

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.

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

1 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`:

$$(1.1) \quad \text{aaaaaaaa} = b, \quad cc = xxx, \quad dd = yyy,$$

$$(1.2) \quad \text{mmmmmmmmmmmmmmmm} = 0 \quad \text{for all } i = 1, \dots, n.$$

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

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

$$(1.3) \quad \text{aaaaaaaa} = b, \quad cc = xxx, \quad dd = yyy,$$

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

(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*`:

$$\text{aaaaaaaa} = b, \quad cc = xxx, \quad dd = yyy,$$
$$\text{mmmmmmmmmmmmmmmm} = 0 \quad \text{for all } i = 1, \dots, n.$$

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

$$(1.4) \quad \text{aaaaaaaa} = b, \quad cc = xxx, \quad dd = yyy,$$
$$\text{mmmmmmmmmmmmmmmm} = 0 \quad \text{for all } i = 1, \dots, n.$$

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

$$(1.5) \quad \begin{aligned} xxxxx &= yyyyyyyyyyyyyyy \\ &+ zzzzzzzzzzzzzzzzzzzz, \end{aligned}$$

$$(1.6) \quad bbb = tttttttttttttttt,$$

$$(1.7) \quad hh = vvvvvvvvvvv.$$

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 T_EX 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`:

$$(1.8) \quad \begin{aligned} xxxxx &= yyyyyyyyyyyyyyy \\ &+ zzzzzzzzzzzzzzzzzzzz, \\ bbb &= tttttttttttttttt, \\ hh &= vvvvvvvvvvv. \end{aligned}$$

- 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`):

$$(1.9) \quad \begin{aligned} aaaaaaaaaaaaaaaaaaaaaa &= bbbbbbbbbbbb, \\ &bbb = xxxxx, \end{aligned}$$

$$(1.10) \quad \begin{aligned} cccc &= yyyyyyy, \\ ddddddd &= zzzzz. \end{aligned}$$

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

$$(1.11) \quad \begin{aligned} aaaaaaaaaaaaaaaaaaaaaa &= bbbbbbbbbbbb, \\ bbbbbbbbbbbbbbbbbbbbbb &= xxxxx, \end{aligned}$$

$$(1.12) \quad \begin{aligned} cccc &= yyyyyyy, \\ ddddddd &= zzzzz. \end{aligned}$$

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

$$\begin{aligned} aa &= bbbb, & dd &= ee & & \text{(by Lemma 2),} \\ hh &= ii, & ll &= kkkkk & & \text{(by (1.12)).} \end{aligned}$$

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:

$$(1.13) \quad aa = bbbb, \quad dd = ee \quad \text{(by Lemma 2),}$$

$$(1.14) \quad hh = ii, \quad ll = kkkkk \quad \text{(by (1.12)).}$$

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

$$(1.15) \quad \begin{aligned} aa &= bbbb, & dd &= ee & & \text{(by Lemma 2),} \\ hh &= ii, & ll &= kkkkk & & \text{(by (1.12)).} \end{aligned}$$

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

$$(1.16a) \quad aa = bbbb, \quad dd = ee \quad (\text{by Lemma 2}),$$

$$(1.16b) \quad hh = ii, \quad ll = kkkkkk \quad (\text{by (1.12)}).$$

or `gather` inside `subequations`:

$$(1.17a) \quad \begin{aligned} aaaaaaaaaaaaaaaaaaaaaaaaaa &= bbbbbbbbbbbb, \\ bbbbbbbbbbbbbbbbbbbbbbbb &= xxxxxx, \end{aligned}$$

$$(1.17b) \quad \begin{aligned} cccc &= yyyyyyy, \\ ddddddd &= zzzzz. \end{aligned}$$

Note the independent labels of the whole group and its parts; writing `\eqref{E:suba}`, we invoke the whole system (1.16), while writing `\eqref{E:suba1}` we refer to (1.16a).

2 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. (2.1)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`:

$$(2.1) \quad \begin{aligned} aaaaaaaaaaaaaaaaaaaaaaaaaa \\ + bbbbbbbbbbbbbbbbbbbbbbbb \\ \leq dddddddddddddddddddddd. \end{aligned}$$

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`:

$$(2.2) \quad \begin{aligned} aaaaaaaaaaaaaaaaaaaaaaaaaa \\ + bbbbbbbbbbbbbbbbbbbbbbbb + dddddddd \\ \qquad \qquad \qquad \times eeeeeeeeeeeeeeeeeeee \\ \leq dddddddddddddddddddddd. \end{aligned}$$

- You can align a group of lines within `multline`, using `aligned` (or `split`, but then you get a warning that `split` will be replaced by `aligned`):

$$(2.3) \quad \begin{aligned} aaaaaaaaaaaaaaaaaa + xxxxxxxxxxxx \\ < bbbbbbbbbbbbbbbbbbbb \\ + dddddddddddddddddddddd \\ < cccccccccccccccc. \end{aligned}$$

- To code an “object” consisting of centred lines within a formula, use `gathered`:

$$(2.4) \quad \text{Pascal}_4 = \begin{array}{c} 1 \\ 1\ 2\ 1 \\ 1\ 3\ 3\ 1 \\ 1\ 4\ 6\ 4\ 1 \end{array}$$

If you want to bottom-align two such objects, apply `gathered[b]`:

$$\begin{array}{cc} & 1 \\ & 1\ 2\ 1 \\ 1\ 2\ 1 & 1\ 3\ 3\ 1 \\ 1\ 3\ 3\ 1 & 1\ 4\ 6\ 4\ 1 \end{array}$$

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

$$\begin{array}{cc} 1 & 1 \\ 1\ 2\ 1 & 1\ 2\ 1 \\ 1\ 3\ 3\ 1 & 1\ 3\ 3\ 1 \\ & 1\ 4\ 6\ 4\ 1 \end{array}$$

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

$$(2.5) \quad \begin{aligned} A = xyzt = ztuv + [f_1(a, b, c, d, e, f, g, h), \\ f_2(a, b, c, d, e, f, g, h), \\ f_3(a, b, c, d, e, f, g, h)] \\ = \text{cccccccccccc} \end{aligned}$$

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

$$\begin{aligned} xxxxxx + [f_1(a, b, c, d, e, f, g, h), \\ f_2(a, b, c, d, e, f, g, h), \\ f_3(a, b, c, d, e, f, g, h)] = \text{tttttttttttttttttttt} \\ = \text{bbbbbbbbbbbbbb} \end{aligned}$$

- `aligned[t]` can also be used, somewhat artificially, when there are no natural places for alignment, but we want to shove a line of `align` to the right:

$$(2.6) \quad \begin{aligned} xxxxx = yyyyyyyyyyyyyy + [eeee \\ \times zzzzzzzzzzzzzzzzzzz] \\ = \text{tttttttttttttttt} \\ = \text{vvvvvvvvvv} \end{aligned}$$

- If you want to place a longer comment in the middle of an aligned construction, you can use `\intertext`:

$$(2.7) \quad \begin{aligned} xxxxx = yyyyyyyyyyyyyy + [eeee \\ \times zzzzzzzzzzzzzzzzzzz] \end{aligned}$$

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

$$\begin{aligned} = \text{tttttttttttttttt} \\ = \text{vvvvvvvvvv} \end{aligned}$$

References

- [1] G. Grätzer, *More Math into L^AT_EX*, 4th ed., Springer, Berlin, 2007.