# 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. **Overleaf**: We will use Overleaf, a free online LaTeX editor, which allows you to write and compile LaTeX documents directly in your browser.
    1. Sign up at Overleaf.
    2. Overleaf offers collaborative features, version control, and a vast library of LaTeX templates.

### Basic Document Structure:

```
\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 became:

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. 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 $\infty$
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 $b$.

## 4. 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:

$$3x + 2y + 0z = 6 \quad (1)$$
$$4x - y = 25 \quad (2)$$

### 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}`.

## 5. 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

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

Then:

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

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 into the equation:

$$2b^2 = (2k)^2 = 4k^2$$

Dividing by 2:

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

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

But if both $a$ and $b$ are even, they are not coprime, which contradicts our original assumption. Therefore, $\sqrt{2}$ must be irrational.

Raw text:

```
Proof: √2 is Irrational

Assume, for contradiction, that √2 is rational. Then it can be expressed as
a fraction a/b, where a and b are coprime integers.

Then:
HERE COMES AN EQUATION.

Squaring both sides:
HERE COMES AN EQUATION.

Multiplying both sides by b2:
HERE COMES AN EQUATION.

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

```
Substituting into the equation:
HERE COMES AN EQUATION.

Dividing by 2:
HERE COMES AN EQUATION.

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

But if both a and b are even, they are not coprime, which contradicts our
original assumption. Therefore, √2 must be irrational.
```