Work through this sheet very carefully.
Submit the file `sheet1.tex` *onto Canvas by 1PM.*

This week we will be exploring how to typeset a mathematical document using LaTeX. The best book on LaTeX in my opinion is the *Not-so-short* (NSS) guide by Tobias Oetiker

`http://tobi.oetiker.ch/lshort/lshort.pdf`

(Open it and have a quick browse.) LaTeX takes practice and it is essential that you spend time with LaTeX outside this lab. For installation instructions (it's free), see

`http://www.howtotex.com/howto`

On your PC, open a programme called *Texmaker*. Click on *File >> New*. You will see a cursor in a window where you'll be doing all the typing. This is called the *"tex file"* or *"script"* or *"source file"* .

LaTeX is not like MS Word - what you see is *NOT* what you get. LaTeX is a bit like a computer code, in the sense that the tex file is the code, and if that runs ("*compiled*" or "*typeset*") correctly, it produces a pdf output. If there's an error in the source code, it will produce no output at all! so be very careful.

1. Hello world! (again). In the blank tex file, type in the following:

```
1  \documentclass{article}
2  \begin{document}
3  Hello world!
4  \end{document}
```

Now save this file as `sheet1.tex` in a new folder called `LaTeX` on your G: drive (create it if necessary). Then click the arrow button next to *Quick Build* to "run" or "typeset" the tex file in to a pdf file (or just hit F1). You should now see a page with only "Hello world!" on it. (The first time might take a while, don't worry.)

Here's a line-by-line analysis of the script.

Line 1: This specifies the type of document you're trying to type. LaTeX will try to come up with an appropriate format. Apart from `article`, there are also `report, letter, book` *etc.*

Line 2: This marks where the visible part of your document begins.

Line 3: Insert your content here.

Line 4: This ends the document. LaTeX ignores whatever comes after this command.

Curly brackets {} and reverse backslash \ are very important in LaTeX. They are used exclusively in LaTeX commands, so get ready to use them A LOT. There are many more such reserved characters and we shall meet them shortly.

▶ **TASK 1**: Add more text (nothing mathematical yet) and typeset again to see the changes reflected in the pdf file. Get used to this two-window routine.

How can we start a new paragraph in LaTeX?

2. Math$. Dollar signs are used to evoke LaTeX's maths mode. Add the following lines to your tex file (don't need to delete anything). Of course make sure it comes before \end{document}.

```
My favourite equation is $E=mc^2$.

Actually, it's $e^{\pi i}+1=0.$
```

Note that we use $ like a bracket around an equation.

☐ Check what happens if you omit the dollar signs.

You will see that LaTeX complains there's been an error (and tells you exactly which lines are problematic). Superscripts, subscripts, Greek letters (\alpha, \beta...) and maths operations (*e.g.* \sqrt) won't work outside dollar signs.

Note in the last line that we used {} as a pair of invisible brackets for the multi-character superscripts. The same idea works with subscripts (using underscore). For example, try adding the following line and typeset.

```
$b_8, b^{-2}, a^3, a_{11}, c_0^{20}$
```

☐ Check what happens if you had typed a_11 instead of a_{11}. Can you understand why this happens?

▶ **TASK 2**: Add the following sentences to your pdf file. (If you still don't know your Greek alphabets, see the NSS guide, page 75.)

The Golden Ratio is the solution of the equation $\phi^2 = \phi + 1$. Remarkably, $\phi^{1/2}$ is approximately $4/\pi$.

3. Equations. The previous task dealt with the so-called *inline* method of maths display. But sometimes we want to display an equation prominently on its own. To do this, we enclose the equation to be displayed on its own line with \[and \]. For example, try adding this to your tex file.

```
Euler's identity states that
\[ e^{i\theta}=\cos\theta+i \sin\theta. \]
```

Remember to punctuate these equations with either , or . where necessary, just like regular sentences[a].

☐ We have just used standard LaTeX functions, `\sin` and `\cos`. Now check what happens if you omit the backslashes in front of the sin and cos. Can you spot the difference?

You should see a rather odd output. Here LaTeX interprets *cos* as variables *c*, *o* and *s* next to one another. The spacing looks strange.

For examples of common maths functions, see the NSS guide, pages 58–60. For mathematical symbols, see pages 75–82.

Don't worry, you won't need to memorise all these commands! In Texmaker, many symbols and functions can be found when you click the buttons along the left-hand edge of the screen – clicking them will save you some time.

☐ Check out where these shortcut buttons are. Try them out.
☐ Do a quick browse through the above pages in the NSS guide.

▶ **TASK 3**: Add the following paragraphs to your pdf file. Note the punctuations.

The Golden Ratio is a solution to the equation

$$\phi^2 = \phi + 1.$$

Not many people know that

$$\phi = 2\cos(\pi/5),$$

and, remarkably,

$$\sqrt{\phi} \approx 4/\pi.$$

By now you should notice that LaTeX ignores your attempt to put in extra spaces (using the space bar or the Enter button). This loss of control is often most difficult for beginners to get over. But keep in mind that LaTeX takes care of formatting automatically - this means we just have to concentrate on the content.

It is possible to tweak how LaTeX handles formatting. For example, to stop LaTeX from automatically indenting each new paragraph, insert the following line just above `\begin{document}`

$$\texttt{\textbackslash setlength\{\textbackslash parindent\}\{0pt\}}$$

More tweaks to come later.

---

[a]Some LaTeX veterans will insist on using the double-dollar signs $$...$$ instead of \[...\]. This is an obsolete command that won't be able to handle many new LaTeX functionalities. Don't use it.

