# Multiline formulas

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• *A general remark*: the constructs ("environments") discussed below require the use of the `amsart` style or `\usepackage{amsmath}` and are of two types:

(1) the `align`, `gather`, `multline` and `alignat` environments concern the whole equations, i.e. they replace `equation` (an exception: `align` can be used inside `gather`);

(2) `split`, `aligned`, `gathered` and `alignedat` are "subsidiary environments": they can only appear inside others, like `equation`, `align` or `gather`, and may embrace only some part of a displayed line.

Some constructs below require `\usepackage{mathtools}` or `\usepackage{enumitem}`.

• *A piece of advice*: forget `eqnarray`!

## 1 One multiline formula

• Quite often one formula (i.e. a sequence of expressions connected by binary operations and relations) takes more than one line. As a rule, one formula (in this sense) should have one number; numbering parts of it separately is seldom necessary. In case of need, you can refer to a specific line of a formula by writing e.g. $(1.1)_2$.

If equation numbers are placed on the left (as in the `amsart` style, and also in IMPAN journals), the number is normally on the first line of a multiline formula; if the numbers are on the right, it is on the last line. (Warning: this convention is followed by many publishers, but not all: sometimes the number is centred.)

• If there are no natural places for alignment, use `multline`:

$$\begin{aligned} (1.1)\quad & aaaaaaaaaaaaaaaaaaaaaaaaaaaa \\ & + bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb \\ & \le ddddddddddddddddddddddddd. \end{aligned}$$

The first line is set (almost) flush left, the last line is (almost) flush right, and the middle lines (if any) are centred.

• You can shove any middle line within `multline` to the right or to the left by making it the argument of `\shoveright` or `\shoveleft`:

$$\begin{aligned}(1.2)\quad & aaaaaaaaaaaaaaaaaaaaaaaaaaaa \\ & + bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb + ddddddddddd \\ & \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \times eeeeeeeeeeeeeeeeeeeeee \\ & \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \leq ddddddddddddddddddddddddd.\end{aligned}$$

• You can align a group of lines within `multline`, using `aligned`:

$$\begin{aligned}(1.3)\quad & aaaaaaaaaaaaaaaaa + xxxxxxxxxxx \\ & \qquad\qquad\qquad\qquad < bbbbbbbbbbbbbbbbbbbbb \\ & \qquad\qquad\qquad\qquad\quad + ddddddddddddddddddddddddddddddddddddddd \\ & \qquad\qquad\qquad\qquad < ccccccccccccccccc.\end{aligned}$$

• To code an "object" consisting of centred lines within a formula, use `gathered`:

$$(1.4)\qquad \mathrm{Pascal}_4 = \begin{gathered} 1 \\ 1\ 2\ 1 \\ 1\ 3\ 3\ 1 \\ 1\ 4\ 6\ 4\ 1 \end{gathered}$$

If you want to bottom-align two such objects, apply `gathered[b]` (then you have to add `split` to centre the equation number):

$$(1.5)\qquad \begin{gathered} 1 \\ 1\ 2\ 1 \\ 1\ 3\ 3\ 1 \end{gathered} \qquad \begin{gathered} 1 \\ 1\ 2\ 1 \\ 1\ 3\ 3\ 1 \\ 1\ 4\ 6\ 4\ 1 \end{gathered}$$

With `gathered[t]`, you get top alignment:

$$\begin{gathered} 1 \\ 1\ 2\ 1 \\ 1\ 3\ 3\ 1 \end{gathered} \qquad \begin{gathered} 1 \\ 1\ 2\ 1 \\ 1\ 3\ 3\ 1 \\ 1\ 4\ 6\ 4\ 1 \end{gathered}$$

• The `aligned[t]` and `aligned[b]` constructions enable independent and/or nested alignments, e.g., `aligned[t]` inside `aligned`:

$$\begin{aligned}(1.6)\quad & A = xyzt = ztuv + [f_1(a,b,c,d,e,f,g,h), \\ & \qquad\qquad\qquad\qquad\quad f_2(a,b,c,d,e,f,g,h), \\ & \qquad\qquad\qquad\qquad\quad f_3(a,b,c,d,e,f,g,h)] \\ & \qquad = ccccccccccccc\end{aligned}$$

or `aligned[b]` inside `aligned`:

$$\begin{aligned} xxxxxxx + [f_1(a,b,c,d,e,f,g,h), & \\ f_2(a,b,c,d,e,f,g,h), & \\ f_3(a,b,c,d,e,f,g,h)] &= ttttttttttttttttttttttttt \\ &= bbbbbbbbbbbbb.\end{aligned}$$

