

Writing Formulas for a \LaTeX Article

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Abstract

A great strength of \LaTeX is the manner it typesets equations. Many publishers of mathematical journals either strongly suggest or require use of \LaTeX . Equation support that is native to \LaTeX has some limitations. The American Mathematical Society (AMS) packages have been created to extend this functionality. Few class files are not compatible with the AMS packages. Mathematical formulas using standard \LaTeX and AMS packages will be discussed.

1 \LaTeX Formula Support

The *article* class has two options pertaining to equations. By default, equations are centered and the equation number is to the right of the equation. Equations can be left aligned with an adjustable math indent using the option *fleqn*. Using the option *leqno* will relocate the numbers on the left.

Formulas are displayed in math mode, where variables are in italics and numbers appear in roman typeface. Spaces are ignored when writing the equation — \LaTeX will insert the appropriate space based on the character. Equations that are in-line with text are enclosed in dollar signs (i.e. $\$...\$$). The formula, $a^2 + b^2 = c^2$, is entered as $\$a^2+b^2=c^2\$$. Exponents or superscripts are preceded by \wedge and subscripts are preceded by $_$. Many exponents, superscripts, and subscripts consist of more than one character. Be sure to include curly brackets around the exponent, superscript, or subscript in those cases (e.g. a_{11} is entered as $\$a_{11}\$$).

If fifty spaces are entered in text mode, only one space displays. In math mode, spaces are ignored completely. Some commands vary in size when they are in-line with the text or are contained on their own line. One example is the summation operator.

Often, formulas are displayed on their own line. The environment used to display the equation depends on several factors:

- Should there be an equation number?
- Is the equation more than one line?
- Are there several formulas that should be grouped together?

1.1 Equations on a Single Line

If the equation does not need an equation number and is no larger than one line, the *displaymath* environment could be used when you don't use the *amsmath* package. The shortcut for the *displaymath* environment is square brackets (i.e. $\[\]$). Notice how the size of the summation differs from the in-line version of the formula:

$$\sum_{i=1}^{\infty} a_i^2$$

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If an equation number is needed and the formula is no larger than one line, the *equation* environment could be used. With the *amsmath* package, there is a special version, *equation**, that yields no number (refer to Section 2). Equation 1 is the same equation using the *equation* environment.

$$\sum_{i=1}^{\infty} a_i^2 \tag{1}$$

By default, the numbering of equations with the *article* class is 1, 2, 3, etc. Cross-references for equations are just like cross-references for lists, tables, and figures. Use the *label* command within the *equation* environment and the *ref* command within the text. Remember to use a naming convention for the key and the key will be case sensitive. If you use the *amsmath* package, use `\eqref{label name}` for your cross-references for automatic parenthesis around the number if you prefer this notation.

1.2 Equations on Multiple Lines

If an equation is longer than one line or several formulas must be grouped together, the *eqnarray* environment could be used. Usually, the *eqnarray* environment is only used if authors cannot use the *amsmath* package because the environments included in this package are easier to use (refer to Section 2). The special version, *eqnarray**, suppresses equation numbers. The *eqnarray* environment behaves like a *tabular* environment consisting of three columns, where the column positioning is right (r), center (c), and left (l), respectively. The ampersand (i.e. &) is still the column delimiter and the double backslash (i.e. \\) is still the row delimiter. The code for factoring a polynomial could be

```
\begin{eqnarray*}
y &=& x^2 + 2x + 1\\
&=& (x+1)(x+1) \\
&=& (x+1)^2
\end{eqnarray*}
```

Due to the column alignment, the equations appear to be aligned around the equals sign. No equation number will be printed because the *eqnarray** environment is used.

$$\begin{aligned} y &= x^2 + 2x + 1 \\ &= (x + 1)(x + 1) \\ &= (x + 1)^2 \end{aligned}$$

The *array* environment is the math mode equivalent of the *tabular* environment. The syntax is exactly the same. An example of a piecewise step function can be input as

```
\begin{equation}
u(t)=\left\{\begin{array}{cc} 0 & t=0 \\ 1 & t\geq 0 \end{array}\right. \right. \text{\textbf{right.}} \text{\textbf{label}}\{eq2\}
\end{equation}
```

Notice the other commands introduced in this example. The commands *left* and *right* can be used to display brackets of the correct size. The bracket to be used occurs directly after the command. In the case of curly brackets, the backslash must be used just like if you were to display a curly bracket in text mode. These commands must always be in pairs. Since our example has a bracket on one side only, a period is used after the *right* command to complete the pair. To place a brace above or below the equation, use the *overbrace* and *underbrace* commands.