4. Fractions. All fractions live in maths mode, either $\$...\$$ or $\backslash[...\backslash]$ (they appear slightly differently). Add the following to your tex file and typeset.

```
The sequence $\frac{1}{3}, \frac{2}{5}, \frac{3}{7}\ldots$ can be
represented as
\[ \frac{n}{2n+1}, \]
where $n=1, 2, 3\ldots$
```

Note: the command `\ldots` reads L-DOTS. (L stands for lower). Also note:

- Each fraction command `{\frac}` must be followed by *two* sets of curly braces[b].
- The fractions you get using $\$...\$$ is smaller than that using $\backslash[...\backslash]$[c].
- `\ldots` has a wider spacing (...) than manually putting in 3 dots like this (...). This is the level of detail and professional typesetting we're dealing with here!

▶ **TASK 4**: Add the following paragraph to your pdf file.

The solution of $ax^2 + bx + c = 0$ (where $a \neq 0$) is given by

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

5. Packages. LaTeX has many free "add-ons" which can be loaded to enhance its capability (*e.g.* colour texts, graphics, fancy layouts). These are called *packages.*

Many packages already come with the huge file that you would have to download when installing LaTeX. One such package is the `amssymb` package (`ams` stands for the American Mathematical Society). To "load" it, simply include the following line just below `\documentclass`.

```
\usepackage{amssymb}
```

The package is now loaded. This allows you to typeset many (strange) maths symbols (on page 79–82 of the NSS guide).

One nice thing `amssymb` allows us to do is to type things like $\mathbb{N}, \mathbb{Z}, \mathbb{C}, \mathbb{Q}$ (this font is called *Blackboard Bold*). Try modifying the equation you typed in the previous question to:

```
\[ \frac{n}{2n+1}, n\in\mathbb{N}.\]
```

Text inside `\mathbb{}` will be typed in Blackboard Bold. If you didn't load `amssymb`, LaTeX will complain that it doesn't understand what `\mathbb` means.

---

[b]There is also an obsolete command `{a \over b}` which works but might produce a warning.
[c]To get big inline fractions, use `\dfrac` instead. This requires the `amsmath` package to be loaded.

▶ **TASK 5**: Add the following paragraph to your pdf file (the symbol | is on your keyboard, above the backslash \).

For $z_1, z_2 \in \mathbb{C}$, we have the Triangle Inequality:

$$|z_1 + z_2| \leq |z_1| + |z_2|.$$

At this point, you might start to worry about the spacing between paragraph. If you'd like a blank line between paragraphs, try loading the package `parskip`.

6. Calculus. Here are some familiar bits of maths from your Calculus course, and how to typeset them. Add these equations to your tex file. Typeset and play with them.

☐ Limits – `\lim`.

```
\[ \lim_{x\to 0}\frac{\sin x}{x} = 1. \]
```

A common mistake is to type `\sinx` instead of `\sin x`. Note that `\sinx` gives an error because it's interpreted as s single command (which doesn't exist).

☐ Summation – `\sum`.

```
\[ \sum_{n=1}^\infty \frac{1}{n^2} = \frac{\pi^2}{6}.\]
```

Note that `\sum` can have both a superscript and a subscript.

☐ Integral – `\int`.

```
\[ \int_1^{10} \frac{dx}{x} = \ln 10. \]
```

☐ Derivative (typed as a fraction).

```
The product rule says
\[ \frac{d(fg)}{dx} = f \frac{dg}{dx} + g \frac{df}{dx}.\]
In shorthand, we can write
\[ (fg)^\prime = fg^\prime + gf^\prime.\]
```

Don't forget the ^ in front of each `\prime` (yes it's a bit weird).

▶ **TASK 6**: Add the following paragraph to your pdf file.

The derivative of a function, f, at $x = a$, is defined as

$$f'(a) = \lim_{x \to a} \frac{f(x) - f(a)}{x - a}.$$

The derivative and the integral are related by the Fundamental Theorem of Calculus, which states that

$$\frac{d}{dx} \int_a^x f(t)dt = f(x).$$

7. <u>Fonts.</u> LaTeX uses a distinctive font (called *Computer Modern*) which, in my opinion, is prettier than anything in Word. There is a way to change the font, but it's not standard practice to do so (remember we're supposed to focus on the *content*).

For now, let's try to change the style of this standard font to **boldface** or *italic.* To do this, just put the required text into `\textbf{}` or `\textit{}`. For example, try:

```
\textbf{Definition.} A function is said to be \textit{bijective} if
it is injective and surjective.
```

To underline some texts, use the command `\underline{}`.

At this point, you might be worried about how much typing there is to do to perform simple tasks. Don't worry – every LaTeX user will have a list of personalised shortcuts, or *macros*, that will cut down a lot of typing. More about this in the coming weeks.

▶ **TASK 7**: Modify the paragraph in the previous task to the following.

The *derivative* of a function, f, at $x = a$, is defined as

$$f'(a) = \lim_{x \to a} \frac{f(x) - f(a)}{x - a}.$$

The derivative and the integral are related by the **Fundamental Theorem of Calculus**, which states that

$$\frac{d}{dx} \int_a^x f(t)dt = f(x).$$

Unfortunately, many students remember this as

$$\frac{d}{dx} \int_a^x f(t)dt = f(x) - f(a),$$

which is <u>definitely</u> wrong.
See Bartle and Sherbert page 218.

8. <u>Final edit.</u> You might sometimes change your mind about some bits of text. Instead of deleting entire paragraphs, sometimes it's better to *"comment out"* those bits just in case they may be useful later. This is similar to the way we inserted comments in MATLAB with the symbol %. The annotation symbol % also works in LaTeX.

For example, inserting % just in front of the last line in the previous task will make it vanish from the pdf.

```
% See Bartle and Sherbert page 218.
```

Alternatively, cut and paste all the unwanted (but potentially useful) stuff and dump it after `\end{document}`, in case you might want to retrieve them later.

▶ **TASK 8**: Go to your tex file and edit it down (delete, comment, or dump) until the output resembles the next page. In the final paragraph, insert an interesting mathematical theorem to demonstrate your LaTeX skills. Be adventurous.

