WHAT'S THE TITLE OF THIS PAPER?

JOHANNES DOE

ABSTRACT. This paper will be about things. Math things. So many math things. Enough math things that the abstract takes up more than one line. Note that hard returns don't actually affect the output.

Skipping a line, however, creates a new paragraph.

0. PREFACE: GETTING STARTED

If you've never used LaTeX (pronounced *LAY-tech*) before, the best way to get started is to download both the tex and pdf versions of this template. To compile the tex file (i.e. to turn it into a nice-looking pdf file), you have two options: you can either download and install a tex editor and compiler (e.g. MikTex) onto your computer, or you can use Overleaf, a terrific online tex editor. Both of these options are free. I recommend starting with Overleaf, and then (once you get the hang of how things work) trying to download and install a local tex editor / compiler on your computer.

To get started, go to `www.overleaf.com` and create a login (you can use your Williams account to create a Google login). Click on the **New Project** button, and select the option **Blank Project**. Give the project a name (make it a single word, e.g. *template*) and click **Create**. Two side-by-side windows should appear. On the left is the tex file; on the right, the compiled pdf file. Delete all the contents of the tex file, and paste the contents of this tex file there. When you hit the **Recompile** button, a beautiful pdf should appear on the right hand window!

A word of caution about overleaf: it will compile your document even if you have errors in your tex code. Directly to the right of the green Recompile button, there's a little icon the says "Logs and output files" if you hover over it. Usually, there's a little number floating there; this number represents how many complaints the compiler has about your code. If the number is in orange, these complaints aren't too bad and you can safely ignore them. If the number is in red, however, you have a serious error in your code that you need to find and address. If you're unable to find the issue, the TAs and I would be happy to help you.

Read on to get a flavor for how LaTeX works. The best way I know of to learn LaTeX–or indeed, any programming language—is to take a working template (like this one!) and mess

around with it. What happens if you change the spacing between words or between lines—how does that affect the compiled output? What if you remove some of the $ signs below? I encourage you to play around!

Finally, both ChatGPT and `tex.stackexchange.com` are your friends. Whatever tex-related question you have—seek and ye shall find!

1. INTRODUCTION

This is an example of a LaTeX document. Sometimes you want accents on ordinary words, like Zoë, Pólya, Erdős, L'Hôpital. Other times you might want some Greek letters, like α, β, γ, etc. There are other alphabets available, too, like $\aleph$, $\beth$, $\gimel$. There are also various useful fonts: $\mathbb{R}$ versus $\mathcal{R}$ versus $\mathfrak{R}$. Because they're used so frequently, I created shortcuts for some common symbols:

Symbol	Formal command	Shortcut
$\mathbb{Z}$	`$\mathbb{Z}$`	`$\Z$`
$\mathbb{Q}$	`$\mathbb{Q}$`	`$\Q$`
$\vdots$	$\vdots$	$\vdots$
$\mathcal{A}$	`$\mathbb{Ac}$`	`$\Ac$`
$\mathcal{B}$	`$\mathbb{Bc}$`	`$\Bc$`
$\vdots$	$\vdots$	$\vdots$
α	`$\alpha$`	`$\a$`
β	`$\beta$`	`$\b$`
$\vdots$	$\vdots$	$\vdots$
$\widehat{X}$	`$\widehat{X}$`	`$\wh{X}$`
$\overline{X}$	`$\overline{X}$`	`$\bar{X}$`

Perhaps you want to *emphasize some text* in italics? Or to **bold it**? Or underline it? Or ~~cross it out~~? There are plenty of other things you can do as well.

Note that all the non-Latin letters are written in between dollar signs. This is also how you write some math within a line of text, like $\chi \pmod q$ or the completion $(\hat{X}, \hat{d})$ of the metric space (X, d). Note that between dollar signs, LaTeX will ignore all spaces, and will treat all letters as variables—unless you specify a special function using a backslash. To see this in action, compare $sinlogx$ and $\sin \log x$. Curly braces { } are also not printed out: they're used to denote the variable of a function. For example, compare $17 \pmod 1 2$ to $17 \pmod{12}$. A different example: $5^1 7$ versus 5^{17}.

Sometimes you have a particularly important bit of math you want to write down, or some math that involves big symbols like integrals or summation signs. In such cases it's best to separate the math from the text, to make it jump out at the reader. We discuss this in the

next section. Note that the sections are labelled[1], which allows me to refer to them; this is the end of Section 1, and we're about to launch into Section 2.

