Introduction to LaTeX and Beamer

Matthew Bush

University of Arizona Math Department Software Interest Group

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What is LaTeX?

LaTeX is a typesetting system designed especially for mathematics, science, and technical writing. LaTeX is a markup language, meaning that you type in plain text, and then compile the plain text into your formatted document. LaTeX is indispensible for anyone working in mathematics.
What is \LaTeX?  

\LaTeX is a gift to the world from the American Mathematical Society.

–Brian Stewart, Wesleyan University Physics Department
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- \LaTeX is a *markup language*, meaning that you type in plain text, and then compile the plain text into your formatted document.
- \LaTeX is indispensible for anyone working in mathematics.
- \LaTeX will occasionally drive you crazy.
What is it good for?

Homework
Writing tests and quizzes
Answering student questions by email
Making presentations

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- Making presentations
The preamble:

- Starts with a `\documentclass[options]{style}` command
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- Most of my homework starts with `\documentclass[12pt]{amsart}
- Includes everything up to the `\begin{document}` command
- This is where you load packages, define new commands, define variables like `\title` and `\author`, etc.
Defining custom commands

- As a shortcut:
  \newcommand{\QQ}{\ensuremath{\mathbb{Q}}},
  \newcommand{\pbar}{\overline{\mathfrak{p}}}, etc.

\expsum{a} \expsum{b} \expsum[m]{b}

\begin{align*}
a_1 + a_2 + \ldots + a_n \\
b_1 + b_2 + \ldots + b_n \\
b_1 + b_2 + \ldots + b_m
\end{align*}
Defining custom commands

- As a shortcut:
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- As a shortcut with arguments:
  \newcommand{\expsum}[2][n]{#2_1+#2_2+\ldots+#2_{#1}}
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\[ \expsum{a} \quad \expsum{b} \quad \expsum[m]{b} \]

\[ a_1 + a_2 + \ldots + a_n \quad b_1 + b_2 + \ldots + b_n \quad b_1 + b_2 + \ldots + b_m \]
The body:

- Includes everything between the `\begin{document}` and `\end{document}` commands

This is where you actually write your document. Anything after `\end{document}` is ignored, so that's often a good place to cut+paste sections of your proof that don't work out, in case you want to borrow any text from them later.

Two modes: math and text
The body:

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Parts of a \LaTeX Document

The body:

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- This is where you actually write your document.
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- Two modes: math and text
Math mode

- Uses different fonts than text mode, so always type your variable names in math mode. $x$ vs. $x$

Things like $1^{st}$ have to be typeset in math mode, as $1^{st}$.

Ignores whitespace. Thisisasentancetypedwithspacesbetweeneachword

Allows you to use various other "alphabets", such as

\mathfrak{ABCDEFGHIJKLMNOPQRSTUVWXYZ}
\mathbb{ABCDEFGHIJKLMNOPQRSTUVWXYZ}
\mathcal{ABCDEFGHIJKLMNOPQRSTUVWXYZ}
greek $\alpha\beta\gamma\delta$

$\Lambda\Phi\Theta$
Math mode

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- Things like $1^{\text{st}}$ have to be typeset in math mode, as $1^{\text{st}}$
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  This is a sentence typed with spaces between each word.
Math mode

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  \( \text{This is a sentence typed with spaces between each word} \)
- Allows you to use various other “alphabets”, such as
  \begin{verbatim}
\textbackslash mathfrak \quad ABCDEFGHIJKLMNOPQRSTUVWXYZ \\
\quad abcdefghijklmnopqrstuvwxyz \\
\textbackslash mathbb \quad ABCDEFGHIJKLMNOPQRSTUVWXYZ \\
\textbackslash mathcal \quad ABCDEFGHIJKLMNOPQRSTUVWXYZ \\
greek \quad \alpha \beta \gamma \delta \Lambda \Phi \Theta
  \end{verbatim}
Math mode

Inline math mode:

- Is delimited by $ signs.

1\text{st} has to be typeset in math mode, as $1^{\text{st}}$
Math mode

Inline math mode:

- Is delimited by $ signs.
- Shows up in the $4x^2 + 2y$ middle of a paragraph of text.
Math mode

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- Is delimited by $ signs.
- Shows up in the $4x^2 + 2y$ middle of a paragraph of text.
- You can use things like ^ for exponents, _ for subscripts.  
  $1^{st}$ has to be typeset in math mode, as $1^{\text{st}}$.