$$u(t) = \left\{ \begin{array}{ll} 0 & t = 0 \\ 1 & t \geq 0 \end{array} \right. \tag{2}$$

Array environments can be nested. A complicated example is

$$\left[\begin{array}{cc} \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \cdots & \cdots & \ddots & \cdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} & \mathbf{0}_{(m-r) \times q} \\ \mathbf{0}_{r \times (n-q)} & \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \end{array} \right]_{m \times n}$$

As stated in [Kopka and Daly \(2004\)](#), there is a difference in spacing between the *array* and *eqnarray* environments due to their purpose. The *eqnarray* command is designed to be a set of formulas, so it uses more space to display the equations. The *array* environment is more appropriate for matrices. Our example of factoring a simple polynomial could be achieved using either environment; however, using the *array* environment

$$\begin{aligned} y &= \sum_{i=0}^n (x_i + 1)^2 \\ &= \sum_{i=0}^n x_i^2 + 2x_i + 1 \\ &= \sum_{i=0}^n x_i^2 + 2 \sum_{i=0}^n x_i + n \end{aligned} \tag{3}$$

is much more difficult to read than using the *eqnarray* environment

$$\begin{aligned} y &= \sum_{i=0}^n (x_i + 1)^2 \\ &= \sum_{i=0}^n x_i^2 + 2x_i + 1 \\ &= \sum_{i=0}^n x_i^2 + 2 \sum_{i=0}^n x_i + n \end{aligned} \tag{4}$$

due to the spacing. There is slightly less typing with Equation 3 because the equal sign is provided in the column definition – `r@{=}`. It would be better to type the equals operator a few more times and type `\nonumber` twice to suppress the equation number on two of the lines with the *eqnarray* environment.

Sometimes, the extra space with the *eqnarray* environment is not desirable and the *array* environment is not appropriate. An example is a long equation that is more than one line. An example would be to input:

```
\begin{eqnarray*}
\lefteqn{y = \alpha + \beta + \gamma + \delta}
&+ \epsilon + \sigma + \tau + \xi \\
&- \zeta
\end{eqnarray*}
```

The *lefteqn* command forces the left column to be zero width and print what is contained in the curly brackets. Notice that the second and third line have an extra space provided by the empty curly bracket pair. Without the empty curly bracket pair, the plus and minus will be treated as the sign of the variable that follows it instead of an operator. Since the column alignment with *eqnarray* is right, center, left, the second and third line begin in the third column. Otherwise, the alignment would be incorrect.

$$\begin{aligned} y &= \alpha + \beta + \gamma + \delta \\ &\quad + \epsilon + \sigma + \tau + \xi \\ &\quad - \zeta \end{aligned}$$

Sometimes an adjustment of space is needed. Use `\,` for a small space, `\:` for a medium space, `\;` for a large space, and `\!` for negative space.

Other commands can be nested, such as fractions ($\frac{\textit{upper}}{\textit{lower}}$) like

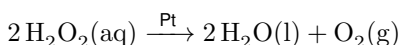
$$\frac{\frac{s+1}{(s+2)(s+3)(s+4)}}{(s+1)(s+2)(s+5)(s+10)}$$

and roots ($\sqrt[\textit{options}]{\textit{number}}$) like

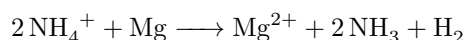
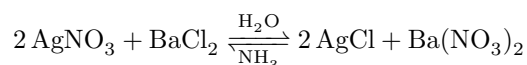
$$\sqrt{\frac{1}{\sqrt{s^2 + 6s + 7}}}$$

1.3 Chemical Equations

There are a few commands that can be used chemical formulas: *mathrm* and *stackrel*. The *mathrm* command outputs text in roman font and the *stackrel* command will stack two objects. However, it is much easier to use the *mhchem* package. In fact, some class files recommend it. The *ce* command can be used in text or math mode. Spaces are important when using the *ce* command which differs from most cases in \LaTeX . If you input $\ce{2H2O2(aq) ->[Pt] 2H2O(l) + O2(g)}$, it will display



Complicated chemical equations can be displayed using the *ce* command. The following reactions are from [Appl \(2000\)](#).



The double harpoon and the text surrounding it were created by inputting $\Leftrightarrow[\textit{text above}][\textit{text below}]$.

1.4 Theorems

\LaTeX provides a command to define theorems and the like. Since the author sets the label for the theorem, there is flexibility to declare theorems, lemmas, axioms, etc. The syntax is $\newtheorem{\textit{name}}[\textit{use same counter as}]{\textit{label}}[\textit{numbering based on}]$.

