Introduction to LaTeX for Mathematical Expressions

The goal of the lesson is to become familiar with LaTeX, specifically for the purpose of writing mathematical expressions.

1. Introduction to LaTeX

What is LaTeX?

LaTeX is a high-quality typesetting system, primarily used for technical and scientific documents. It is particularly powerful for formatting complex mathematical equations and formulas, making it a preferred choice in academia and research.

What are the advantages of LaTeX?

- **Handling Complex Documents**: It is ideal for mathematical formulas, citations, and cross-referencing in technical writing.
- **Consistent Layout**: Automatically ensures a uniform, professional design by separating content from formatting.
- **Scalability**: Suitable for large projects, allowing version control and modular structure.
- **Longevity**: LaTeX's plain text format ensures long-term compatibility and durability.
- **Academic Preference**: Often required in academic and scientific publishing.

Getting Started:

1. **Papeeria**: We will use Papeeria, a browser-based LaTeX editor that runs document compilation in the cloud: https://www.papeeria.com/

Basic Document Structure:

```latex
\documentclass{article}  % Specifies the document class (article, report, book, etc.)
\begin{document}          % Begins the content of the document
% Your content goes here
\end{document}            % Ends the content of the document
```

1. **\documentclass{article}**: Defines the overall layout and style of the document.
2. **\begin{document}** and **\end{document}**: Everything between these commands will be included in the output document.

2. Writing Basic Mathematical Expressions

Inline vs. Display Math

1. **Inline Math**: For mathematical expressions that appear within a line of text, use $…$.
    1. E.g. $E = mc^2$ is written as `$E = mc^2$` in LaTeX.
2. **Display Math**: For standalone equations, use $$…$$.
    1. E.g. To display $$E = mc^2$$ on its own line, use `$$E = mc^2$$`.

Example

```
\documentclass{article}
\begin{document}

The equation $E = mc^2$ is famous in physics. It is so important that we can
highlight $$E = mc^2$$ by putting it to a separate line.

\end{document}
```

This code will become:

The equation $E = mc^2$ is famous in physics. It is so important that we can highlight

$$E = mc^2$$

by putting it to a separate line.

Basic Mathematical Symbols

1. **Exponents (superscripts)**: Use ^ for superscripts.
    1. E.g. x^2 is written as x^2.
2. **Subscripts**: Use `_` for subscripts.
    1. E.g. a_1 is written as a_1.
3. **Fractions**: Use `\frac{numerator}{denominator}`.
    1. E.g. $\frac{a}{b}$ is written as $\frac{a}{b}$.

Examples

```
\documentclass{article}
\begin{document}

% Exponent and subscript
The formula for the area of a circle is $A = \pi r^2$.

% Fraction
The equation $\frac{a}{b} = c$ represents a fraction.

% Combined
The equation for kinetic energy is $K = \frac{1}{2}mv^2$.

\end{document}
```

This code will become:

The formula for the area of a circle is $A = \pi r^2$.
The equation $\frac{a}{b} = c$ represents a fraction.
The equation for kinetic energy is $K = \frac{1}{2}mv^2$.

3. Basic Text Formatting in LaTeX

LaTeX also allows you to format text, which is useful for emphasizing certain parts of your documents.

Bold text

Use the `\textbf{…}` command:

1. Example: `\textbf{This is bold}` → **This is bold**

Italic text

Use the `\textit{…}` command:

1. Example: `\textit{This is italic}` → *This is italic*

Underline text

Use the `\underline{…}` command:

1. Example: `\underline{This is underlined}` → <u>This is underlined</u>

Combining formats

You can even combine them:

1. Example: `\textbf{\textit{Bold and italic}}` → ***Bold and italic***
2. Example:

```
\documentclass{article}
\begin{document}

Here is some \textbf{bold text}, some \textit{italic text}, and some
\underline{underlined text}.

You can also combine them, like \textbf{\textit{bold and italic}}.

\end{document}
```

This will become:

Here is some **bold text**, some *italic text*, and some <u>underlined text</u>.
You can also combine them, like ***bold and italic***.

4. Special Mathematical Symbols in LaTeX

LaTeX provides a variety of symbols to accurately represent mathematical expressions.

1. The **plus-minus symbol** is used to denote values that can be either positive or negative and is written as `\pm`, which displays as $\pm$.
2. To express **square roots**, the square root symbol is used, which is written as `\sqrt{…}`. For example, `\sqrt{2}` produces $\sqrt{2}$
3. For **higher-order roots**, such as a cubic root, the syntax is `\sqrt[3]{…}`, yielding $\sqrt[3]{9}$
4. Another common symbol is the **infinity symbol**, represented as `\infty`, and it is displayed as ∞
5. For **greater than or equal to** and **less than or equal to** symbols, use `\geq` and `\leq`, which render as $\geq$ and $\leq$, respectively.