Submit `sheet1.tex` onto *Canvas* (*Assignments >> LaTeX worksheet I*).
Only submit the tex file. Do not submit the pdf, log or aux file!

Hello world! This is a maths document created by [*insert your name*].

The Golden Ratio is a solution to the equation

$$\phi^2 = \phi + 1.$$

Not many people know that

$$\phi = 2\cos(\pi/5),$$

and, remarkably,

$$\sqrt{\phi} \approx 4/\pi.$$

The solution of $ax^2 + bx + c = 0$ (where $a \neq 0$) is given by

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

For $z_1, z_2 \in \mathbb{C}$, we have the Triangle Inequality:

$$|z_1 + z_2| \leq |z_1| + |z_2|.$$

The *derivative* of a function, f, at $x = a$, is defined as

$$f'(a) = \lim_{x \to a} \frac{f(x) - f(a)}{x - a}.$$

The derivative and the integral are related by the **Fundamental Theorem of Calculus**, which states that

$$\frac{d}{dx} \int_a^x f(t)dt = f(x).$$

Unfortunately, many students remember this as

$$\frac{d}{dx} \int_a^x f(t)dt = f(x) - f(a),$$

which is definitely wrong.

[*Insert an interesting mathematical theorem here to demonstrate your LaTeX skills. The more skills you can show, the more marks you will get. Pythagoras' theorem will not get you very far with this task.*]

Work through this sheet very carefully.
Submit the file `sheet2.tex` *onto Canvas by 3PM.*

Go to *Canvas* ≫ *IUM2016-17* ≫ *Files* ≫ *LaTeX worksheets* and download `sheet2-blank.tex`. Save it as `sheet2.tex` in your LaTeX folder on your G: drive (or your laptop). This week you will be modifying this template.

This is quite a common practice with LaTeX - you work with a template which gets increasingly refined each time you use it. With years of practice, you will end up with your own powerful all-purpose template.

1. <u>The `article` document class.</u> Note how the title, author and date are easily created in a LaTeX article.

   □ Try using % to comment out the `\date` command. What happens? Can you think of a way to completely remove the date from the heading?

   ▶ **TASK 1**: Put your name in the `author` field. Completely remove the date.

2. <u>Environments.</u> An environment is a structure of the form
   $$\begin{array}{l} \texttt{\textbackslash begin\{♡♡♡\}} \\ \quad \dots \\ \texttt{\textbackslash end\{♡♡♡\}} \end{array}$$
   where ♡♡♡ is the name of the environment. There are lots of environments in LaTeX. We've already seen one important environment last week: the `document` environment. Can you see it in the tex file?

   Another environment in the template tex file is the `abstract` environment.

   Here's yet another environment: the `itemize` environment. It's used for making lists. Try typing the following in the 'Lists' section.

```
1  There are 3 possibilities
2  \begin{itemize}
3  \item $x>0$
4  \item $x<0$
5  \item $x=0$
6  \end{itemize}
```

   □ Try replacing both instances of `itemize` by `enumerate`. What happens?

   IMPORTANT: For every `\begin`, there must be a matching `\end`.

   ▶ **TASK 2**: Create the list on the next page using the `itemize` and `enumerate` environments.

These are second-year maths modules.

1. Pure maths
   - Linear and abstract algebra
   - Analysis
   - Functions of a complex variable (optional)
2. Applied maths
   - Differential equations
   - Vector calculus
   - Introduction to numerical analysis (optional)
3. Others
   - Statistical inference and methods (optional)
   - Free elective (optional)

3. <u>Aligned equations</u>. Often we need to present equations on several lines. For instance,

$$
\begin{align}
x + y + z &= 1, \tag{1}\\
x - 2y &= 3, \tag{2}\\
x - y + 3z &= 0. \tag{3}
\end{align}
$$

To do this, we need the `align` environment, which is part of the `amsmath` package. So the first step is to load it by including

`\usepackage{amsmath}`

somewhere in the "preamble" (anything that comes before `\begin{document}` is said to be part of the *preamble*). Now the above equations can be typeset as follows:

```
1  \begin{align}
2  x+y+z &= 1,\\
3  x-2y &= 3,\\
4  x-y+3z &= 0.
5  \end{align}
```

Things to note:

- The symbol & is used to mark the position where the equations are to be lined up (in this case we want to line up all the equal signs).
- \\ tells LaTeX to begin a new line.

Note that the equations are automatically labelled. To suppress a certain equation from being numbered, put `\notag` at the end of that equation. For example, see what happens when you modify the previous example to:

```
1  \begin{align}
2  x+y+z &= 1,\notag\\
3  x-2y &= 3,\\
4  x-y+3z &= 0.\notag
5  \end{align}
```

To turn off *all* numbering, use `\begin{align*}` and `\end{align*}` instead.

In general, when numbered things are starred*, the numbering is suppressed (so you can have `section*`, `figure*` *etc.*).

Sometimes you might want to manually name some equations with special symbols like (∗) or (†). To do this, use the command `\tag{}`, as follows.

```
1  \begin{align*}
2  x+y+z &= 1,\\
3  x-2y &= 3,\tag{$*$}\\
4  x-y+3z &= 0.
5  \end{align*}
```

Note that within the `\tag` function, the maths mode is turned off. If you didn't include the dollar signs, you'd get (*) instead of (∗).

▶ **TASK 3**: In the template, go to subsection 'The `align` environment' and typeset the following extract.

$$
\begin{aligned}
\frac{d}{dx}(\ln(\sin x)) &= \frac{1}{\sin x}\frac{d}{dx}(\sin x)\\
&= \frac{1}{\sin x}(\cos x)\\
&= \cot x.
\end{aligned}
\tag{$\star$}
$$

4. Cross-referencing. Numbered things in LaTeX can always be referred to automatically using the `\label`, `\eqref` or `\ref` commands. For instance, let's go back to the previous example and modify it as follows:

```
1  \begin{align}
2  x+y+z &= 1, \label{A}\\
3  x-2y &= 3,  \label{B}\\
4  x-y+3z &= 0.
5  \end{align}
```

You should see these equations numbered (1),(2) and (3) as before. The difference is that now we've placed invisible labels at the end of the equations that we want to refer to later. A label can contain any text or number (you could label an equation Rainbow or Unicorn if you wish), but try to use something easy to remember and relevant to the object you're labelling.

