

# Introduction to LaTeX for Mathematical Expressions

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

## 1. Introduction to LaTeX

### What is LaTeX?

1. 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?

1. **Precision and Control:** LaTeX allows precise formatting of documents and mathematical expressions.
2. **Consistency:** LaTeX automatically manages references, labels, and numbering, ensuring consistency throughout your document.
3. **Professional Quality:** Documents created in LaTeX look professional and are publication-ready.

### 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.

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## 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  $\frac{\text{numerator}}{\text{denominator}}$ .
  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{d}{dx}` 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:

$$\begin{aligned} 3x + 2y + 0z &= 6 & (1) \\ 4x - y &= 25 & (2) \end{aligned}$$

### 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:

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Then:

HERE COMES AN EQUATION.

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