• To move a line within an aligned structure to the left or to the right, use `MoveEqLeft` with a positive or negative parameter (this requires `\usepackage{mathtools}`):

$$\begin{aligned} xxxxx &= yyyyyyyyyyyyyy + [eeee \\ &\qquad\qquad\qquad\qquad \times zzzzzzzzzzzzzzzzz] \\ &= ttttttttttttttttt \\ &= vvvvvvvvvv. \end{aligned} \tag{1.7}$$

• If the formulas are left-numbered, you can also label a longer statement as a "formula", by treating it as an item of an itemized list (this requires `\usepackage{enumitem}`; the "leftmargin" parameter has to be adjusted according to the width of the formula number):

(1.8) Here you can place any statement, even taking several lines of text and including displayed formulas, like

$$aaaa = bbb.$$

(1.9) Next item.

## 2 Several formulas or sets of displayed conditions

• Separate formulas should end with a comma or semicolon—to make it clear that the next line is not a continuation of the preceding one.

• If there are no natural places for vertical alignment, use `gather`:

$$aaaaaaaaaa = b, \quad cc = xxx, \quad dd = yyy, \tag{2.1}$$

$$mmmmmmmmmmmmm = 0 \quad \text{for all } i = 1, \dots, n. \tag{2.2}$$

Note the spacing between parts of a formula on the same line; you can use `\quad` (small space), `\quad\␣` (medium space) or `\qquad` (large space).

• If a formula number is unnecessary, you can "switch it off", using `\notag`:

$$\begin{aligned} aaaaaaaaaa = b, \quad cc = xxx, \quad dd = yyy, \\ mmmmmmmmmmmmm = 0 \quad \text{for all } i = 1, \dots, n. \end{aligned} \tag{2.3}$$

(A formula number not cited in text is "information noise"; also, the number takes some space and often causes the formula to occupy one line more. As a rule, number only those formulas that are referred to later.)

• If no number is necessary, use `gather*`:

$$\begin{aligned} aaaaaaaaaa = b, \quad cc = xxx, \quad dd = yyy, \\ mmmmmmmmmmmmm = 0 \quad \text{for all } i = 1, \dots, n. \end{aligned}$$

• If you need one centred number (for a group of equations), instead of `gather` use `gathered` inside `equation`:

$$\begin{aligned} aaaaaaaaaa = b, \quad cc = xxx, \quad dd = yyy, \\ mmmmmmmmmmmmm = 0 \quad \text{for all } i = 1, \dots, n. \end{aligned} \tag{2.4}$$

• You can also "gather" several "multlines", using the subsidiary construct `multlined`, available in `mathtools`, with optional parameters indicating the placement of formula numbers and the width of the formulas:

$$\begin{aligned} aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa \\ + bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb \\ \times yyyyyyyyyyy \\ = xxxxxxxxxxxxxxxxxxxxxxxxxxx, \end{aligned} \tag{2.5}$$

$$\begin{aligned} ccccccccccccccccccccccccccccccccccccc \\ = ddddddddddddddddddddddddddddddddddddddd. \end{aligned} \tag{2.6}$$

• In most cases, however, we want to align something, and then we use `align`:

$$xxxxx = yyyyyyyyyyyyyy + zzzzzzzzzzzzzzzzz, \tag{2.7}$$

$$bbb = ttttttttttttttttt, \tag{2.8}$$

$$hh = vvvvvvvvvv. \tag{2.9}$$

Note that the alignment symbols, called ampersands (`&`), should be placed **to the left** of binary relation signs; if, as above, part of an expression is continued on the next line, put `&\quad` before the binary operation sign.

Remember that you cannot place `&` signs anywhere: the parts between two `&` signs and between `&` and `\\` should be "separate formulas" (in the TEX sense), so you cannot e.g. put a `&` inside `{ }` or inside `\left-\right`.