Now try adding the following line of text (outside the `align` environment).

```
Adding equations (\ref{A}) and (\ref{B}) gives $2x-y+z=4$.
```

If you see (?) in the output, don't panic - just typeset again. Sometimes you need to typeset twice for LaTeX to pick up all the cross-referencing[a]. .

---
[a] If you're too lazy to type in brackets around each `\ref...`, you could use `\eqref` instead. But this doesn't work for other kinds of objects (*e.g.* sections).

You might ask, what's the point of cross-referencing? Why don't we just type the equation numbers manually?

Well, imagine writing a report with lots of numbered equations. As you reorganise and shuffle your equations around, or add/delete equations in between, you can imagine that all the equation numbers will change constantly. With the `\label`-`\ref` system, all changes are updated automatically. Same goes for chapter numbers, sections, figures *etc.*

▶ **TASK 4**: In the subsection 'Cross-referencing', typeset the extract in the box below. Make sure you use `\label` and `\ref`.

Here are the three families of *conic sections*.

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1. \tag{4}$$

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1. \tag{5}$$

$$y^2 = 4ax. \tag{6}$$

Equation (4) represents an **ellipse**, (5) represents a pair of **hyperbolae**, and (6) represents a **parabola**.

Every numbered thing in LaTeX can be labelled, including equation, section, subsections, figure, chapter, and even page number. All you do is attach a label using `\label`, and refer to it using `\ref`.

For example, to label the first section in our article, go to the line `\section{Lists}` and put the label at the end, like so:

```
\section{Lists}\label{lists}
```

And now try adding the following line just above it.

```
We discuss lists in Section \ref{lists}.
```

▶ **TASK 5**: Add labels to all the sections and subsections so far. Then, insert the following paragraph just above the section 'Lists' . Use `\ref` instead of typing in the numbers manually. Don't cheat or you'll regret it later! [Hint: use `\S` for the section symbol §.]

We discuss lists in Section 1. Section 2 covers aligned equations, including the `align` environment (§2.1) and cross-referencing (§2.2).

5. <u>Brackets.</u> In the section 'Brackets', try to typeset this expression.

$$\left(\frac{1}{x-2} \right)$$

You may find that your brackets aren't quite big enough. LaTeX can automatically adjust the bracket size to match the content, like so:

```
\[ \left( \frac{1}{x-2} \right) \]
```

You should now obtain the output shown above. The `\left` and `\right` also work in the same way with $[\ldots]$ and $|\ldots|$.

□ Try producing $\left[\dfrac{1}{x-2} \right]$ and $\left| \dfrac{1}{x-2} \right|$.

Even with the auto-resizing, sometimes it is necessary to specify the size of brackets by hand, for example, when only one side of the bracket is needed (LaTeX won't typeset if it finds a `\left` without a matching `\right`), or when an exaggerated effect is desired. LaTeX has five sizes of brackets to choose from. Try this example:

```
Here are the 5 sizes of brackets: $( \big( \Big( \bigg( \Bigg($
```

For a complete list of brackets (aka. *delimiters*) see page 78 of the NSS guide.

▶ **TASK 6**: Typeset the following working. Use `\left` and `\right` where necessary.

$$\int \frac{4}{x^2-4} dx = \int \left(\frac{-1}{x+2} + \frac{1}{x-2} \right) dx$$
$$= -\ln|x+2| + \ln|x-2|$$
$$= \ln\left| \frac{x-2}{x+2} \right| + C.$$

6. <u>Adding text in equations.</u> We might want the occasional text to justify certain steps. For example,

$$\int \ln x \, dx = x \ln x - \int 1 \, dx \quad \text{(by parts)}$$

The above equation can be typeset as follows (try it).

```
\[ \int\ln x\,dx = x\ln x - \int 1\,dx \quad\text{(by parts)} \]
```

- I have added `\,` to insert a tiny space in front of dx.
- The `\quad` command[b] skips a horizontal space roughly equal to that of an 'M'. `\qquad` gives double that space.

---

[b]From the Italian typography term *quadratone* (big square).

- Text within an equation can be inserted using the `\text{}` command[c]. If you didn't use `\text`, your text will look italic (like variables) with no spacing (try removing `\text` to see the awful result).

For reference, I've included a list of commands for adjusting horizontal and vertical space on the last page. Avoid overusing these commands – try to let LaTeX do the formatting work for you as much as possible. Remember:

Don't treat LaTeX like Microsoft Word.

▶ **TASK 7**: Modify your answer in the previous task to produce the following extract.

$$\int_0^1 \frac{4}{x^2 - 4}\, dx = \int_0^1 \left(\frac{-1}{x + 2} + \frac{1}{x - 2} \right)\, dx \quad \text{(by partial fractions)}$$

$$= \left[-\ln|x + 2| + \ln|x - 2| \right]_0^1$$

$$= \left[\ln\left|\frac{x - 2}{x + 2}\right| \right]_0^1$$

$$= \ln(1/3).$$

▶ **TASK 8**: Edit your tex file so that the output resembles the file `sheet2-model.pdf` on Canvas. Don't worry if your spacing is slightly different.

As in last week's assignment, comment unwanted lines out with % (or dump them behind `\end{document}`) instead of deleting them.

In the final section called "Example problem", type out a specific example for **one** of the following problems.

(a) Differentiate something interesting, OR

(b) Integrate something interesting, OR

(c) Evaluate an interesting limit.

