet*.

$$\begin{aligned} \textbf{Math bold}: &\ \textbf{2 Greek gammas}, \gamma \textbf{ and } \boldsymbol{\Gamma} \\ \textit{Math italics}: &\ \textit{2 Greek gammas}, \gamma \textit{ and } \Gamma \\ \mathsf{Math\ sans\ serif}: &\ \mathsf{2\ Greek\ gammas}, \gamma \mathsf{\ and\ } \Gamma \\ \text{Math roman}: &\ \text{2 Greek gammas}, \gamma \text{ and } \Gamma \\ \mathtt{Math\ typewriter}: &\ \mathtt{2\ Greek\ gammas}, \gamma \mathtt{\ and\ } \Gamma \\ \mathit{Math\ normal}: &\ \mathit{2\ Greek\ gammas}, \gamma \mathit{\ and\ } \Gamma \end{aligned}$$

The respective commands to produce the text above are `\mathbf`{*text*}, `\mathit`{*text*}, `\mathsf`{*text*}, `\mathrm`{*text*}, `\mathtt`{*text*}, `\mathnormal`{*text*} (the default). Note that the default setting is math italics.

Note: symbols and math alphabets are disjoint sets. There are no italicized, slanted, or sans serif versions. However, if you want to make a bold symbol, you

can use the `\boldsymbol{`*symbol*`}` command. Compare $\boldsymbol{\alpha}$ to α. There are four alphabets of symbols in LaTeX:

Alphabet	Command	Examples
Greek	symbol specific	α, β, γ
Calligraphic	`\mathcal{}`	$\mathcal{A}$, $\mathcal{B}$, $\mathcal{C}$
Euler Fraktur	`\mathfrak{}`	$\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$
Blackboard bold	`\mathbb{}`	$\mathbb{A}$, $\mathbb{B}$, $\mathbb{C}$

You can, of course, combine commands relating to symbols. If you want to type $\boldsymbol{\mathcal{AMS}}$, you can't do so using the `\mathbf{}` command since the font is a symbol alphabet, not a math alphabet. But you can combine the `\boldsymbol{`*symbols*`}` with the Calligraphic alphabet. Try the command `\boldsymbol{\mathcal{AMS}}`. Note: the command `\mathcal{\boldsymbol{AMS}}` doesn't work. Can you guess why?

Some symbols do not have a bold version, such as the $\sum$ symbol. To get a bold version, use the `\pmb{`*symbol*`}` command. From this we get $\pmb{\sum}$. The `\pmb{}` command typesets three very closely spaced symbols to get a rudimentary bold version. However, this does destroy LaTeX's implicit spacing for the symbol, which is no longer treated as a large operator. Compare

$$\sum_{i=1}^{n} i^2 \quad \pmb{\sum}_{i=1}^{n} i^2 \quad \boldsymbol{\sum}_{i=1}^{n} i^2 \quad \sum_{i=1}^{n} i^2$$

The first variant is the regular one. The second variant use the `\pmb{}` command, which LaTeXno longer treats as a large operator. The third variant defines `\pmb{\sum}}` as a math operator with the command `\DeclareMathOperator{\boldsum}{\pmb{\sum}}` in the header. The fourth variant does the same as the third but uses the `*`ed version: `\DeclareMathOperator*{\boldsumlim}{\pmb{\sum}}`

Vertical spacing is also an issue when typesetting formulas. We can control vertical spacing with the `{\mathstrut ...}` command or the `\vphantom{...}` command. the `{\mathstrut ...}` command inserts an invisible vertical space. The `\phantom{...}` command measures the height of its argument and places a math strut of that height. Generally the second option is more versatile than the former. Compare $\sqrt{a}+\sqrt{b}$ to $\sqrt{a}+\sqrt{b}$ (`\mathstrut`) or $\sqrt{a}+\sqrt{b}$ (`\vphantom{}`).

We can use the `\smash{...}` command to tell LaTeX to pretend that $\frac{1}{\int_{-\infty}^{\infty} e^{x^2}\,dx}$ or an argument like it doesn't protrude above or below the current line.

We can attach tags to equations with the `\tag{`*argument*`}` command.

(my customized tag)
$$\int_{-\infty}^{\infty} e^{x^2}\,dx$$

Since the customized tag explicitly inserts a tag, it does not matter if we use the `\[ \]`, `equation*`, or `equation` environments. Also, tags are absolute, so they will not change if the equation is moved, unless the argument is a reference to a label. If we use the variant `\tag*{`*argument*`}`, the parentheses are omitted.

my customized tag
$$\int_{-\infty}^{\infty} e^{x^2}\,dx$$

To be able to reference equations, we use the `\label{`*argument*`}` command. We can have both a tag and a label

$$\int_{-\infty}^{\infty} ze^{z^2}dz \tag{q_{52}}$$

and we can now reference the equation with the `\ref{`*label*`}` to get q_{52} or alternatively we may use `\eqref{`*label*`}` to get (q_{52}). Since the tag we used was static, the reference will always yield the same value, but if equation were labeled by some other means then the reference would yield the current label of the equation.

The `subequations` environment allows the implicit numbering of the equations to follow the pattern of 1a, 1b, ...

$$1 + 1 = 2 \tag{1a}$$

$$2 + 2 = 4 \tag{1b}$$

If you plan to do some creative things with fraction formatting, use the `\genfrac{`*left-delim*`}{`*right-delim*`}{`*thickness*`}{`*mathstyle*`}{`*numerator*`}{`*denominator*`}` command. The *thickness* argument is the thickness of the fraction line, which is in the form $x$pt (the default is 0.4 pt). For the *mathstyle* argument, choose 0 for `\displaystyle`, 1 for `\textstyle`, 2 for `\scriptstyle`, or 3 for `\scriptscriptstyle` (the default is 0). All argument must be specified for this command, but the empty argument gives the default value.

The `\boxed{...}` command creates a box around math formula.

$$\boxed{\int_{-\infty}^{\infty} e^{x^2}dx} \tag{2}$$