Summation

The general form of summation in LaTeX is written using the `\sum` command. For example, the sum from $i=1$ to n is given by:

$$\sum_{i=1}^{n} i^2$$

This expression sums the squares of integers from 1 to n.

Derivative

The derivative of a function $f(x)$ with respect to x is represented in LaTeX using the `\frac` command for fractions. The notation for the derivative of $f(x)$ with respect to x is:

$$\frac{d}{dx} f(x)$$

This gives the rate of change of $f(x)$ with respect to x.

Partial Derivative

For partial derivatives, the `\partial` command is used. The partial derivative of a function $f(x, y)$ with respect to x is:

$$\frac{\partial}{\partial x} f(x, y)$$

This expression gives the partial derivative of f with respect to x, holding other variables constant.

Partial Integration

Partial integration, also known as integration by parts, can be expressed in LaTeX. For the specific example of integrating $x \sin(x)$ from a to b, the integral is written as:

\[\int_{a}^{b} x \sin(x) \, dx \]

This represents the definite integral of $x \sin(x)$ with respect to x from a to b.

5. Aligning Equations

Align Environment

1. The `align` environment is used to align multiple equations. Each line of the equation is aligned using the `&` symbol, typically before the equal sign or any other operator.
2. Use `\\` to separate lines.

Example

```
\documentclass{article}
\usepackage{amsmath}
\begin{document}

\begin{align}
  3x + 2y + 0z &= 6 \\
  4x - y &= 25
\end{align}

\end{document}
```

This code will become:

$$3x + 2y + 0z = 6 \tag{1}$$
$$4x - y = 25 \tag{2}$$

Explanation:

1. **\usepackage{amsmath}**: The `amsmath` package is required for advanced mathematical typesetting features, including the `align` environment.
2. **&**: This symbol is used to align equations at the specified point, usually before an operator like =.

Tips:

1. You can label equations using the `\label{}` command and refer to them later with `\ref{}`.
2. Example:

```
\begin{equation} \label{eq:quadratic}
x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
\end{equation}
```

To refer to this equation later, use `Equation \ref{eq:quadratic}`.

6. Lists

LaTeX provides environments for creating both unordered and ordered lists.

Unordered Lists

Use the `itemize` environment to create a bulleted list. Each item starts with the \item command.

```
\begin{itemize}
  \item apple
  \item banana
  \item raspberry
\end{itemize}
```

- apple
- banana
- raspberry

Ordered Lists

Use the `enumerate` environment to create a numbered list.

```
\begin{enumerate}
  \item Denver Broncos
  \item Buffalo Bills
  \item Dallas Cowboys
\end{enumerate}
```

1. Denver Broncos
2. Buffalo Bills
3. Dallas Cowboys

7. Exercise

Reproduce the following mathematical proof in LaTeX. Use inline and display math, as well as basic and special symbols! Save the result in PDF format!

Proof: $\sqrt{2}$ is Irrational

Assumptions:

- Assume, for contradiction, that $\sqrt{2}$ is rational.
- It can therefore be expressed as a fraction $\frac{a}{b}$.
- a and b are coprime integers.

We can write:

$$\sqrt{2} = \frac{a}{b}$$

Squaring both sides:

$$2 = \frac{a^2}{b^2}$$

Multiplying both sides by b^2:

$$2b^2 = a^2$$

This implies that a^2 is even, so a must also be even. Let $a = 2k$ for some integer k.

Substituting $a = 2k$ into the equation:

$$2b^2 = (2k)^2$$

Dividing by 2:

$$b^2 = 2k^2$$

This implies that b^2 is even, so b must also be even.

Conclusion: If both a and b are even, then they are not coprime. This contradicts our original assumption. **Therefore, $\sqrt{2}$ is irrational.**

Raw text:

```
Proof: 2 is Irrational

Assumptions:
Assume, for contradiction, that $\sqrt{2}$ is rational.
It can therefore be expressed as a fraction $\frac{a}{b}$.
```

```
a and b are coprime integers.

We can write:
EQUATION

Squaring both sides:
EQUATION

Multiplying both sides by b2:
EQUATION

This implies that a2 is even, so a must also be even. Let a = 2k for some
integer k.

Substituting a = 2k into the equation:
EQUATION

Dividing by 2:
EQUATION

This implies that b2 is even, so b must also be even.

Conclusion: If both a and b are even, then they are not coprime.
This contradicts our original assumption. Therefore, 2 is irrational.
```

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