Imagine you're writing this as a model solution for A-level students, so present your solution step-by-step and include justifications where appropriate. Try to demonstrate your LaTeX skills as much as possible. An easy, boring example will not get you a high score.

Submit the final `sheet2.tex` onto *Canvas* (*Assignments* ≫ *LaTeX worksheet II*).

Submit only the tex file. Do not submit the pdf file!

---

[c]The `\text{}` command is part of the `amsmath` package.

Appendix: Space adjustment

Occasionally you might disagree with LaTeX's choice of spacing or placement of things. Use these commands sparingly. Don't treat LaTeX like Word.

Horizontal space

Command	Result
`a|b`	$a|b$
`a\,|b`	$a\ |b$
`a\:|b`	$a\ |b$
`a\;|b`	$a\ |b$
`a\quad |b`	$a\quad|b$
`a\qquad |b`	$a\qquad|b$
`a\hspace{2 cm}|b`	$a\hspace{2cm}|b$
`a\hspace{1.5 in}|b`	$a\hspace{3cm}|b$

I normally use `\,` to skip a single space, especially in integrals.

Apart from `cm` and `in`, see page 130 of the NSS guide for other possible units in LaTeX.

Vertical space

- **New line:** `\\` or `\newline`

- **New page:** `\newpage`

- **Vertical space:** Use `\vspace{}` in a similar way to `\hspace{}`. If you don't have a number in mind, you can also try one of the following 3 commands:

Command		`\smallskip`	`\medskip`	`\bigskip`
Result	Upstairs Downstairs	Upstairs Downstairs	Upstairs Downstairs	Upstairs Downstairs

- **Flexible spaces:** `\vfill` creates a flexible vertical space that acts like a spring (useful for, say, pushing some text down the bottom of a page). Similarly `\hfill` creates a flexible horizontal space within a line.

Work through this sheet very carefully.
Submit the file `sheet3.tex` and a figure file onto Canvas by 3PM.

On our Canvas page, download `sheet3-blank.tex`, save it as `sheet3.tex`. We will be modifying this template this week. We will also need many concepts from previous sheets.

1. <u>Matrices</u> (and vectors) can be created using the `matrix` environment. Copy the following script into the *Matrices* section and typeset.

```
1  \[
2  \begin{matrix}
3  a & b \\
4  c & d
5  \end{matrix}
6  \]
```

Note:

- The `matrix` environment only works in maths mode (it lives inside \[...\] or an `align` environment - see last week's sheet).
- Enter the matrix row by row. Use & to jump to the next entry. Use \\ to begin a new row. Spaces don't matter. Note that there is no \\ in the last row.

Of course we often want matrices to come with a pair of brackets. Here's how.

☐ In the example above, try changing both instances of `matrix` to `pmatrix` (p for parenthesis).

☐ Try also the `bmatrix, Bmatrix, vmatrix` and `Vmatrix` environments.

(Note that these commands are part of the `amsmath` package which I've preloaded for you in the template.)

▶ **TASK 1**: Typeset the following extract. Note that you need to create new subsections. Copy and paste to speed things up. Replace ♡ with the correct answer for the determinant.

1.1 Vector addition

$$\begin{pmatrix} a_1 \\ b_1 \\ c_1 \end{pmatrix} + \begin{pmatrix} a_2 \\ b_2 \\ c_2 \end{pmatrix} = \begin{pmatrix} a_1 + a_2 \\ b_1 + b_2 \\ c_1 + c_2 \end{pmatrix}.$$

1.2 Matrix determinant

$$\begin{vmatrix} 1 & 2 & 0 \\ 5 & 2 & 1 \\ 2 & 1 & 0 \end{vmatrix} = \heartsuit.$$

1

2. <u>Table.</u> Copy the following script into the *Tables* section of the template.

```
1  \begin{tabular}{c|l}      % that's letter l and not number 1
2  $\mathbb{R}$ & Real numbers\\
3  $\mathbb{C}$ & Complex numbers
4  \end{tabular}
```

Note the following:

- <u>Line 1</u>: The brackets {c|l} specifies that you want two columns: the first column is *centered* (c) and the second column is *left* (l) justified. You could also have a *right* (r) justified column.
  The vertical bar tells LaTeX to draw a vertical line separating the two columns. If you didn't want vertical line, just use {cl} instead. If you want double lines, use {c||l}.

- <u>Lines 2-4</u>: Use & and \\ to fill in the entries in the same way as in matrices.

Now you might want to add a description of each column in the top row. To do this, use \hline to create a horizontal line where needed.

```
1  \begin{tabular}{c|l}
2  Symbol & Description\\
3  \hline
4  $\mathbb{R}$ & Real numbers\\
5  $\mathbb{C}$ & Complex numbers
6  \end{tabular}
```

At the moment, the table we created is sitting on a line like regular text. However, we often want a table to be a special eye-catching centrepiece with no interfering texts around it. In typographical term, this kind of object is called a *float*. The types of float most often used in a scientific article are *tables* and *figures*.

To convert our humble figure into a float, put the entire *tabular* environment in a *table* environment as follows:

```
\begin{table}
\centering
% Insert the tabular environment here
\end{table}
```

Note that \centering simply centres the table horizontally.

LaTeX tries to place the table where it finds most appropriate - this could be the top of the page, or bottom of a page, or on a page of its own if the table is very big.

Don't panic if the positions of tables and figures keep changing as your document grows. That's supposed to happen. Just let LaTeX do its thing[1].

---

[1] It's possible to override LaTeX's decision by putting a *placement specifier* (*e.g.* to force a table or a figure to appear at a specific spot). See page 49 of the NSS guide.

It is good practice to provide a little caption describing what the table is about. To do this, place the following line just above `\end{table}`

```
\caption{Some common sets of numbers.}
```

▶ **TASK 2**: Create the table below.