• If you need one centred number for a group of aligned equations, use `split` or `aligned` inside `equation`:

$$\begin{aligned} xxxxx &= yyyyyyyyyyyyyy \\ &\quad + zzzzzzzzzzzzzzzzz, \\ bbb &= ttttttttttttttttt, \\ hh &= vvvvvvvvvv. \end{aligned} \tag{2.10}$$

• If you have two "split" sets of equations and you want them to have a common alignment, you have to use two `split`'s inside `align` (this is the advantage of `split` over `aligned`):

$$aaaaaaaaaaaaaaaaaaaaaa = bbbbbbbbbbbb, \tag{2.11}$$

$$\begin{aligned} bbbb &= xxxxxx, \\ ccccc &= yyyyyyy, \\ ddddddddd &= zzzzz. \end{aligned} \tag{2.12}$$

If you do not want "aligned alignments", use `split` or `aligned` inside `gather`:

$$aaaaaaaaaaaaaaaaaaaaaa = bbbbbbbbbbbb, \tag{2.13}$$

$$\begin{aligned} bbbbbbbbbbbbbbbbbbbbbbb &= xxxxxx, \\ ccccc &= yyyyyyy, \\ ddddddddd &= zzzzz. \end{aligned} \tag{2.14}$$

• If you need several aligned "columns", you can still use `align` or `align*`, but you have to add additional ampersands separating the columns:

$$\begin{aligned} aa &= bbbbb, & dd &= ee & &\text{(by Lemma 2)}, \\ hh &= ii, & ll &= kkkkkk & &\text{(by (2.14))}. \end{aligned}$$

However, here you do not control the spacing between the columns. If you want to prescribe it, use `alignat` (or `alignat*`), which has a parameter (the number of columns) and requires specifying the intercolumn spaces:

$$aa = bbbbb, \quad dd = ee \qquad \text{(by Lemma 2)}, \tag{2.15}$$
$$hh = ii, \qquad ll = kkkkkk \qquad \text{(by (2.14))}. \tag{2.16}$$

• `alignat` also has a subsidiary version, `alignedat`, which you can put inside `equation` if you need one centred number:

$$\begin{aligned} aa = bbbbb, \quad dd = ee \qquad & \text{(by Lemma 2)}, \\ hh = ii, \qquad ll = kkkkkk \qquad & \text{(by (2.14))}. \end{aligned} \tag{2.17}$$

• If you want the consecutive equations of a group of equations to be numbered e.g. (2a), (2b) etc., use `subequations`, inside which you can place the previous constructs, e.g., `alignat` inside `subequations`:

$$aa = bbbbb, \quad dd = ee \qquad \text{(by Lemma 2)}, \tag{2.18a}$$
$$hh = ii, \qquad ll = kkkkkk \qquad \text{(by (2.14))}. \tag{2.18b}$$

or `gather` inside `subequations`:

$$\begin{aligned} &aaaaaaaaaaaaaaaaaaaaaaa = bbbbbbbbbbbb, \\ &bbbbbbbbbbbbbbbbbbbbbbb = xxxxxx, \end{aligned} \tag{2.19a}$$

$$\begin{aligned} ccccc &= yyyyyyy, \\ ddddddd &= zzzzz. \end{aligned} \tag{2.19b}$$

Note the independent labels of the whole group and its parts; writing `\eqref{E:suba}`, we invoke the whole system (2.18), while writing `\eqref{E:suba1}` we refer to (2.18a).

• If you want to place a longer comment in the middle of an aligned construction, you can use `\intertext` (this only works within `align` or `align*`, but not with `aligned`):

$$\begin{aligned} xxxxx = yyyyyyyyyyyyyyy + [eeee \\ \times zzzzzzzzzzzzzzzzz] \end{aligned} \tag{2.20}$$

(*note that we have not used the full strength of* $(H)$ *here, but only the concavity of* $f$)

$$\begin{aligned} &= ttttttttttttttttt \\ &= vvvvvvvvvvv. \end{aligned}$$

# References

[1] G. Grätzer, *More Math into LaTeX*, 4th ed., Springer, Berlin, 2007.