Fractions and complicated expressions can be small and harder to read.

Compare $\sum_{i=0}^{n} x_i + 1$ and $\sum_{i=0}^{n} x_i + 1$.
Math mode

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- Ignores whitespace.

This is a sentence typed with spaces between each word

- Fractions and complicated expressions can be small and harder to read.

Compare $\sum_{i=0}^{n} \frac{x^i+1}{2}$ and $\sum_{i=0}^{n} \frac{x^i + 1}{2}$
Math Mode

Displayed math mode:

- Is delimited by \begin{nameofenvironment} and \end{nameofenvironment}, or by \[ and \]

\[
\text{re}_\theta = r \cos(\theta) + ir \sin(\theta)
\]

You can do everything you can do in inline math mode.

I use mostly align and alignat and their starred variants. Most environments generate line numbers, the starred variants don't, although you can add labels when you want.
Math Mode

Displayed math mode:

- Is delimited by `\begin{nameofenvironment}` and `\end{nameofenvironment}`, or by `\[
` and `\]`
- Shows up on a line all by itself, centered

\[ re^{i\theta} = r \cos(\theta) + ir \sin(\theta) \]
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  \[ re^{i\theta} = r \cos(\theta) + ir \sin(\theta) \]
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- Shows up on a line all by itself, centered
  \[ re^{i\theta} = r \cos(\theta) + ir \sin(\theta) \]
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- Lots of different environments
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\[ r e^{i\theta} = r \cos(\theta) + i r \sin(\theta) \]

- You can do everything you can do in inline math mode.
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- I use mostly align and alignat and their starred variants.
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\[ re^{i\theta} = r \cos(\theta) + ir \sin(\theta) \]

- You can do everything you can do in inline math mode.
- Lots of different environments
- I use mostly `align` and `alignat` and their starred variants.
- Most environments generate line numbers, the starred variants don’t, although you can add labels when you want.
Align and alignat are multiline math environments, with the math in one or more columns, each of which has an alignment point.
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\begin{align*}
  f(-4) &= -66231 & f(-2) &= 3197 & f(0) &= -7 \\
  f(1) &= 1499 & f(3) &= -2923 & f(10) &= 1280093
\end{align*}
When using alignat, you have to specify the number of columns.

\begin{alignat}{3}
f(-4) &= -66231 & f(-2) &= 3197 & f(0) &= -7 \\
f(1) &= 1499 & f(3) &= -2923 & f(10) &= 1280093
\end{alignat}

\begin{align*}
  f(-4) &= -66231 & f(-2) &= 3197 & f(0) &= -7 \\
  f(1) &= 1499 & f(3) &= -2923 & f(10) &= 1280093
\end{align*}
Beamer is a documentclass for making presentations (like this one!)
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Beamer can be wonderful, but it can also be a royal pain to troubleshoot.
Beamer

- Beamer is a documentclass for making presentations (like this one!)
- Beamer can be wonderful, but it can also be a royal pain to troubleshoot.
- Compile often!
Beamer is a documentclass for making presentations (like this one!)

Beamer can be wonderful, but it can also be a royal pain to troubleshoot.

Compile often!

Your presentation is a PDF file that can be displayed anywhere.
Your document should start with \documentclass{beamer}
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Each slide is contained inside a `\begin{frame} \end{frame}` environment.
Your document should start with `\documentclass{beamer}`

Each slide is contained inside a
`\begin{frame} \end{frame}` environment.

Each slide is broken up into overlays.
Some text \pause more text
Overlays

Some text \pause more text
Some text \pause more text

Doesn't work in any of the multiline math environments.
Some text \pause more text

- Doesn’t work in any of the multiline math environments.
- Limited in what you can control.
Overlays

- Some text \pause more text
  - Doesn't work in any of the multiline math environments.
  - Limited in what you can control.
- \onslide<1,2>{text}
Overlays

- Some text \pause more text
  - Doesn't work in any of the multiline math environments.
  - Limited in what you can control.
- \onslide<1,2>{{text}}
  - Will show up only on overlays 1 and 2 (numbering starts with 1)
Overlays

- Some text \pause more text
  - Doesn't work in any of the multiline math environments.
  - Limited in what you can control.
- \onslide<1,2>{text}
  - Will show up only on overlays 1 and 2 (numbering starts with 1)
  - On all other overlays, it will be invisible, but still take up room.
Overlays

\only<3>{text}

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Overlays

- \only<3>{text}
  - Will show up only on overlay 3 (just like \onslide)
Hey look, a hippo!