For example if a lemma was defined as $\newtheorem{\textit{lemma}}[\textit{theorem}]{\textit{bfseries Lemma}}[\textit{subsection}]$, it would share a counter with theorems and the number would include the subsection. After it is defined, you can use the environment by name like any other environment. A theorem that uses the subsection optional argument but not the other would appear as

1.5 Theorem & Lemma Example - subsection 1

Theorem 1.5.1. *This is Theorem 1.5.1.*

[Kopka and Daly \(2004\)](#) and [Grätzer \(2007\)](#) provide additional commands in math mode.

2 AMS

AMS was involved with \TeX from the very beginning. Shortly after the creation of \LaTeX , AMS- \LaTeX was created extending its functionality. As seen in [Kopka and Daly \(2004\)](#), AMS- \LaTeX contains:

- packages that extend mathematical typesetting;

- extra classes for AMS publications; and
- additional fonts.

The *amsmath* package will be discussed in this module. This package provides additional optional arguments, such as the *tbtag*s option. By default, the equation numbers are centered vertically for the *split* environment, which will be explained later in this section. Using the *tbtag*s option will align the equation number with the first row of the equation when it is used with the *leqno* option. Otherwise the *tbtag*s option will align the equation number with the last row of the equation. In addition, there are several options pertaining to the location of the limits of particular operators (e.g. summation).

Some extensions to \LaTeX mathematics support include bold for symbols, commands to eliminate spacing issues (i.e. `\iint`), more spacing commands, and special commands for multiple limits. The availability of the *genfrac* command allows users to generate their own commands. For more information, refer to [Kopka and Daly \(2004, pp. 269-277\)](#). By default, equation numbers are a single digit and sequential. With the *amsmath* package, `\numberwithin{equation}{section}` will change the equations numbers to depend on sections.

2.1 Environments for Matrices

The *amsmath* package provides several environments for matrices: *matrix*, *pmatrix*, *bmatrix*, *Bmatrix*, *vmatrix*, and *Vmatrix*. A nice feature about these commands are that the brackets are included with the environment. The *matrix* environment has none, *pmatrix* is enclosed in parenthesis, *bmatrix* is enclosed in square brackets, *Bmatrix* is enclosed in curly brackets, *vmatrix* is enclosed in vertical lines, and *Vmatrix* is enclosed in double vertical lines. An example of *bmatrix*, *vmatrix*, and *Vmatrix* is

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

$$\det(A) = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}$$

$$\left\| \begin{matrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{matrix} \right\|_2^2 \leq \left\| \begin{matrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{matrix} \right\|_1 \left\| \begin{matrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{matrix} \right\|_\infty$$

2.2 Environments for Equations on Multiple Lines

The *amsmath* package provides several equation environments to extend the support of multi-line equations. For long equations, there are the *multline* and *split* environments. For systems of equations, there are the *gather* and *align* environments.

The *multline* environment has a predetermined alignment. The first line is left justified, the final line is right justified, and all other lines are centered when the *fleqn* option is not used. An example of *multline* is shown in Equation 5. A line break is forced with a double backslash.

$$\begin{aligned} \frac{x}{x+1} &= 1 - \frac{2}{x} + \frac{4}{x^2} - \frac{8}{x^3} + \frac{16}{x^4} - \frac{32}{x^5} + \frac{64}{x^6} - \frac{128}{x^7} + \frac{256}{x^8} - \frac{512}{x^9} + \frac{1024}{x^{10}} - \frac{2048}{x^{11}} \\ &\quad + \frac{4096}{x^{12}} - \frac{8192}{x^{13}} + \frac{16384}{x^{14}} - \frac{32768}{x^{15}} + \frac{65536}{x^{16}} - \frac{131072}{x^{17}} + \frac{262144}{x^{18}} \\ &\quad - \frac{524288}{x^{19}} + \frac{1048576}{x^{20}} - \frac{2097152}{x^{21}} + \frac{4194304}{x^{22}} - \frac{8388608}{x^{23}} \\ &\quad + \frac{16777216}{x^{24}} - \frac{33554432}{x^{25}} + \frac{67108864}{x^{26}} - \frac{134217728}{x^{27}} + \frac{268435456}{x^{28}} - \frac{536870912}{x^{29}} + \dots \end{aligned} \quad (5)$$

