Tutorial 7: Writing mathematics with LaTeX 2ε

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In this tutorial you will see how LaTeX 2ε can be used to produce l♡vely formulae. First, create a LaTeX document and call it `mymath.tex`. Create the title "Writing mathematics with LaTeX 2ε", author, date — well, the usual as seen with the previous tutorials. Begin a numbered section in the document and call it "The basics".

You'll need *The Not So Short Introduction to LaTeX 2ε* at the ready.

1 The basics

LaTeX 2ε can be used to enter formulae *inside text*. For example:

> If x and y are the lengths of the two sides of a right angle triangle that meet at right angle, the length of the other side (the hypotenuse of the triangle) is x^2+y^2.

This is produced by inputting

```
If $x$ and $y$ are the lengths of the two sides of a
right angle triangle that meet at right angle, the
length of the other side (the hypotenuse of the
triangle) is $x^2+y^2$.
```

You see that an in-text mathematical equation is produced by surrounding the formula with the $ sign. Try the above and process to see what you get.

Now try to produce the sentence

> I'll try to produce x^{20}. Is there any problem?

Can you guess what to do? Yes, ... So do it!

The command `$\frac{1}{2}$` produces the fraction $\frac{1}{2}$, but we often prefer to write $1/2$ inside text. This is simply produced with `$1/2$`. `\frac` should be used in *display mode*, i.e. when an equation or formula is written on its own line.

Please, produce the following formula

$$1+\frac{1}{2}+\frac{1}{2^2}+\cdots+\frac{1}{2^{n-1}}=\frac{1-\frac{1}{2^n}}{1-\frac{1}{2}}=2(1-2^{-n})$$

by typing

```
\[
1+\frac{1}{2} +
\frac{1}{2^2} + \cdots + \frac{1}{2^{n-1}} =
\frac{1-\frac{1}{2^n}}{1-\frac{1}{2}}
= 2(1 - 2^{-n})
\]
```

Not working? Be careful with the curly brackets. What is the difference between `\cdots` and `\ldots`?

`\[` and `\]` are shortcuts for `\begin{displaymath}` and `\end{displaymath}`. This environment produces an equation in so-called display mode. The `displaymath` environment is used to create a single *unnumbered* equation centered on a line.

Did you notice how a fraction size is adjusted when this fraction is in the numerator of another one? It is probably better to modify the equation to get:

$$1+\frac{1}{2}+\frac{1}{2^2}+\cdots+\frac{1}{2^{n-1}}=\frac{1-1/2^n}{1-1/2}=2(1-2^{-n})$$

Modify your version and recompile. You can still improve the display by making the brackets bigger in the right hand side of the equation. This is done by using "`\left(`" and "`\right)`" — you can use `\left` and `\right` with other characters, e.g. square brackets, curly brackets. An important constraint is that `\left` and `\right` come in pairs. LaTeX 2_ε calculates the height of the expression between the pairs and fits the brackets to the correct size.

$$1+\frac{1}{2}+\frac{1}{2^2}+\cdots+\frac{1}{2^{n-1}}=\frac{1-1/2^n}{1-1/2}=2\left(1-2^{-n}\right)$$

Did you manage to get that? Isn't that wonderful?! Who wants to go back to using Microsoft Word? ☺

The mode (in text or display) affects the style of equations. For example, type

```
\[
\sum_{i=1}^n \frac{1}{2^i}
= \left(1-\frac{1}{2^n}\right)
\]
```

and process it[1]. Then try this:

```
I include this equation
$\sum_{i=1}^n \frac{1}{2^i}
= \left(1-\frac{1}{2^n}\right)$
in this small sentence.
```

You used the same formula but between $ signs. What do you get? Any observation when comparing with what you got in display mode (the mode of presentation used by LaTeX 2_ε in the `displaymath` environment)?

You can impose the use of display mode style in text by using the `\displaystyle` command.

For example try this:

```
I include this equation
$\displaystyle \sum_{i=1}^n \frac{1}{2^i} =
\left(1-\frac{1}{2^n}\right)$
in this small sentence.
```

[1]The beginning of the formula reads *sum from i equal one to n* and is no different from a loop in a program that adds up things.

This is OK in a one paragraph sentence but what about this:

```
I want to show this equation in display mode.
Are you sure you want to do that? Yes!
Are you really sure? Yes!!
Are you really really sure?
Yes, Yes, Yes, Yes !!!!
How many times should I say it. Yeeeeees!
So be it! The equation is
$\displaystyle \sum_{i=1}^n \frac{1}{2^i}
= \left(1-\frac{1}{2^n}\right)$
and this does not look too good in my opinion
but I warned you you should
not do that! No, no, no, you should not
do that unless you have a very good
reason for doing it.
```

Try it. Do you like it? Yurk! Try again by removing the `\displaystyle`. Isn't that better?