Symbol	Description	Example
$\mathbb{Z}$	Integers	0
$\mathbb{R}$	Real numbers	π
$\mathbb{C}$	Complex numbers	$\sqrt{-1}$

Table 1: Some common sets of numbers

Note that the table has been automatically numbered. To refer to this table in the text, use `\label` and `\ref` as we did last week.

Remember: You should never type things like this in your tex file:

```
See Table 1, Figure 3, Equation 12
```

You will regret it when you add, delete or reorganise your content, as those numbers will all change! Instead, you should type something like

```
See Table \ref{...}, Figure \ref{...}, Equation \ref{...}
```

where ... are the label names which you can easily associate with those objects.

▶ **TASK 3**: Label the table you created with some helpful name by placing `\label{...}` just above `\end{table}`. Then, insert the following bit of text in the *Tables* section. Use `\ref`.

> Maths is full of numbers. Table 1 shows the set notation for some common types of numbers.

3. <u>Figure.</u> LaTeX can handle many figure formats (pdf, png, jpg, eps...). For this exercise, we will use a pdf figure

Go onto Canvas again and download a file called `compare.pdf`. Make sure you save it in the **same directory** as your tex file, otherwise your figure won't appear!

Now let's include this figure in our tex file. We must first do this.

☐ Load the `graphicx` package with the command `\usepackage{graphicx}` in the preamble.

(When you try to typeset with a package that has not been installed, Texmaker will complain that the package is missing. It will then ask your permission to look for the package from a *"random package repository"* (which is usually `www.ctan.org` or its mirrors). Agree to everything until everything typesets OK!)

Now, in the section *Figures*, include the following script:

```
1  \begin{figure}
2      \centering
3      \includegraphics[width = 4in]{compare.pdf}
4      \caption{Word VS LaTeX. Who's the winner?}
5      \label{figcompare}
6  \end{figure}
```

The syntax for including a figure is very similar to that for a table. Note:

- Line 3: Square brackets are used to enclose *optional* arguments in LaTeX commands. In this case, we can specify the `width`, `height` (in any unit that LaTeX recognises), `scale` (magnification factor) or `angle` (rotation in degree) in the square brackets. Without the square brackets, the figure will appear in the original size.
- □ Try removing the square brackets in line 3 and typeset.
- Line 5: Label the figure in the same way as how we labelled the table.

▶ **TASK 4**: Produce a graph (in pdf) of an interesting function. I recommend using MuPad (startup MATLAB and type `mupad`). For example, to plot $y = \sin(x)$ from $x = 0$ to 2π, type

$$plot(sin(x),x=0..2*PI)$$

Then, right click on the graph and click *Export Graphics* to a pdf file. Save it in the **same directory** as the tex file you're working on. Include the graph in the *Figures* section with a suitable caption and label.

Once that's done, insert the following bit of text in the *Figures* section,

Figure ♡ shows [*insert a brief mathematical discussion of your graph.*]

where ♡ is an automatically generated number. Keep the discussion short - just one or two sentences will do.

4. Macros. Do you ever wish LaTeX commands weren't so long and tedious to type? Well, the good news is, you can make them as short as you like!

Macros are user-defined shorthands (or abbreviations) for long, complicated commands that you use frequently. They will make your life much easier, and your LaTeX experience will be much more enjoyable.

Here's an example. In the section *Macros*, let's try to make the first sentence bold:

A bad maths joke.

Normally, we would use the command `\textbf`, but instead, let's try to to shorten `\textbf` it to, say, `\bb`.

Type in the following line in the preamble (just above `\begin{document}`).

```
\newcommand{\bb}{\textbf}
```

Now we can use our new *macro* (*i.e.* shortcut) anywhere in the document, including

```
\bb{A bad maths joke.}
```

To create your own personalised macro, follow this construction.

$$\newcommand{A}[n]{B}$$

where

- `A` = your macro.
- `n` = number of arguments (optional, hence in square brackets). More on this later.
- `B` = what your macro stands for.

To see exactly how this works, study some of my favourite macros collected over the years on the next page. Try as many of them as you can. I'm confident you'll find some of them very useful for your maths article.

For each type of macro, I have also given ideas for creating your own macros. Note that there is also the command `\def` which is now considered obsolete, but I still use it for a couple of 'hacks' (see the final example in the table).

▶ **TASK 5**: Create at least **two** new macros. Demonstrate how to use them in the *Macros* section. You can comment out or delete the given text in the template.

Try creating macros from different categories in the table. Either try the suggested extension ideas, or create one of your own. Perhaps go over your tex file again and replace any long commands you've used with macros.

Warning: If the name of your macro clashes with one of LaTeX's built-in commands, an error is reported, and you should pick another name[2].

▶ **TASK 6**: Edit your tex file so that it resembles `sheet3-model.pdf` on Canvas. Dont worry if the positions of your figure and table are different from mine.

Submit the following onto Canvas:

- `sheet3.tex`, and
- the pdf file of your graph

---

[2]If you insist on overriding a LaTeX command, replace `\newcommand` with `\renewcommand`. Avoid doing this unless there's a very good reason.

Examples of Macros

Description	Examples, usage and extension ideas
Command abbreviation	Example: `\newcommand{\bb}{\textbf}`
	Usage: `This is \bb{bold}`!
	Try this on: `\textit`, `\texttt`, `\underline`...

Text abbreviation	Examples:
	`\newcommand{\van}{Vandermonde matrix}`
	`\newcommand{\ie}{\textit{i.e.}}`

	Usage: `The \van\ is non-singular, \ie\ it is invertible.` (The extra backslash creates a little space if needed.)
	Try this on: *e.g.*, *et al. etc.*; any long but frequently-used phrases.
Maths stuff	Example: `\newcommand{\R}{\mathbb{R}}`
	Usage: `$x\in\R$`
	Try this on: $\mathbb{Q}, \mathbb{Z}, \lim_{n\to\infty}, f''$.
One-argument macro	Example: `\newcommand{\bkt}[1]{\left( #1 \right)}`
	Usage: `\[ \bkt{\frac{1}{1+x}}^n \]`
	Try this on: $[\ldots]$, $\langle\ldots\rangle$, $\{\ldots\}$
Two-argument macro	Example: `\newcommand{\diff}[2]{\frac{\textrm{d}#1}{\textrm{d}#2}}`
	Usage: `\[ \diff{y}{x} \]` Note: I've used a Roman 'd' instead of italic d.
	Try this on: 2nd derivatives, partial derivatives.
Environment	Example: `\def\ba#1\ea{\begin{align}#1\end{align}}`
	Usage: `\ba x+y=z \ea`
	Try this on: `align*`, `itemize`, `enumerate`, `matrix`.

