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{multline}
\text{aaaaa} + \text{bbbbb} \\
\leq \text{ddddd}
\end{multline}

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

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

\begin{equation}
\begin{aligned}
aaaaaaaaaaaaaaaaaaaaaaaaaaa \\
+ bbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbbb + ddddddddddd \\
\times eeeeeeeeeeeeeeeeeeeeee \\
\leq dddddddddddddddddddddd.
\end{aligned}
\end{equation}

• You can align a group of lines within \texttt{multline}, using \texttt{aligned}:

\begin{equation}
\begin{aligned}
aaaaaaaaaaaaaaaaaaa + xxxxxxxxxxxx \\
< bbbbbbbbbbbbbbbbbbbbbbb \\
+ dddddddddddddddddddddd \\
< ccccccccccccccccccc.
\end{aligned}
\end{equation}

• To code an “object” consisting of centred lines within a formula, use \texttt{gathered}:

\begin{equation}
Pascal_4 = \\
\begin{array}{c}
1 \\
1 2 1 \\
1 3 3 1 \\
1 4 6 4 1
\end{array}
\end{equation}

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

\begin{equation}
\begin{array}{c}
1 \\
1 2 1 \\
1 2 1 \\
1 3 3 1 \\
1 3 3 1 \\
1 4 6 4 1
\end{array}
\end{equation}

With \texttt{gathered[t]}, you get top alignment:

\begin{equation}
\begin{array}{c}
1 \\
1 2 1 \\
1 2 1 \\
1 3 3 1 \\
1 3 3 1 \\
1 4 6 4 1
\end{array}
\end{equation}

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

\begin{equation}
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)] \\
= ccccccccccccccc
\end{equation}

or \texttt{aligned[b]} inside \texttt{aligned}:

\begin{equation}
\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)] = tttttttttttttttttttttttt \\
= bbbbbbbbbbbbbbb.
\end{aligned}
\end{equation}
Multiline formulas

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

\begin{align}
xxx &= yyyyyyyyyyyyyyy + [cccc \\
&\quad \times \variegated{zzzzzzzzzzzzzzzz}]

 &= \variegated{ttttttttttttttttttt}

 &= \variegated{vvvvvvvvvvv}.
\end{align}

• 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 \texttt{\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 \texttt{gather}:

\begin{align}
\begin{aligned}
aaaaaaa &= b, \\
cc &= xxx, \\
dd &= yyy,
\end{aligned}
\end{align}

\begin{align}
\begin{aligned}
\variegated{mmmmmmmmmmmmmm} &= 0 \\
&\quad \text{for all } i = 1, \ldots, n.
\end{aligned}
\end{align}

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

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

\begin{align}
\begin{aligned}
aaaaaaa &= b, \\
cc &= xxx, \\
dd &= yyy,
\end{aligned}
\end{align}

\begin{align}
\begin{aligned}
\variegated{mmmmmmmmmmmmmm} &= 0 \\
&\quad \text{for all } i = 1, \ldots, n.
\end{aligned}
\end{align}

(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 \texttt{\hspace{\variegated{\text{gather\star}}}:

\begin{align}
\begin{aligned}
aaaaaaa &= b, \\
cc &= xxx, \\
dd &= yyy,
\end{aligned}
\end{align}

\begin{align}
\begin{aligned}
\variegated{mmmmmmmmmmmmmm} &= 0 \\
&\quad \text{for all } i = 1, \ldots, n.
\end{aligned}
\end{align}

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

\begin{align}
\begin{aligned}
aaaaaaa &= b, \\
cc &= xxx, \\
dd &= yyy,
\end{aligned}
\end{align}

\begin{align}
\begin{aligned}
\variegated{mmmmmmmmmmmmmm} &= 0 \\
&\quad \text{for all } i = 1, \ldots, n.
\end{aligned}
\end{align}
• You can also “gather” several “multiline”, using the subsidiary construct multlined, available in mathtools, with optional parameters indicating the placement of formula numbers and the width of the formulas:

\[
\begin{align*}
\text{aaaaaa} & + \text{bbbbbbbbbbbbbbbbbbbbbbbbbbbbbb} \\
\times \text{yyyyyyyyyyyy} \\
= \text{xxxxxxxxxxxxxxxxxxxxxxxxx},
\end{align*}
\]