You can also do integrals and products[2]. Try to produce[3]

$$\ln\left(\prod_{i=1}^{n} x_i\right) = \sum_{i=1}^{n} \ln(x_i)$$

and

$$e^{\sum_{i=1}^{n} x_i} = \prod_{i=1}^{n} e^{x_i}$$

2 More on brackets, arrays, subscripts

Remember I told you you could use `\left` and `\right` to create matching pairs of surrounding brackets of the same size. Sometimes you want a single delimiter. For example you may want to write

$$|x| = \begin{cases} x & \text{if } x \geq 0 \\ -x & \text{otherwise} \end{cases}$$

[2] $\prod_{i=1}^{n}$ means compute the product of all elements indexed from $i = 1$ to $i = n$.
[3] You'll need `\ln` and `\prod`. `x_i` produces x_i.

To do so you may want to create an `array`. This is similar to the `tabular` environment but it is in math mode. First let see how we create a matrix.

You may want to try the following

```
\[
\begin{array}{rl}
x & x \ge 0 \\
-x &
\end{array}
\]
```

OK, now let us add the words "if" and "otherwise". How does this look? Probably you get the following

$$\begin{array}{rl} x & if x \geq 0 \\ -x & otherwise \end{array}$$

The problem is that LaTeX 2ε sees the two words as maths. To avoid this problem try to put them in an `mbox`. You should get

$$\begin{array}{rl} x & \text{if} x \geq 0 \\ -x & \text{otherwise} \end{array}$$

You see that the "if" is stuck against the x. To avoid this you can use `if~`; the `~` means a fixed space. The final result should be

$$\begin{array}{rl} x & \text{if } x \geq 0 \\ -x & \text{otherwise} \end{array}$$

You can use `\left\{` and `\right\}` to surround the array with curly brackets to get

$$\left\{ \begin{array}{rl} x & \text{if } x \geq 0 \\ -x & \text{otherwise} \end{array} \right\}$$

If you don't want the right-hand side curly bracket you just replace "`\right\}`" with "`\right.`" — remember that `\left` and `\right` come in pair. To get an invisible delimiter you use "." behind the `\right`. In so doing you get

$$\left\{ \begin{array}{rl} x & \text{if } x \geq 0 \\ -x & \text{otherwise} \end{array} \right.$$

You should now be able to modify your code to obtain the desired result

$$|x| = \left\{ \begin{array}{rl} x & \text{if } x \geq 0 \\ -x & \text{otherwise} \end{array} \right.$$

In this section we have seen a bit more about brackets, but we have also seen the environment `array` that mathematicians use all the time. A two-dimensional array of mathematical symbols/numbers, called a matrix, is usually displayed as follows:

$$\begin{pmatrix} -2 & 3 \\ 1 & -1 \end{pmatrix}$$

The general form of a 2×2 matrix is:

$$(a_{ij}) = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$$

We have seen in the previous section that we could produce superscript by using the caret character (`^`). To produce subscript you use the underscore character. Can you display the general form above? How did I produce "2×2"?

Now, here is the most important question: Can you create a duck face[4]?

3 More on equations

You can produce numbered equations using the `equation` environment.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{1}$$

Can you produce the $\pm$ and the square root? Notice the number automatically put on the right near the margin. If just after the `\begin{equation}` you add a label (command `\label` seen in tutorial 4) then you can refer to the equation using the `\ref` command. So try to refer to equation 1.

You can place several formulae separated by spaces in an equation using `\quad`, `\qquad` to make spaces.

$$x_1 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}, \qquad x_2 = \frac{-b + \sqrt{b^2 - 4ac}}{2a} \tag{2}$$

You can produce equations that are aligned as a block of equations using the `align` environment[5].

[4] You may want to use the `rotating` package.

[5] This environment requires the package `amsmath`. `align` is simpler than `eqnarray` but both environments are not perfect and not as powerful as the `IEEEeqnarray` environment according to the `lshort` guide.

Hereafter is an example of use of `align`

$$C(n) = 1 + \sum_{i=1}^{n-1} C(i) \tag{3}$$

$$C(n-1) = 1 + \sum_{i=1}^{n-2} C(i) \tag{4}$$

Have a look in the `lshort` guide provided in blackboard. By the way how did I get the marginal note on the right? Maybe you'll want to do a little search on that...

lshort
V5.01
p. 62

...Now that you have had a look at the guide you should be able to get rid of the numbering to produce:

$$C(n) = 1 + \sum_{i=1}^{n-1} C(i)$$

$$C(n-1) = 1 + \sum_{i=1}^{n-2} C(i)$$

but you'd better reintroduce the numbering as you want to produce this[6]:

Subtracting equations 4 from equation 3 you get

$$\begin{aligned} C(n) - C(n-1) &= 1 + \sum_{i=1}^{n-1} C(i) - 1 - \sum_{i=1}^{n-2} C(i) \\ &= \cancel{1} + \sum_{i=1}^{n-2} \cancel{C(i)} + C(n-1) - \cancel{1} - \sum_{i=1}^{n-2} \cancel{C(i)} = C(n-1) \end{aligned}$$

The equation above is on multiple lines and the LaTeX 2ε guide should tell you how to produce it. You'll have to do a bit of research to know how you can *cancel* terms in equations — The clue is in the name.

After all that: Congratulations! Your are becoming LaTeXperts!

[6] Don't forget you should use `\label` and `\ref`.