Quick and Dirty Introduction to LaTeX

Lecture 2: Typesetting Mathematics

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Math Mode

Math Mode

Math mode allows you to put inline mathematics in a paragraph.

Inline math mode can be started and ended three ways:

- Begin with a single dollar sign $ and end with another single dollar sign $.
- Begin with \(and end with \).
- Begin with \begin{math} and end with \end{math}.

Math Mode

For example, the line

The Pythagorean Theorem tells us that $a^2+b^2=c^2$.

gives us

The Pythagorean Theorem tells us that $a^2 + b^2 = c^2$.

Math Mode

The code

```
\lim_{x\to a}f(x)=L
```

gives you $\lim_{x\to a} f(x) = L$ in math mode and

$$\lim_{x\to a} f(x) = L$$

in display math mode.

Notice an underscore in math mode gives you a subscript. (A caret ^ gives you a superscript).

Math Mode

The command \frac{a}{b} gives you $\frac{a}{b}$ in math mode and

$$\frac{a}{b}$$

in display math mode.

Math Mode

The code

```
\sum_{k=0}^\infty\frac{(-1)^k}{k+1} =
\int_0^1\frac{dx}{1+x}
```

gives you $\sum_{k=0}^{\infty} \frac{(-1)^k}{k+1} = \int_0^1 \frac{dx}{1+x}$ in math mode and

$$\sum_{k=0}^{\infty} \frac{(-1)^k}{k+1} = \int_0^1 \frac{dx}{1+x}$$

in display math mode.

Math Mode

The code

```
\lim_{x\rightarrow 0} \frac{\sin x}{x} = 1
```

gives you $\lim_{x\rightarrow 0} \frac{\sin x}{x} = 1$ in math mode and

$$\lim_{x\rightarrow 0} \frac{\sin x}{x} = 1$$

in display math mode.

Math Mode

Use the \sqrt{} command to produce square roots:

```
$\sqrt{\frac{a}{b}}$
```

produces $\sqrt{\frac{a}{b}}$.

If you need an *n*th root, use \sqrt[n]{} instead.

```
$\sqrt[10]{\frac{a}{b}}$
```

produces $\sqrt[10]{\frac{a}{b}}$.

Math Mode

The code

```
\int_a^b f(x)\, dx
```

gives you $\int_a^b f(x)\, dx$ in math mode and

$$\int_a^b f(x)\, dx$$

in display math mode. The control symbol \, is a **thin space**.

Control sequences for binary operators

Math Mode

Control sequences for binary relations. You can negate these by adding \not as a prefix.

$\leq$	\leq	$\geq$	\geq	$\equiv$	\equiv
$\ll$	\ll	$\gg$	\gg	$\doteq$	\doteq
$\prec$	\prec	$\succ$	\succ	$\sim$	\sim
$\preceq$	\preceq	$\succeq$	\succeq	$\simeq$	\simeq
$\subset$	\subset	$\supset$	\supset	$\approx$	\approx
$\subseteq$	\subseteq	$\supseteq$	\supseteq	$\cong$	\cong
$\sqsubset$	\sqsubset	$\sqsupset$	\sqsupset	$\bowtie$	\Join
$\sqsubseteq$	\sqsubseteq	$\sqsupseteq$	\sqsupseteq	$\bowtie$	\bowtie
$\in$	\in	$\ni$	\ni, \owns	$\propto$	\propto
$\vdash$	\vdash	$\dashv$	\dashv	$\models$	\models
$\mid$	\mid	$\parallel$	\parallel	$\perp$	\perp
$\smile$	\smile	$\frown$	\frown	$\asymp$	\asymp
:	:	$\notin$	\notin	$\neq$	\neq

Math Mode

Control sequences for binary operators.

$+$	+	$-$	-
$\pm$	\pm	$\mp$	\mp
$\cdot$	\cdot	$\div$	\div
$\times$	\times	$\setminus$	\setminus
$\cup$	\cup	$\cap$	\cap
$\sqcup$	\sqcup	$\sqcap$	\sqcap
$\vee$	\vee or \lor	$\wedge$	\wedge, \land
$\oplus$	\oplus	$\ominus$	\ominus
$\odot$	\odot	$\oslash$	\oslash
$\otimes$	\otimes	$\bigcirc$	\bigcirc
$\bigtriangleup$	\bigtriangleup	$\bigtriangledown$	\bigtriangledown
$\lhd$	\lhd	$\rhd$	\rhd
$\unlhd$	\unlhd	$\unrhd$	\unrhd

Math Mode

Control sequences for binary operators.

$\triangleleft$	\triangleleft
$\triangleright$	\triangleright
$\star$	\star
$*$	\ast
$\circ$	\circ
$\bullet$	\bullet
$\diamond$	\diamond
$\uplus$	\uplus
$\amalg$	\amalg
$\dagger$	\dagger
$\ddagger$	\ddagger
$\wr$	\wr

Control sequences for BIG operators

Math Mode

Control sequences for BIG Operators.

