**LaTeX Math**

**Outline**
- Equation modes
  - Inline vs. display
  - Numbered vs. unnumbered
- Math symbols, subscripts, & superscripts
- Brackets & parentheses
- Functions
- Multiline equations

**Equations: Inline Mode**
- Used for writing formulas that are part of a text
- To put equations in inline mode, use one of 3 delimiters:
  - \(\)
    - Pythagorean theorem \((x^2+y^2=z^2)\) was proved...
  - $\$
    - The equation \(S=\pi r^2\) states...
  - \begin{math} \end{math}
- \(E=mc^2\)

**Equations: Display Mode**
- Write expressions that are not part of a text or paragraph
- Are therefore put on separate lines
- Has two versions: numbered and unnumbered
- To print your equations in display mode, use one of these delimiters:
  - \[\]
  - $$\$$
  - $$E=mc^2$$
  - \begin{displaymath} \end{displaymath}
  - \begin{equation} \end{equation}

**Numbered vs. Unnumbered**
- Under “equation” environment, equations are numbered
- Label can be added for future reference within the document
- Example:
  - \begin{equation} \label{eu_eqn} \end{equation}
  - \[ e^{\pi i} + 1 = 0 \]
  - \end{equation}
- Equation \ref{eu_eqn} is known as...
- To remove the number, use “equation*” or “displaymath” environments instead
- Example:
  - \begin{equation*} \end{equation*}
  - \[ e^{\pi i} + 1 = 0 \]
  - \end{equation}

**Math Symbols**
- Math symbols are represented using commands
- Greek letters:
  - \(\alpha \beta \gamma \rho \sigma \delta \epsilon \ldots\)
- Binary operators:
  - \(\times \otimes \oplus \cup \cap \ldots\)
- Relation operators:
  - \(< \> \subset \supset \subseteq \supseteq \ldots\)
- Others:
  - \(\ast \| \sum \prod \ldots\)
**Subscripts & Superscripts**

- Subscripts & superscripts are written using symbols `^` and `_`.
- `^` and `_` only apply to the single following character.
- If the expression contains long superscripts or subscripts, these need to be collected in braces:
  - `$a_1^2 + a_2^2$`
- Some mathematical operators may require subscripts & superscripts.
- The most frequent case is the summation (`\sum`) operator.
- Subscript sets the lower bound.
- Superscript sets the upper bound.
- `$\sum_{i=1}^{\infty} \frac{1}{n^s}$`

**Operators using Subscripts & Superscripts**

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**Brackets & Parentheses**

- 4 types of brackets:
  - `(, )` → `(, )`
  - `[, ]` → `[, ]`
  - `\{, \}` → `{, }`
  - `<, >` → `<, >`
- To set sizes dynamically based on the contents inside brackets:
  - Use left & right commands:
    - `\left( \right)`
    - `\left[ \right]`
    - `\left\{ \right\}`
    - `\langle, \rangle`
- To control sizes explicitly:
  - `\lfloor` & `\lceil`
  - `\rfloor` & `\rceil`
  - `\lfloor` & `\lceil`
- Both `\left` and `\right` commands are needed, even if only one bracket needs to be displayed.

**Fractions & Binomial Coefficients**

- Fractions are displayed using command `\frac{}{}`.
- The text inside the first pair of braces is the numerator.
- The text inside the second pair is the denominator.
- `$\binom{n}{k} = \frac{n!}{k!(n-k)!}$`
- Binomial coefficients are common elements in math expressions.
- The command `\binom{}{}` is very similar to fractions.
- Parameters are passed inside the 2 pairs of braces.
- `$\binom{n}{k} = \frac{n!}{k!(n-k)!}$`

**Functions**

- LaTeX has commands for well-known functions.
- Characters in mathematical mode are usually shown in italics.
- Exponential function names require different formatting.
- Some functions take parameters that are handled in a special way.
- `$\sin(x)$` (sine `\sin` function)
- `$\cos(x)$` (cosine `\cos` function)
- `$\tan(x)$` (tangent `\tan` function)
- `$\log(x)$` (logarithmic function `\log`)
- `$\exp(x)$` (exponential function `\exp`)
- `$\max(x)$` (maximum function `\max`)
- `$\min(x)$` (minimum function `\min`)
- `$\arg(x)$` (argument function `\arg`)
- `$\gcd(x)$` (greatest common divisor function `\gcd`)
- `$\Pr(x)$` (probability function `\Pr`)
- `$\lim(x)$` (limit function `\lim`)
- `$\sup(x)$` (supremum function `\sup`)
- `$\inf(x)$` (infimum function `\inf`)
- `$\forall$` (for all `\forall` symbol)
- `$\exists$` (there exists `\exists` symbol)
- `$\neg$` (not `\neg` symbol)
- `$\Delta$` (delta `\Delta` symbol)
- `$\LaTeX$` (LaTeX `\LaTeX` symbol)
- `$\cdots$` (horizontal ellipsis `\cdots`)
- `$\ldots$` (vertical ellipsis `\ldots`)

**Multiline Equation**

- To format multiline equation, use “\begin{eqnarray}” environment.
- Use `\\` as line break.
- Use `\&` to align equations.
- Use `\nonumber` to remove number for one of the equation.

**Examples:**

- `\begin{eqnarray}
  2x - 3y & = & 12 \nonumber
  3x + 7y & = & 12
\end{eqnarray}`
USE amsmath PACKAGE

• amsmath package
  • AMS stands for American Mathematical Society
  • Offers additional commands for formatting equations
• To use the package, add the following in the preamble of the document
  • \usepackage{amsmath}

• \"multline\" environment:
  • The part before \ will be aligned to the left and the part after will be aligned to the right
• \"align\" environment:
  • Align multiple equations vertically based on & symbol
• \"gather\" environment
  • Center equations without aligning them

SPACING

• LaTeX ignores the spaces in math mode
• To control spacing special commands can be used
• Spacing around operators and relations are governed by specific skip lengths
  • \text{} for function-like symbols
  • \! for negative space
  • \, for thin space
  • \; for medium space
  • \quad for large space
  • \qquad for very large space

LaTeX code Description
\! -3/18 of \quad (= -3 mu)
(\null) (= 0 mu)
, 3/18 of \quad (= 3 mu)
; 4/18 of \quad (= 4 mu)
\ (space after backslash!)
equivalent of space in normal text
\quad space equal to the current font size (= 18 mu)
\qquad twice of \quad (= 36 mu)

Tuesday, October 23, 2018

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DISPLAY STYLES

• Some mathematical elements change their styles & text size depending on the context
• Equations under inline model are generally smaller than under display model
• 4 commands can be used to manually adjust the display style:
  • \displaystyle: formats the fraction as if it were in display mode
  • \textstyle: formats the fraction as if it were in inline mode
  • \scriptstyle
  • \scriptscriptstyle

MATH FONTS

• Typefaces of the fonts often have special meanings in math
• Represent real numbers with a blackboard bold font
• Represent topological spaces with calligraphic font
• There are commands available but support a limited number of characters

• For Calligraphic typeface:
  • \mathcal{Q}
• For Fraktur typeface:
  • \mathfrak{SZ}
• For Blackboard bold typeface:
  • \mathbb{R}