- \only<3>{text}
  - Will show up only on overlay 3 (just like \onslide)
  - All other overlays will be typeset as if it didn't exist.
Overlays

Too late, it’s gone

- \only<3>{text}
  - Will show up only on overlay 3 (just like \onslide)
  - All other overlays will be typeset as if it didn’t exist.

- Passing arguments directly to lists
Overlays

- \only<3>{text}
  - Will show up only on overlay 3 (just like \onslide)
  - All other overlays will be typeset as if it didn't exist.

- Passing arguments directly to lists
  - Use the same syntax as \onslide and \only
Overlays

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Passing arguments directly to lists
  - Use the same syntax as \onslide and \only
  - Either place it after the \item command, or [<+->] before the first item for automatic pauses
Overlays

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  - Will show up only on overlay 3 (just like \onslide)
  - All other overlays will be typeset as if it didn't exist.

- Passing arguments directly to lists
  - Use the same syntax as \onslide and \only
  - Either place it after the \item command, or [<-] before the first item for automatic pauses

- \begin{itemize}
  \item<2-4> On overlays 2, 3 and 4.
  \item<5-> On overlays from 7 onward
\end{itemize}
Here are some examples of cool things you can do with beamer:
**Trivial Example** Certainly, the unit disc $D^n \subseteq \mathbb{R}^n = \{x \in \mathbb{R}^n : |x| \leq 1\}$ is a Kakeya set.

**Non-Trivial Examples** In $\mathbb{R}^n$, by allowing the center of our line segment to move, we can obtain a Kakeya set strictly smaller than $D^n$.

Here, the diameter of the outer circle is equal to the length of the moving line segment, showing visually that the area of the traced-out shape is strictly smaller than that of the corresponding $D^2$. 
But we can actually do better than that.

This is a quarter-Kakeya set, which means that it contains all lines in $1/4$ of all possible directions. By concatenating 4 such sets, we can form a Kakeya set.

By subdividing the set and translating the subdivisions closer together, we can create a new quarter-Kakeya set with strictly smaller area.
We can picture $\mathbb{F}_5^2$ as the set of points in the white area of this diagram.
We can picture $\mathbb{F}_5^2$ as the set of points in the white area of this diagram.

The grey area represents the “wrapping” property of $\mathbb{F}_5$. Points with the same coordinates are identified.
This is all one frame!

Start by setting $K_0$ to be the empty subset of $\mathbb{F}_5^2$

We need lines from the cosets:

- $(0,1)$, $(0,2)$, $(0,3)$, $(0,4)$
- $(1,0)$, $(2,0)$, $(3,0)$, $(4,0)$
- $(1,4)$, $(2,3)$, $(3,2)$, $(4,1)$
- $(1,3)$, $(2,1)$, $(3,4)$, $(4,2)$
- $(1,1)$, $(2,2)$, $(3,3)$, $(4,4)$
- $(1,2)$, $(2,4)$, $(3,1)$, $(4,3)$
Form $K_1$ by adding a line in direction $(0, 1)$.

We need lines from the cosets:

$(0,1)\quad (0,2)\quad (0,3)\quad (0,4)$
$(1,0)\quad (2,0)\quad (3,0)\quad (4,0)$
$(1,4)\quad (2,3)\quad (3,2)\quad (4,1)$
$(1,3)\quad (2,1)\quad (3,4)\quad (4,2)$
$(1,1)\quad (2,2)\quad (3,3)\quad (4,4)$
$(1,2)\quad (2,4)\quad (3,1)\quad (4,3)$
Form $K_2$ by adding a line in direction $(1, 0)$ intersecting $K_1$ at 1 point.

This is clearly the maximum possible number of intersections.

