How to Typeset Long Formulas

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Hello Real Analysis students! This is your grader speaking. Since I'll be grading and offering constructive criticism on your assignments, I figure I should also assume some responsibility for making sure that you get the right pointers on how to make your homework look as professional as possible. There are lots of guides online that you can use to research how to make LaTeX do all sorts of things, and to be perfectly honest I think doing your own research is the best way to find a lot of stuff out. However, there were some things that required some digging when I was learning LaTeX, and I'd rather tell you straight off how to do certain things so you don't tear your hair out like me. To that end, I have written this little guide on how to write LaTeX code to show a long formula.

What I mean by "long formula" is the type of thing that reads as follows.

$$\begin{aligned}
\frac{d}{dx}\tan x &= \frac{d}{dx}\left(\frac{\sin x}{\cos x}\right) \\
&= \frac{\cos x \times \frac{d}{dx}\sin x - \sin x \times \frac{d}{dx}\cos x}{\cos^2 x} \\
&= \frac{\cos x \times \cos x - \sin x \times (-\sin x)}{\cos^2 x} \\
&= \frac{\cos^2 x + \sin^2 x}{\cos^2 x} \\
&= \frac{1}{\cos^2 x} \\
&= \sec^2 x.
\end{aligned}$$

The important thing here is that the progression of the formula is clearly shown line by line. This is done using the ***align**** environment (the asterisk is intentional and is part of the title of the environment). When this environment is used, the result looks *much* neater than the same thing done in normal display math. Below I have typeset the same formula step by step, only this time I am using the normal display math environment. (You can easily look up how to access display math mode online.)

$$\frac{d}{dx}\tan x = \frac{d}{dx}\left(\frac{\sin x}{\cos x}\right) = \frac{\cos x \times \frac{d}{dx}\sin x - \sin x \times \frac{d}{dx}\cos x}{\cos^2 x}$$

$$= \frac{\cos x \times \cos x - \sin x \times (-\sin x)}{\cos^2 x} = \frac{\cos^2 x + \sin^2 x}{\cos^2 x} = \frac{1}{\cos^2 x} = \sec^2 x.$$

This is actually with me "helping" the display math environment a little bit by forcing a line break, which is normally not possible in display math mode (I did it by exiting display math mode and then re-entering it). The same formula, when typeset in display math without any "help," looks like this:

$$\frac{d}{dx}\tan x = \frac{d}{dx}\left(\frac{\sin x}{\cos x}\right) = \frac{\cos x \times \frac{d}{dx}\sin x - \sin x \times \frac{d}{dx}\cos x}{\cos^2 x} = \frac{\cos x \times \cos x - \sin x \times (-\sin x)}{\cos^2 x} = \frac{\cos^2 x + \sin^2}{\cos^2 x}$$

Now you see why some "help" was need in order to get this into display math mode - normal display math doesn't even fit on the page! If you're typing just one expression or maybe two connected by a single equals sign, then display math is fine. But if you're trying to show a string of formulas/expressions over many steps, then ***align**** is really more appropriate. One line, cluttered with many equals signs and complicated expressions, is sometimes considered bad manners and can be much more difficult to read than the same thing spread out over several lines.

To be sure, LaTeX is a very versatile package and I'm sure there are as many ways of creating the line-by-line formula evolution above as there are mathematicians. The one that I've come to rest on, though, as I said, is the ***align**** environment. The purpose of this document is to give a primer on how to use this environment to typeset neat-looking things like what we have above. I apologize if this guide is a little hand-holding, but I'm assuming that the reader — like me — is starting out learning LaTeX with no prior computer programming experience.

First, you need to call up the ***align**** environment. There are a bunch of "environments" in LaTeX that are useful for different purposes, and ***align**** is great at getting math to align correctly line-by-line. (The ***align*** environment [without the asterisk] is also good for another slightly different purpose, which I'll cover at the end.) To call up ***align****, type the following line in your code:

```
\begin{align*}
(your code will go here)
```

This tells your typesetting program that you are now entering a mode of layout that precisely aligns things as you want them. After you put in the code for the actual formulas, you will need to tell LaTeX that you are exiting ***align****, so you want to have the following:

```
\begin{align*}
(your code will go here.)
\end{align*}
```

Now comes the fun part, where you actually put in the formulas. We'll start with a really simple example — expanding a binomial raised to a power. Let's

say we want to show $(x+y)^2 = x^2 + 2xy + y^2$, step by step. We'd like the output to look like this:

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

We'll go through this line by line. First, you create the opening and closing for the ***align**** environment:

```
\begin{align*}

\end{align*}
```

Now, the first line is the one that sets the standard for where the future lines will be aligned. This is done by inserting an ampersand (the "&" symbol) right before the character where you want everything to align. Since we want the equals signs to line up, we'll put the ampersand before the equals sign in the first line.

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

To tell the ***align**** environment that you are skipping to the next line, you cannot just hit the Enter key and begin typing a new line. In this environment, you need to tell LaTeX that you are starting a new line by putting in a double backslash, \\.

```
\begin{align*}
(x+y)^2 &= (x+y)(x+y) \\
(the next line will go here)
\end{align*}
```

The ***align**** environment requires exactly one ampersand on each line; the character right after the ampersand in the second line, third line, etc., will be aligned vertically with the character after the ampersand in the first line. Since we want to line up the equals signs, we will put an ampersand right before the equals signs in the subsequent lines:

```
\begin{align*}
(x+y)^2 &= (x+y)(x+y) \\
```

```
&= x^2 + xy + yx + y^2 \\
&= x^2 + xy + xy + y^2 \\
&= x^2 + 2xy + y^2.
\end{align*}
```

This code produces the desired output:

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

The alignment can take place at any point you want; if, for example, for some reason you wanted to align the y^2 on the second line with the equals sign in the first line, you could do it by inserting the ampersand at the appropriate point:

```
\begin{align*}
(x+y)^2 &= (x+y)(x+y) \\
= x^2 + xy + yx + &y^2 \\
&= x^2 + xy + xy + y^2 \\
&= x^2 + 2xy + y^2.
\end{align*}
```

This will, of course, produce some strange-looking output:

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

but if you want to do it, there it is.

Now, a word on the ***align*** environment (without the asterisk). The input for this environment is the same as for ***align****, except now numbers will be inserted on the right-hand side of the page so that each line may be easily referred to later on:

```
\begin{align}
(x+y)^2 &= (x+y)(x+y) \\
```

```
&= x^2 + xy + yx + y^2 \\
&= x^2 + xy + xy + y^2 \\
&= x^2 + 2xy + y^2
\end{align}
```

will produce output that looks like this:

$$\begin{aligned}
(x+y)^2 &= (x+y)(x+y) && (1)\\
&= x^2 + xy + yx + y^2 && (2)\\
&= x^2 + xy + xy + y^2 && (3)\\
&= x^2 + 2xy + y^2. && (4)
\end{aligned}$$

For most purposes the ***align**** environment is more appropriate for typesetting evolution of formulas, but if you want to be able to number the lines of your calculations so as to more easily refer back to them, then drop the asterisk.

OK, that's all for now!