Alignment of formulas

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1 Introduction

One of the most difficult aspects of typesetting mathematics is splitting long formulas across several lines and aligning a group of formulas. Many of these aspects cannot be done automatically, and it is up to you to control how this is to done. In all cases, your judgement should be based on making the formula as readable as possible.

Some control is available using LaTeX's `eqnarray` and `eqnarray*` environments. However, this command is rather limited for many applications and if you are creating a new document in which you envisage a large number of long formulas or equations I strongly recommend you use the AMS packages that are available.

2 Using the package

Unless you are using one of the AMS's own class files, you load the package by the command `\usepackage{amsmath}`. This loads lots of useful new commands, including the alignment environments referred to earlier. These are:

1. `equation` essentially as usual
2. `multline` for single equations or formulas going over two or more lines
3. `split` as for multline, but with extra control over alignment
4. `gather` for several equations grouped together
5. `align` for several equations grouped together, with alignment
6. `alignat` similar to align but with some extra alignment features

In most cases, there are starred and unstarred versions of these—the starred versions do not produce any numbering automatically. There are a few other related commands, such as: the `\intertext` command which interpolates text without messing up the alignment; the `subequations` environment which numbers a groups of equations as *5a*, *5b*, *5c*, etc.; the `cases` environment for definitions by cases, and a few other useful things. I'm not going to describe in detail how these commands ae used—you can get that from the documentation. Instead, the next section contains some examples and you can quickly get started by comparing the output with the LaTeX source, which is called `align.tex` and can be obtained from the usual directory.

3 Examples

Many of these examples are directly taken from the documentation of AMSLaTeX, which is recommended reading if further details are required.

Use of `equation*`:

$$a = b$$

Use of `equation`:

$$a = b \tag{1}$$

Use of `split` and `equation`:

$$\begin{split} a &= b + c - d \\ &\quad + e - f \\ &= g + h \\ &= i \end{split} \tag{2}$$

Use of `multline`:

$$\begin{multline} a + b + c + d + e + f + b + c + d + e + f + b + c + d + e + f \\ + b + c + d + e + f + b + c + d + e + f + i + j + k + l + m + n \end{multline} \tag{3}$$

Use of `gather`:

$$a_1 = b_1 + c_1 \tag{4}$$
$$a_2 = b_2 + c_2 - d_2 + e_2 \tag{5}$$

Use of `align`:

$$\begin{aligned} a_1 &= b_1 + c_1 && (6) \\ a_2 &= b_2 + c_2 - d_2 + e_2 && (7) \end{aligned}$$

Other uses for `align`:

$$\begin{aligned} a_{11} &= b_{11} & a_{12} &= b_{12} && (8) \\ a_{21} &= b_{21} & a_{22} &= b_{22} + c_{22} && (9) \end{aligned}$$

Use of `flalign*`:

$$\begin{aligned} a_{11} &= b_{11} & a_{12} &= b_{12} \\ a_{21} &= b_{21} & a_{22} &= b_{22} + c_{22} \end{aligned}$$

Use of `\equation` and `\split`:

$$\begin{split}H_c = \frac{1}{2n}\sum_{l=0}^{n}(-1)^l(n-l)^{p-2}\sum_{l_1+\dots+l_p=l}\prod_{i=1}^{p}\binom{n_i}{l_i}\\ \cdot[(n-l)-(n_i-l_i)]^{n_i-l_i}\cdot\Bigl[(n-l)^2-\sum_{j=1}^{p}(n_i-l_i)^2\Bigr].\end{split} \tag{10}$$

Use of `\align` to align textual annotations:

$$\begin{align} x &= y_1 - y_2 + y_3 - y_5 + y_8 - \dots && \text{by (14)} \tag{11}\\ &= y' \circ y^* && \text{by (5)} \tag{12}\\ &= y(0)y' && \text{by Axiom 1.} \tag{13}\end{align}$$

Use of `\aligned` to control placement of inner alignments:

$$\begin{aligned}[t] \alpha &= \alpha\alpha\\ \beta &= \beta\beta\beta\beta\beta\\ \gamma &= \gamma \end{aligned} \qquad \text{versus} \qquad \begin{aligned}[b] \delta &= \delta\delta\\ \eta &= \eta\eta\eta\eta\eta\eta\\ \varphi &= \varphi \end{aligned}$$

“Cases” constructions:

$$P_{r-j} = \begin{cases} 0 & \text{if } r-j \text{ is odd,}\\ r!\,(-1)^{(r-j)/2} & \text{if } r-j \text{ is even.}\end{cases} \tag{14}$$

Use of `\smash` and `\vphantom` to control vertical size:

$$\begin{aligned} \Bigl\langle u \Bigm| \sum_{i=1}^{n} F(e_i,v)e_i \Bigr\rangle &= \sum_{i=1}^{n} F(e_i,v)\langle u|e_i\rangle\\ &= \sum_{i=1}^{n}\langle u|e_i\rangle F(e_i,v)\\ &= \sum_{i=1}^{n}\overline{\langle e_i|u\rangle}F(e_i,v)\\ &= F\Bigl(\sum_{i=1}^{n}\langle e_i|u\rangle e_i, v\Bigr) = F(u,v), \end{aligned}$$

(Note that without `\phantom` and `\smash` the brackets would be too big because of the limits on the summations.) `\phantom` is also useful if you are splitting a long equation over two lines and you want a large left bracket on one line to match a large right bracket on the next:

$$\begin{aligned} x = \frac{1}{2}\Bigl(&\sum_{i=1}^{n} F(e_i,v)e_i + \sum_{i=1}^{n} G(e_i,v)e_i + \sum_{i=1}^{n} H(e_i,v)e_i +\\ &\sum_{i=1}^{n} I(e_i,v)e_i + \sum_{i=1}^{n} K(e_i,v)e_i + \sum_{i=1}^{n} J(e_i,v)e_i\Bigr) \end{aligned}$$

(Note also the adjustment to the vertical spacing in this example.)

Use of `\intertext`:

Proof. (a) Given $\mathbf{v}$, we have

$$\begin{aligned} 1\,\mathbf{v} &= (-1)(-1)\mathbf{v} \\ &= (-1)(-1)\mathbf{v} + \mathbf{0} \\ &= (-1)(-1)\mathbf{v} + (\mathbf{v} + (-1)\mathbf{v}) \\ &= (-1)(-1)\mathbf{v} + ((-1)\mathbf{v} + \mathbf{v}) \\ &= ((-1)(-1)\mathbf{v} + (-1)\mathbf{v}) + \mathbf{v} \\ &= \mathbf{0} + \mathbf{v} \\ &= \mathbf{v}. \end{aligned}$$

(b) Again,

$$\begin{aligned} 0\,\mathbf{v} &= (1 + (-1))\mathbf{v} \\ &= 1\mathbf{v} + (-1)\mathbf{v} \\ &= \mathbf{v} + (-1)\mathbf{v} \\ &= \mathbf{0}. \end{aligned}$$

For (c),

$$\begin{aligned} \lambda\mathbf{0} &= \lambda(\mathbf{0} + (-1)\mathbf{0}) \\ &= \lambda\mathbf{0} + \lambda((-1)\mathbf{0}) \\ &= \lambda\mathbf{0} + (-1)(\lambda\mathbf{0}) \\ &= \mathbf{0} \end{aligned}$$

as required. $\square$