We need lines from the cosets:

$$(0,1) (0,2) (0,3) (0,4)$$
$$(1,0) (2,0) (3,0) (4,0)$$
$$(1,4) (2,3) (3,2) (4,1)$$
$$(1,3) (2,1) (3,4) (4,2)$$
$$(1,1) (2,2) (3,3) (4,4)$$
$$(1,2) (2,4) (3,1) (4,3)$$
Form $K_3$ by adding a line in direction $(1, 4)$ (drawn as $(1, -1)$) intersecting $K_2$ at 2 points.

This is clearly the maximum possible number of intersections.

We need lines from the cosets:

- $(0,1)$, $(0,2)$, $(0,3)$, $(0,4)$
- $(1,0)$, $(2,0)$, $(3,0)$, $(4,0)$
- $(1,4)$, $(2,3)$, $(3,2)$, $(4,1)$
- $(1,3)$, $(2,1)$, $(3,4)$, $(4,2)$
- $(1,1)$, $(2,2)$, $(3,3)$, $(4,4)$
- $(1,2)$, $(2,4)$, $(3,1)$, $(4,3)$
Form $K_4$ by adding a line in direction $(4, 2)$ (drawn as $(-1, 2)$) intersecting $K_3$ at 3 points.

This is clearly the maximum possible number of intersections.

We need lines from the cosets:

- $(0,1)$  $(0,2)$  $(0,3)$  $(0,4)$
- $(1,0)$  $(2,0)$  $(3,0)$  $(4,0)$
- $(1,4)$  $(2,3)$  $(3,2)$  $(4,1)$
- $(1,3)$  $(2,1)$  $(3,4)$  $(4,2)$
- $(1,1)$  $(2,2)$  $(3,3)$  $(4,4)$
- $(1,2)$  $(2,4)$  $(3,1)$  $(4,3)$
Form $K_5$ by adding a line in direction $(1, 1)$ intersecting $K_4$ at 4 points.

This is clearly the maximum possible number of intersections.

We need lines from the cosets:

- $(0,1)$, $(0,2)$, $(0,3)$, $(0,4)$
- $(1,0)$, $(2,0)$, $(3,0)$, $(4,0)$
- $(1,4)$, $(2,3)$, $(3,2)$, $(4,1)$
- $(1,3)$, $(2,1)$, $(3,4)$, $(4,2)$
- $(1,1)$, $(2,2)$, $(3,3)$, $(4,4)$
- $(1,2)$, $(2,4)$, $(3,1)$, $(4,3)$
Form $K_6$ by adding a line in direction $(1, 2)$ intersecting $K_5$ at 3 points.

In this case, 3 turns out to be the only possible number of intersections.

We need lines from the cosets:

$(0,1) \quad (0,2) \quad (0,3) \quad (0,4)$
$(1,0) \quad (2,0) \quad (3,0) \quad (4,0)$
$(1,4) \quad (2,3) \quad (3,2) \quad (4,1)$
$(1,3) \quad (2,1) \quad (3,4) \quad (4,2)$
$(1,1) \quad (2,2) \quad (3,3) \quad (4,4)$
$(1,2) \quad (2,4) \quad (3,1) \quad (4,3)$
Remove the lines, since they aren't even part of $\mathbb{F}_5^2$.

We need lines from the cosets:

- $(0,1) (0,2) (0,3) (0,4)$
- $(1,0) (2,0) (3,0) (4,0)$
- $(1,4) (2,3) (3,2) (4,1)$
- $(1,3) (2,1) (3,4) (4,2)$
- $(1,1) (2,2) (3,3) (4,4)$
- $(1,2) (2,4) (3,1) (4,3)$
Finally, remove the coloration indicating when a point was first added to $K$.

We now have our Kakeya Set $K$, with $|K| = 17$.

We need lines from the cosets:

\( (0,1) \) \( (0,2) \) \( (0,3) \) \( (0,4) \)  
\( (1,0) \) \( (2,0) \) \( (3,0) \) \( (4,0) \)  
\( (1,4) \) \( (2,3) \) \( (3,2) \) \( (4,1) \)  
\( (1,3) \) \( (2,1) \) \( (3,4) \) \( (4,2) \)  
\( (1,1) \) \( (2,2) \) \( (3,3) \) \( (4,4) \)  
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