Any of the middle lines can be moved to the left or right using `\shoveleft` and `\shoveright`. An example is

$$\begin{aligned} \frac{x}{x+1} = & 1 - \frac{2}{x} + \frac{4}{x^2} - \frac{8}{x^3} + \frac{16}{x^4} - \frac{32}{x^5} + \frac{64}{x^6} - \frac{128}{x^7} + \frac{256}{x^8} - \frac{512}{x^9} + \frac{1024}{x^{10}} - \frac{2048}{x^{11}} + \frac{4096}{x^{12}} \\ & - \frac{8192}{x^{13}} + \frac{16384}{x^{14}} - \frac{32768}{x^{15}} + \frac{65536}{x^{16}} - \frac{131072}{x^{17}} + \frac{262144}{x^{18}} - \frac{524288}{x^{19}} + \frac{1048576}{x^{20}} - \frac{2097152}{x^{21}} + \frac{4194304}{x^{22}} \\ & - \frac{8388608}{x^{23}} + \frac{16777216}{x^{24}} - \frac{33554432}{x^{25}} + \frac{67108864}{x^{26}} - \frac{134217728}{x^{27}} + \frac{268435456}{x^{28}} - \frac{536870912}{x^{29}} + \dots \end{aligned} \quad (6)$$

The *split* environment differs from *multline* in two ways. First, it must be called in math mode, so it must be used in conjunction with another environment such as the *equation* environment. Generally, authors use *split* when they want to specify the alignment more precisely. The ampersand (i.e. `&`) precedes the character that will be used in the alignment. The same equation using *split* would be

$$\begin{aligned} \frac{x}{x+1} = & 1 - \frac{2}{x} + \frac{4}{x^2} - \frac{8}{x^3} + \frac{16}{x^4} - \frac{32}{x^5} + \frac{64}{x^6} - \frac{128}{x^7} + \frac{256}{x^8} - \frac{512}{x^9} + \frac{1024}{x^{10}} - \frac{2048}{x^{11}} \\ & + \frac{4096}{x^{12}} - \frac{8192}{x^{13}} + \frac{16384}{x^{14}} - \frac{32768}{x^{15}} + \frac{65536}{x^{16}} - \frac{131072}{x^{17}} + \frac{262144}{x^{18}} \\ & - \frac{524288}{x^{19}} + \frac{1048576}{x^{20}} - \frac{2097152}{x^{21}} + \frac{4194304}{x^{22}} - \frac{8388608}{x^{23}} \\ & + \frac{16777216}{x^{24}} - \frac{33554432}{x^{25}} + \frac{67108864}{x^{26}} - \frac{134217728}{x^{27}} + \frac{268435456}{x^{28}} - \frac{536870912}{x^{29}} + \dots \end{aligned} \quad (7)$$

Notice the location of the equation number when using *split* and when using *multline*. The *multline* environment places the number on the last line of the equation (refer to Equation 5). The equation number is vertically centered for the *split* example (refer to Equation 7) due to the use of the *equation* environment. The option *tbtags* can be used to force the equation number placement to be the same as the *multline* environment.

For systems of equations, the *gather* environment is used if you want each line to be centered. Each line will be given an equation number unless `\notag` is used.

$$\begin{aligned} y &= \sum_{i=0}^n (x_i + 1)^2 \\ &= \sum_{i=0}^n x^2 + 2x + 1 \\ &= \sum_{i=0}^n x^2 + 2 \sum_{i=0}^n x + n \end{aligned} \quad (8)$$

The *align* environment allows alignment using the ampersand in the same way as the *split* environment. Column alignment is right, left, right, left, etc.

$$\begin{aligned} y &= \sum_{i=0}^n (x_i + 1)^2 \\ &= \sum_{i=0}^n x^2 + 2x + 1 \\ &= \sum_{i=0}^n x^2 + 2 \sum_{i=0}^n x + n \end{aligned} \quad (9)$$

Equation 2 represents a step function. With *amsmath*, this task is easier using the *cases* environment.

```
\begin{equation*}
u(t)=\begin{cases} 0 & \text{if } t=0 \\ 1 & \text{if } t>0 \end{cases}
\end{equation*}
```

The *subequations* environment provides a numbering scheme for subequations; however, one of the equation environments must be supplied within *subequations* because the environment does not supply math mode. Often *align* or *gather* is used with it.

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} u \quad (10a)$$

$$y = [C_1 \quad C_2] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + Du \quad (10b)$$

2.3 Additional Theorem Support

Another useful package is *amsthm*. This package extends theorem support. There are additional options for the display of theorems using `\theoremstyle{style}`. The styles available are listed in the table below.

Style	Format
<i>plain</i>	label and number are boldface / text is italic
<i>definition</i>	label and number are boldface / text is normal
<i>remark</i>	label, number, and text are normal

There is a *proof* environment available with this package as well.

3 More Documentation about Symbols

On the CTAN website, there is a PDF containing a comprehensive \LaTeX symbol list. Some symbols require font and package downloads and others are installed with most \TeX distributions. In addition, there is an [online database of symbols provided by RIT Libraries](#).

References

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