$\sum$	\sum	$\oint$	\oint
$\prod$	\prod	$\bigvee$	\bigvee
$\coprod$	\coprod	$\bigwedge$	\bigwedge
$\int$	\int	$\bigoplus$	\bigoplus
$\bigcup$	\bigcup	$\bigotimes$	\bigotimes
$\bigcap$	\bigcap	$\bigodot$	\bigodot
$\bigsqcup$	\bigsqcup	$\bigoplus$	\bigoplus

Control sequences for Arrows

Math Mode

Control sequences for arrows.

$\leftarrow$	\leftarrow	$\longleftarrow$	\longleftarrow
$\rightarrow$	\rightarrow	$\longrightarrow$	\longrightarrow
$\leftrightarrow$	\leftrightarrow	$\longleftrightarrow$	\longleftrightarrow
$\Leftarrow$	\Leftarrow	$\Longleftarrow$	\Longleftarrow
$\Rightarrow$	\Rightarrow	$\Longrightarrow$	\Longrightarrow
$\Leftrightarrow$	\Leftrightarrow	$\Longleftrightarrow$	\Longleftrightarrow
$\mapsto$	\mapsto	$\longmapsto$	\longmapsto
$\hookleftarrow$	\hookleftarrow	$\hookrightarrow$	\hookrightarrow
$\leftharpoonup$	\leftharpoonup	$\rightharpoonup$	\rightharpoonup
$\leftharpoondown$	\leftharpoondown	$\rightharpoondown$	\rightharpoondown
$\rightleftharpoons$	\rightleftharpoons	$\iff$	\iff

Math Mode

Control sequences for arrows.

$\uparrow$	\uparrow
$\downarrow$	\downarrow
$\updownarrow$	\updownarrow
$\Uparrow$	\Uparrow
$\Downarrow$	\Downarrow
$\Updownarrow$	\Updownarrow
$\nearrow$	\nearrow
$\searrow$	\searrow
$\swarrow$	\swarrow
$\nwarrow$	\nwarrow
$\rightsquigarrow$	\leadsto

Control Sequences for Miscellaneous Symbols

Math Mode

Control Sequences for Miscellaneous Symbols:

$\ldots$	\dots	$\cdots$	\cdots
$\hbar$	\hbar	$\imath$	\imath
$\Re$	\Re	$\Im$	\Im
$\forall$	\forall	$\exists$	\exists
$'$	\'	$\prime$	\prime
∇	\nabla	$\triangle$	\triangle
$\bot$	\bot or \perp	$\top$	\top
$\diamondsuit$	\diamondsuit	$\heartsuit$	\heartsuit
$\neg$	\neg or \lnot	$\flat$	\flat

Math Mode

Miscellaneous symbols

$\vdots$	\vdots	$\ddots$	\ddots
$\jmath$	\jmath	ℓ	\ell
$\aleph$	\aleph	$\wp$	\wp
$\mho$	\mho	∂	\partial
$\emptyset$	\emptyset	∞	\infty
$\Box$	\Box	$\Diamond$	\Diamond
$\angle$	\angle	$\surd$	\surd
$\clubsuit$	\clubsuit	$\spadesuit$	\spadesuit
$\natural$	\natural	$\sharp$	\sharp

Control Sequences for Functions

Math Mode

Control Sequences for Functions:

\arccos	\arcsin	\arctan	\arg	\cos	\cosh	\cot
\coth	\csc	\deg	\det	\dim	\exp	\gcd
\hom	\inf	\ker	\lg	\lim	\liminf	\limsup
\sinh	\sup	\tan	\tanh			

Math Mode

You can get every Greek letter, upper and lower case, by control words:

Γ \Gamma	α \alpha	ν \nu	$\digamma$ \digamma
Δ \Delta	β \beta	ξ \xi	ε \varepsilon
Λ \Lambda	γ \gamma	π \pi	$\varkappa$ \varkappa
Φ \Phi	δ \delta	ρ \rho	φ \varphi
Π \Pi	ϵ \epsilon	σ \sigma	ϖ \varpi
Ψ \Psi	ζ \zeta	τ \tau	ϱ \varrho
Σ \Sigma	η \eta	υ \upsilon	ς \varsigma
Θ \Theta	θ \theta	ϕ \phi	ϑ \vartheta
Υ \Upsilon	ι \iota	χ \chi	
Ξ \Xi	κ \kappa	ψ \psi	
Ω \Omega	λ \lambda	ω \omega	
	μ \mu		

Figure 1: Control words for Greek letters

Math Mode

You can get the following math alphabets (and others):