Submit `sheet4.tex` *and* `myref.bib` *onto Canvas by 3PM.*

This week is all about *referencing* (also known as *citation*).

1. <u>What is citation and and why should we bother?</u> In a piece of scientific writing, a citation normally goes at the end of an important statement that you do not have time to prove or discuss in detail. A citation gives credit where it's due.

   But in the age of Google, why can't we all cite *"the internet"* as the source of all knowledge? Well, the Google era is also the *fake-news* era. There are lots of false information on the internet. Anyone can put anything on a website at any time (including Wikipedia).

   On the other hand, if you want to publish a academic book or a journal paper, your work will have to be read and approved by the editor and expert referees – this is called the 'peer review' process. I am not suggesting that everything that has ever been published in books and journals is true, but at least we can be pretty confident that it unlikely to be complete nonsense.

   So, cite only *published* (peer-reviewed) material as far as possible. This includes books and journal papers. Cite websites only in exceptional circumstances (*e.g.* government agencies, science experiments, data repository, or when crediting electronic images).

2. <u>How do citations look like?</u> A typical **book** citation looks like this.

   > Pears, R. and Shields, G. (2016), *Cite them right: the essential referencing guide*, Palgrave Macmillan.

   The information included are: the authors, year published, book title and the name of the publisher.

   A typical **journal paper** citation looks a bit more mysterious.

   > Chongchitnan, S. (2009), Physical Review D **79**, 4, 043522.

   - *Chongchitnan, S.* is the author.
   - The paper was published in the year 2009.
   - The name of the journal is *Physical Review D*. Often journal names are abbreviated (*e.g.* Phys Rev D).
   - The paper was published in volume 79, issue 4, page 043522. Each journal will have its own (often strange) cataloguing system.

   Depending on the citation style (which we will cover later), the title of the paper is often not shown. The above citation style is called the *Harvard* style.

3. <u>Basic referencing.</u>

▶ **TASK 1**: Go to *Canvas* and open `maths-article-template.tex`. Typeset the article and browse through quickly.

Study the tex file to see how basic referencing is done in LaTeX. Look for where the commands `\cite` occur.

Key points to note in the tex file.

- The `\cite{}` command is used to insert a citation.
- The `thebibliography` environment (towards the end of the file) is where you put the list of references.
- The number 99 tells LaTeX that our list of references will go up to a 2-digit number, and LaTeX will then adjust the margin accordingly (it doesn't matter if you type 99 or any other 2 digit numbers).
  As you're unlikely to have more than 99 references (unless you are writing a review article), it's safe to use 99 as the default option.
- Type in the detail of each reference using the `\bibitem{}` command.
  There is no 'best' style for referencing. Whatever you do, use only one style in your article. Be consistent.
- Give each `\bibitem` a nickname (this works like `\label` from previous weeks). I normally use the first author's last name, but of course you can call each paper anything you like. Remember that these labels are case sensitive.

▶ **TASK 2**: Using `maths-article-template.tex` as inspiration, create a new 'blank' document called `sheet4.tex` (or you can use any 'blank' template from previous weeks). We will work on this file from now on. Add the following two sentences to the text.

A good book on referencing is [♡], available in BJL.

Andrew Wiles published his proof of Fermat's Last Theorem in 1995 [♢].

where ♡ and ♢ should be automatically generated numbers.

For ♡, cite the Pears and Shields book (details on previous page).

For ♢, cite Wiles's famous paper called '*Modular Elliptic Curves and Fermat's Last Theorem*', which you should search for and add as a `\bibitem`. Follow the Harvard style shown on the previous page.

Oh, if you see [?], try to typeset again. If it doesn't go away, you probably have made a mistake in the labelling or the citation.

4. Ordering of references.

☐ In the bibliography, try switching the 2 `\bibitem`'s and typeset at least twice.

You should now see the following.

Andrew Wiles published his proof of Fermat's Last Theorem in 1995 [1].

What happened? Well, the numbering corresponds to the order that the `\bibitem`'s are listed. Here are the two acceptable options for ordering your references.

A. Order the list alphabetically by the first authors' last names.
B. Order the list by the order of appearance in the text.

It is not too hard to do option A manually as you go along. But option B is more difficult to maintain as the text constantly changes. It gets worse when you are writing a long report.

Thankfully, there is a way to sort all this out automatically, using a system called BibTeX (coming up next).

▶ **TASK 3**: Samuel Eilenberg and Saunders Mac Lane wrote a seminal paper in algebra called '*General theory of natural equivalences*'. Search for it and add it as a `\bibitem`.

Now add the following paragraph to your text.

Eilenberg and Mac Lane were the pioneers of *category theory*, an important branch of abstract algebra. Their paper [♡] is generally regarded as *the* seminal work in this field.

(where ♡ represents another automatically generated number.)

▶ **TASK 4**: Load the package hyperref. You should find that everything you `\cite` or `\ref` is now clickable in the PDF. This is a very useful package.

5. BibTeX. This is a cousin of the LaTeX system which deals with references automatically. You don't need to worry about the ordering of `\bibitem`'s. We will simply dump all our references into one file with `.bib` extension. Follow these steps.