It's worth pointing out that LaTeX does the spacing, line-breaking, and page-spacing for you. This is usually very useful, but occasionally annoying (you might wish to format things differently than LaTeX does!). My advice: on a first pass, don't worry about the formatting and let LaTeX handle it. At the end, if you choose to format something differently, I (or a TA) can help you with that.

2. FORMATTING EQUATIONS

Sometimes you want to highlight a mathematical statement by having it appear on its own line, separated from the rest of the text. There are a few way to do this. Here's one:

$$\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}. \tag{2.1}$$

In this case, the equation is numbered automatically by LaTeX, and you can refer to the equation by simply writing `\eqref{name-of-equation}`, which will produce the appropriate output, in this case (2.1). The major advantage of using `\eqref{}` rather than simply writing (2.1) yourself is that if you make edits, the equation numbers might all change. By using the `\eqref{}` command, LaTeX will automatically produce the most up-to-date name of the equation.

Sometimes you want an equation to have a special name, rather than a number. This is done using the `\tag{}` command:

$$\sum_{n=1}^{\infty} \frac{1}{n^4} = \frac{\pi^4}{90}. \tag{♣}$$

Whatever symbol you put in the tag command (I put ♣, but common ones are †, ‡, or ∗) will be the name of that equation. You can still refer back to the equation using the same command as earlier, producing (♣).

Most often, though, you don't need a label for the equation—you just want to state it once, but you never need to refer to it again. In this case, simply sandwich your math code between `\[` and `\]`:

$$\gamma := \lim_{N \to \infty} \left(\sum_{n=1}^{N} \frac{1}{n} - \log N \right)$$

Note that you can also put text and spacing into these math environments, like so:

$$\text{Is} \quad \gamma := \lim_{N \to \infty} \left(\sum_{n=1}^{N} \frac{1}{n} - \log N \right) \quad \text{a rational number?}$$

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[1]Sometimes when you refer to something, LaTeX will produce **??** rather than the proper reference. This could mean you have a typo in your reference, but sometimes it simply means you have to compile your document one more time; references are only put in place upon a second compile.

Sometimes you might wish to put a limit or a sum within the text, rather than having it jump out as a displayed equation. For example, you might write $\lim_{n\to\infty} a_n = 4$. If you prefer the subscript underneath the limit symbol, you can use the `\limits` command: $\lim\limits_{n\to\infty} a_n = 4$.

This also works for sums and products, e.g. $\sum_{n=1}^{\infty} \frac{1}{n^2}$ versus $\sum\limits_{n=1}^{\infty} \frac{1}{n^2}$.

3. Multiline equations

Sometimes you need to align two equations, or parts of an equation. If you want to define something piecewise, the best environment to use is `cases`, like so:

$$f(x) := \begin{cases} 1 & \text{if } x \in \mathbb{Q} \\ 0 & \text{otherwise.} \end{cases}$$

Sometimes you need to align two mathematical statements, for example when describing a function. This can be efficiently done using the `split` environment:

$$\begin{split} f : \mathbb{R} &\longrightarrow \mathbb{R} \\ x &\longmapsto x^2 \end{split}$$

Note that the `\\` is used to indicate a line break, and the `&` is used for the alignment. You should play around with placement of one of the ampersands to get a better feel for this.

While we're on the subject of functions, you might need a few other types of arrows. The command `\hookrightarrow` creates the injection arrow: $A \hookrightarrow B$. The command `\surjectarrow` creates the surjection arrow: $A \twoheadrightarrow B$. The command `\bijectarrow` creates the bijection arrow: $A \hookrightarrow\kern-1.5ex\twoheadrightarrow B$.

If you need to align more than just one position, the `align` (for numbered equations) or `align*` (for unnumbered equations) environments works well:

$$\begin{aligned} u &= \arctan x & dv &= 1\,dx \\ du &= \frac{1}{1+x^2}dx & v &= x. \end{aligned}$$

(Note that the `\,` creates a small space; other spacing in math mode can be achieved using `\;` or `\:` or `\!` (the last example deletes a space) or `\quad` or `\qquad`.)

Finally, sometimes you have a mathematical line that's too long to fit on a single line. In this case, use the `multline` or `multline*` environments:

$$\begin{multlined} a + b + c + d + e + f + g + h + i + j + k+ \\ l + m + n + o + p + q + r + s + t + w + x + y + z \end{multlined}$$

Next we consider theorems and definitions.

4. Theorems and definitions

Here's a theorem:

Theorem 4.1 (Linnik, 1942)**.** *Let N_χ denote the least nonresidue for χ, i.e. the least positive integer n for which $\chi(n) \neq 1$. Then $N_\chi \ll_\epsilon D^\epsilon$.*

Remark. Note that LaTeX uses its own numbering system. As with equations and sections, one can label the theorem and refer to it later, e.g. Theorem 4.1.