Example	Command	Required package
ABCdef	\mathrm{ABCdef}	
ABCdef	\mathit{ABCdef}	
ABC	\mathnormal{ABC}	
$\mathcal{ABC}$	\mathcal{ABC}	**eucal** with option: **mathcal**
	\mathscr{ABCdef}	**eucal** with option: **mathscr**
$\mathfrak{ABCdef}$	\mathfrak{ABCdef}	**eufrak**
$\mathbb{ABC}$	\mathbb{ABCdef}	**amsfonts** or **amssymb**

The Authoritative Reference

If you need to find the control sequence for a symbol, you can google the symbol using something like

LaTeX symbol for subset not equal to

or consult (or download) the 422 page document *The Comprehensive LaTeX Symbol List* at

https://tug.ctan.org/info/symbols/comprehensive/symbols-a4.pdf.

Display Math Mode

Display Math Mode

We have already discussed the control sequence \[which starts display math mode and the control sequence \] that ends display math mode.

Display Math Mode: The equation environment

In addition, there is the equation environment that does exactly the same thing, but it also provides a number tag to the equation.

The code

```
\begin{equation}
e^{i\theta}=\cos\theta+ i\sin\theta
\end{equation}\label{eqn:Euler}
```

gives us

$$e^{i\theta} = \cos\theta + i\sin\theta \tag{1}$$

Notice the equation environment automatically numbers the equation. Also notice I have given this equation a label by the code \label{eqn:Euler}.

Display Math Mode: The align environment

The commands

```
\begin{align}
a_1 &= b_1 + c_1 \\
a_2 &= b_2 + c_2
\end{align}
```

give you

$$a_1 = b_1 + c_1 \tag{2}$$
$$a_2 = b_2 + c_2 \tag{3}$$

The symbols after the ampersands are aligned vertically.

These equations are tagged with the numbers 2 and 3 because an earlier equation was tagged with the number 1. LaTeX does the numbering automatically for you.

Display Math Mode: The align* environment

The commands

```
\begin{align*}
a_1 &= b_1 + c_1 \\
a_2 &= b_2 + c_2
\end{align*}
```

give you

$$a_1 = b_1 + c_1$$
$$a_2 = b_2 + c_2$$

Notice the lines are aligned, but not numbered. The difference is the asterisk after `align`.

Display Math Mode: Matrices

The code

```
\[
\begin{pmatrix}
a & b \\
c & d
\end{pmatrix}
\]
```

gives you

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

The "p" puts parentheses around the matrix. There are also \begin{bmatrix}, \begin{vmatrix}, \begin{Vmatrix}, and \begin{matrix}. I'll let you play with those.

Display Math Mode: The aligned environment

The commands

```
\[
f(x)=
\left\{
\begin{aligned}
-x, &\quad \mbox{if }x< 0\\
x, &\quad \mbox{if }x\geq 0
\end{aligned}
\right.
\]
```

give you

$$f(x) = \begin{cases} -x, & \text{if } x < 0 \\ x, & \text{if } x \geq 0 \end{cases}$$

Display Math Mode: The aligned environment

Notice the commands outlined in red:

```
\[
f(x)=
\left\{
\begin{aligned}
-x, &\quad \mbox{if }x< 0\\
x, &\quad \mbox{if }x\geq 0
\end{aligned}
\right.
\]
```

for each \left there must be a corresponding \right. The command \right. gives you the closing "right" with no symbol after it.

Display Math Mode: \left and \right

The commands \left and \right also automatically adjust the size of symbols appearing after them.

If we use parentheses, we get

$$\left(\frac{x+y}{x-y}\right)$$

This is produced by this code

```
\[
\left(\frac{x+y}{x-y}\right)
\]
```

Display Math Mode: \left and \right

If we use \left and \right with the parentheses, we get

$$\left(\frac{x+y}{x-y}\right)$$

This produced by this code

```
\[
\left(\frac{x+y}{x-y}\right)
\]
```

Display Math Mode

Loading the package amsfonts allows you to use the command $\mathbb{}$, which gives you "broadback" letters:

Usage: `\mathbb{R}`. Requires `amsfonts`.

$$\mathbb{A}\,\mathbb{B}\,\mathbb{C}\,\mathbb{D}\,\mathbb{E}\,\mathbb{F}\,\mathbb{G}\,\mathbb{H}\,\mathbb{I}\,\mathbb{J}\,\mathbb{K}\,\mathbb{L}\,\mathbb{M}\,\mathbb{N}\,\mathbb{O}\,\mathbb{P}\,\mathbb{Q}\,\mathbb{R}\,\mathbb{S}\,\mathbb{T}\,\mathbb{U}\,\mathbb{V}\,\mathbb{W}\,\mathbb{X}\,\mathbb{Y}\,\mathbb{Z}$$

One lowercase letter is available with a distinct name: $\mathbb{k}$ `\Bbbk`