☐ Create a new file in TeXmaker with the following content.

```
@book{pears,
        Author = {Pears, R. and Shields, G.},
        Title = {Cite them right: the essential referencing guide},
        Publisher = {Palgrave Macmillan},
        Year = {2016} }
```

Save this file as <u>myref.bib</u> (not **.tex**). The name doesn't matter as long as it has a **.bib** extension. Make sure it's in the same directory as your tex file.

This strange chunk of text contains all the info needed for BibTeX to create a nice bibliography. Although this kind of BibTeX entries are often long and complicated, they can usually be downloaded online (as in the next example).

☐ Comment out the entire `thebibliography` environment (or dump behind `\end{document}`). **Do not delete these entries** as I'll be checking them.

☐ Add these 2 lines at the end of your tex file (before `\end{document}` obviously).

```
\bibliography{myref}              % the name of your .bib file
\bibliographystyle{abbrv}         % the style name
```

The style `abbrv` is one of BibTeX's default styles (more about this later).

☐ Typeset once with the usual Quick Build (or press F1). You should see that all the references in the text appear as question marks. For example,

A good book on referencing is [?], available in BJL.

☐ In TeXmaker, you will see a drop down menu where *Quick Build* is. Choose "BibTeX" and click the arrow (or, equivalently, press F11).

Then do Quick Build *two* more times.

This sequence of *LaTeX-BibTeX-LaTeX-LaTeX* (or F1-F11-F1-F1) will completely link your tex and bib files[1].

You should now see

A good book on referencing is [1], available in BJL.

and the reference section should also appear at the end.

If you're concerned that we see "R. Pears" instead of "Pears, R.", don't worry (there's an easy way to change this later). It's fine as long as our format is consistent throughout the entire list.

You don't always have to type in the chunk of BibTeX info manually (I rarely do). Journal websites and many online repositories (like `arXiv.org`, `jstor.org`) or Google Scholar allow you to 'export' details of references directly into BibTeX format which you can just copy and paste into your bib file.

Let's now try to sort out the paper by Andrew Wiles, which at the moment should still show up as [?]. Follow these steps.

☐ Go to `http://www.jstor.org/stable/2118559`

☐ Click '*Cite this item*', and choose *'Export a Text file (for BibTex)'*.

☐ Copy the entire chunk of BibTeX info and add it into `myref.bib`. The chunk looks roughly like this

```
@article{10.2307/2118559,
....
 year = {1995}
 }
```

---

[1] It's possible to change the setting of Quick Build so that it does all 4 commands in one click.

☐ Replace the long nickname of the article '10.2307/2118559' by whatever name you used earlier to refer to that paper. Save the `.bib` file.

☐ Go back to your tex file and repeat the F1-F11-F1-F1 procedure. You should now see the paper correctly cited in the text.

Not all the info in the BibTeX chunk are needed or displayed. For the `@article` type, the only compulsory fields are `author, title, year, journal`. BibTeX chooses what to display according to the 'style' specified.

Now try BibTeX-ing for yourself.

▶ **TASK 5**: Cite the Eilenberg and Mac Lane paper using BibTeX.

Note that it doesn't matter what order you paste the references into the `.bib` file.

▶ **TASK 6**: Add the following list to your text.

- For a good textbook on Calculus, see [X].
- Stephen Hawking wrote many papers on black holes (see [Y1,Y2] for example).
- A useful website for learning how to use BibTeX is [Z].

where X is a book citation, Y1 and Y2 are journal papers, and Z is a website (only cite websites in exceptional circumstances like this). Use the following template in your bib file to cite a website.

```
@misc{nickname,
 howpublished = {\url{http://...}},
 author = {},                % if known
 note = {Accessed 5/5/2016}  % if you like
}
```

Note that the `\url` is part of the **hyperref** package.

You can cite more than one reference in one go. For example, to cite papers nicknamed `hawking1` and `hawking2`, use the command

`\cite{hawking1, hawking2}`.

Optional: Loading the package **cite** will help tidy up numbering when multiple sources are cited at the same time. For instance, [1-3] will appear instead of [2,3,1].

6. Changing style. It's very easy to change citation style with BibTeX.

There are many styles that come pre-loaded with the initial LaTeX installation. Some of these 'default' styles include `abbrv` (which we've been using), `plain, acm, ieeetr, alpha` and many more.

☐ In your tex file, on the line that says `\bibliographystyle{...}`, change `abbrv` to `alpha`. Study the differences. Do you see why this style is called `alpha`?

☐ Try another default style.

Academic journals often have their own preferred style of bibliography. They do this by providing authors with a `.bst` file, which dictates the bibliography format (for example, we have been using `abbrv.bst` which came as part of the initial installation).

On *Canvas*, I have provided a few `.bst` files from real journals for you to play with. The journals I stole these files from are

- Annals of Mathematics (`aomalpha.bst`)
- Nature (`naturemag.bst`)
- Nuclear Fusion (`nf.bst`)
- Journal of High-Energy Physics (`jhep.bst`)

To use `nf.bst`, for example, download it into the same folder as your tex file. Then change the `\bibliographystyle` to

```
\bibliographystyle{nf}          % the style name
```

▶ **TASK 7**: Experiment with all these default+journal styles. Use your favourite one in this week's assignment. Add the following sentence to the text.

The bibliography style I used for this document is ♡.

where ♡ is the name of the style you used (duh).

Now edit your tex file so that the output resembles `sheet4-model.pdf` on *Canvas*.

When you're done, submit `sheet4.tex` and `myref.bib` onto *Canvas* (*Assignments >> LaTeX worksheet IV*).

You don't need to submit the bst file you used this week. I will use my own copy.

Remember: I won't be able to see any of your references without the `.bib` file.

Take-away message: At first, BibTeX might look like a lot of extra work, but in the long run a lot of time and effort will be saved. If you decide to reorganise your content, add or remove references, or change citation style, BibTeX updates the bibliography automatically with no extra work. Plus, the `.bib` file can be reused.