The above example shows how to add attributes to a theorem (in the case of Theorem 4.1, to Linnik). Sometimes a theorem has a fancy name that you might wish to use, rather than simple Theorem 5.3 or whatever. Here's an example:

Fundamental Theorem of Algebra. This is a really fundamental theorem. About algebra. It was Gauss' Ph.D. thesis, because Gauss.

Note that the `FTA` environment was defined in the preamble of the tex document (search for FTA and you'll find it). You can create your own environments in the same way!

There are environments other than `theorem` that work in exactly the same way:

Definition (Closure)**.** The closure of a set is a blah blah blah.

Proposition 4.2. *Some cool little result.*

Conjecture 4.3. *A would-be awesome result. If only I could prove it.*

Lemma 4.4. *A workhorse theorem: useful, but not that interesting on its own.*

Corollary 4.5. *This follows easily from the lemma.*

To write proofs, use the `proof` environment:

Theorem 4.6. *I claim that I claim things.*

Proof. Consider the following proof. It's proved. □

Remark. Note that the qed symbol is placed automatically at the end. If your proof ends in an equation, the qed symbol will be placed in an odd position. To fix this, use the `\qedhere` command, as illustrated below:

Proof of Theorem 4.1. Let

$$G_k(\eta) := \{n \leq \eta x : P^+(n) \leq x^{1/k}\} \qquad \text{and} \qquad H_k(\eta) := \{n \leq \eta x : P^-(n) > x^{1/k}\},$$

where $P^\pm(n)$ denote the greatest and least prime divisors of n. Then

$$\sum_{n \in G_k(\eta)} \frac{a(n)f(n\theta)}{n} = \sum_{n \leq \eta x} \frac{a(n)f(n\theta)}{n} - \sum_{r \in H_k(\eta)} \frac{a(r)}{r} \sum_{m \in G_k(\eta/r)} \frac{a(m)f(mr\theta)}{m}.$$

It follows that

$$\left| \sum_{n \in G_k(\eta)} \frac{a(n)f(n\theta)}{n} \right| \leq M + \left(\sum_{r \in H_k(\eta)} \frac{1}{r} \right) \cdot \max_{\substack{r \in H_k(\eta) \\ \theta \in [0,1]}} \left| \sum_{n \in G_k(\eta/r)} \frac{a(n)f(n\theta)}{n} \right|. \qquad \square$$

5. Lists

Sometimes you want to make a list. The simplest version of this is the `itemize` environment:

- First item on the list.
- Oh, I guess there's a second one, too.

Sometimes you want to number the items in your list:

(1) Hello?
(2) Goodbye.

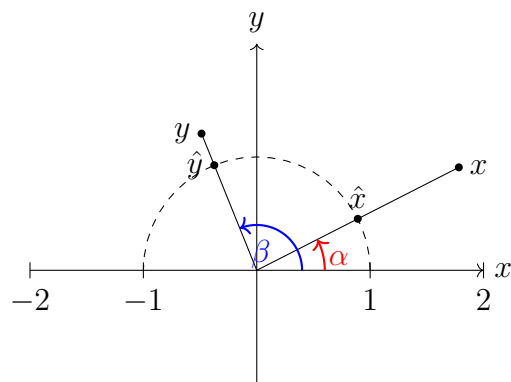Or you might want to number in a fancy way, say for the 4th problem set:

4.1 Fancy
4.2 Shmancy.

Or use Roman numerals:

(i) Blah.
(ii) Bleh.

6. Coloring and drawing

If you want to draw pictures, I strongly suggest using TikZ. There's terrific documentation online, but just for a flavor, here's a sample of what this looks like:

An illustration of a proof from linear algebra

If you want to write in color, the `\color{}` command works well. However, you need extra braces around the phrase you wish to be colored.

7. Citations and references

Here's a sample of how to create references. There are articles you might refer to, for example the one by Pólya [2]. Or maybe the classic text by Serre [3].

References

[1] Yu. V. Linnik, *On representing large integers with positive definite ternary quadratic forms*, Izv. Akad. Nauk CCCP **4** (1940), 363–402.

[2] G. Pólya, *Über die Verteilung der quadratischen Reste und Nichtreste*, Göttingen Nachrichten (1918), 21–29.

[3] J.-P. Serre, *A course in arithmetic*, Graduate Texts in Mathematics, Vol. 7, Springer Verlag, 1973.