(2.5)

\[
\begin{align*}
\text{cccccccccccccccccccccccccccccccccccc} \\
= \text{ddddddddddddddddddddddddddddddddddddd}.
\end{align*}
\]

(2.6)

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

\[
\begin{align}
\text{xxxxx} = & \text{yyyyyyyyyyyyyyyy} \\
& + \text{zzzzzzzzzzzzzzzzzzzz},
\end{align}
\]

(2.7)

\[
\begin{align}
\text{bbb} = & \text{tttttttttttttttttt},
\end{align}
\]

(2.8)

\[
\begin{align}
\text{hh} = & \text{vvvvvvvvvvv}.
\end{align}
\]

(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:

\[
\begin{align}
\text{xxxxx} = & \text{yyyyyyyyyyyyyyyy} \\
& + \text{zzzzzzzzzzzzzzzzzzzz},
\end{align}
\]

(2.10)

\[
\begin{align}
\text{bbb} = & \text{tttttttttttttttttt},
\end{align}
\]

(2.11)

\[
\begin{align}
\text{hh} = & \text{vvvvvvvvvvv}.
\end{align}
\]

(2.12)

• 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):

\[
\begin{align}
\text{aaaaaa} & = \text{bbbbbbbbbbbbbb}, \\
\text{bbbb} & = \text{xxxxx},
\end{align}
\]

(2.11)

\[
\begin{align}
\text{cccc} = & \text{yyyyyyyy},
\end{align}
\]

(2.12)

\[
\begin{align}
\text{dddddd} = & \text{zzzzz}.
\end{align}
\]

(2.13)

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

\[
\begin{align}
\text{aaaaaa} & = \text{bbbbbbbbbbbbbb}, \\
\text{bbbbbbbbbbbbbbbbbbbbbbbb} & = \text{xxxxx},
\end{align}
\]

(2.13)

\[
\begin{align}
\text{cccc} = & \text{yyyyyyyy},
\end{align}
\]

(2.14)

\[
\begin{align}
\text{dddddd} = & \text{zzzzz}.
\end{align}
\]

(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:

\[
\begin{align}
\text{aa} & = \text{bbbbb}, \\
\text{dd} & = \text{ee} \quad \text{(by Lemma 2)},
\end{align}
\]

\[
\begin{align}
\text{hh} & = \text{ii}, \\
\text{ll} & = \text{kkkkk} \quad \text{(by (2.14))}.
\end{align}
\]
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:

\begin{alignat}{2}
\text{(2.15)} & \quad aa = bbbb, & \quad dd = ee \quad \text{(by Lemma 2)}, \\
\text{(2.16)} & \quad hh = ii, & \quad ll = kkkkkk \quad \text{(by (2.14))}.
\end{alignat}

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

\begin{alignedat}{2}
\text{(2.17)} & \quad aa = bbbb, & \quad dd = ee \quad \text{(by Lemma 2)}, \\
& \quad hh = ii, & \quad ll = kkkkkk \quad \text{(by (2.14))}.
\end{alignedat}

• 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`:

\begin{alignat}{2}
\text{(2.18a)} & \quad aa = bbbb, & \quad dd = ee \quad \text{(by Lemma 2)}, \\
\text{(2.18b)} & \quad hh = ii, & \quad ll = kkkkkk \quad \text{(by (2.14))}.
\end{alignat}

or `gather` inside `subequations`:

\begin{alignat}{2}
\text{(2.19a)} & \quad aaaaaaaaaaaaaaaaaaaa = bbbbbbbbbbbbb, \\
& \quad bbbbbbbbbbbbbbbbb = xxxxx, \\
& \quad cccccc = yyyy, \\
& \quad ddddddd = zzzzz.
\end{alignat}

Note the independent labels of the whole group and its parts; writing \texttt{eqref{E:suba}}, we invoke the whole system (2.18), while writing \texttt{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 \texttt{\intertext} (this only works within `align` or `align*`, but not with `aligned`):

\begin{alignat}{2}
\text{(2.20)} & \quad xxxx = yyyyyyyyyyyyy + [eeee} \\
& \quad \times \text{xxxxxxxxxxxxxxxxxxxxx}] \\
\text{(note that we have not used the full strength of (H) here, but only the concavity of f)} \\
& \quad = ttttttttttttt \\
& \quad = vvvvvvvvv.
\end{alignat}

References