Writing Mathematics

Notes on LaTeX for Birkbeck Students

By Sarah Hart

Contents

Chapter 1

Introduction

In this chapter we'll look at how to get LaTeX onto your system. We'll give you a guided tour of the program TeXStudio, which is the program in which you will create documents, and which interacts with LaTeX to produce the pdf outputs. Then we'll go through the process of creating basic documents. Later chapters will look in more detail at producing mathematics, tables, figures, bibliographies, and styles of document such as presentations and dissertations. We'll begin with the syllabus, learning outcomes and recommended resources.

1.1 Syllabus

1. Understanding the process: knowing what LaTeX actually does and how to produce a readable output; producing a very simple document with basic text (assessed by Worksheet 1)

2. Writing mathematics: how to write equations, arrays, matrices and include symbols such as Greek letters, the symbols for the sets of integers, rational numbers and so on, integrals, sums and products (assessed by Worksheets 1 and 2)

3. Producing lists and tables (assessed by Worksheets 1 and 2)

4. Importing graphics (assessed by Worksheet 2)

5. Producing presentations: creating slides, gradual reveal and other effects (assessed by Worksheet 3)

6. Producing dissertations: title pages, chapters, tables of contents, references (assessed by Worksheet 4)

1.2 Learning Outcomes

On successful completion of this module a student will be expected to be able to:

- Be aware of some of the possible methods of producing typed mathematics, and the advantages and disadvantages of each

- Be able to use simple LaTeX commands, for example on Moodle discussion boards, to type formulae

- Be able to compile documents to produce `pdf` outputs

- Produce different fonts and sizes of text, equations and other mathematical expressions, matrices, arrays, tables and diagrams

- Be able to label theorems, tables, figures and other items, and refer back to them by labels

- Be able to produce a list of references and know how to cite them

- Be able to import graphics into a LaTeX document

- Be able to produce: articles, presentations and dissertations in LaTeX

1.3 Recommended Books

These notes aim to guide you through the process of learning LaTeX. For further resources, there is a wealth of information and support at ctan.org, and in fact nearly any LaTeX question can be answered with a quick online search. However here are three books you may consider getting.

- *A Not So Short Introduction to LaTeX*, by Tobias Oetiker, Hubert Partl, Irene Hyna and Elisabeth Schlegl. The authors have kindly made this available (free) online but it can also be downloaded as a `pdf` from the Moodle page for the Writing Mathematics module. The instructions about setting things up in the first chapter are not particularly relevant to us because they are under the impression that most people use (and like) UNIX, which is not the case! But after that it's pretty good, with lots of examples. More detail than you need in places though – it's great that there is a way to produce documents in Mongolian, but you may not feel you need to know that at this stage.

- *Learning LaTeX*, by David F. Griffiths and Desmond J. Higham. SIAM, 1997. ISBN-10: 0898713838, ISBN-13: 978-0898713831. This is an excellent beginners guide, covering most of what you need to know without any extraneous (and possibly confusing) information. It does have some omissions, for example it doesn't cover the Beamer package for producing presentations, and its treatment of how to turn a .tex file into something readable is a little dated. But as a concise and readable guide it does a good job.

- *The LaTeX Companion*, by Michel Goossens and Frank Mittelbach. Addison-Wesley 2004. ISBN-10: 0201362996 ISBN-13: 978-0201362992. This book is over 1000 pages long! It is a comprehensive guide, going far further into the gory details than is necessary for this course. However some of you may like going into gory details, in which case this book is for you.

1.4 How the software works

LaTeX is a very powerful typesetting system. Its aim is to present your document in a logical, aesthetically pleasing way. So if you are producing an article, there is an underlying structure of sections, subsections and numbered theorems, definitions, examples and so on within that. You can label and refer back to them in an automated way so that adding a new theorem at the start of the article does not require you to go through renumbering all your references.

The system will arrange spacing, the size and font of text and headings, and other things, consistently according to the underlying structure. You can overrule it if necessary but usually you won't want or need to. The main reason we use it though, is because of its ability to produce professional-looking typeset mathematics. This is done by way of commands such as `\alpha` for the Greek letter α. All this together means that when you are typing your document, it will not look like the final pdf output. To produce the output (your completed document with all its shiny mathematics and neat layout) you need to run your file through the LaTeX compiler, and out will pop a `.pdf`. The rough process looks like this:

- Create your document, let's call it '*MyFile*', with instructions for mathematics and layout in their 'raw' form. You will do this in a text editor (the program TeXStudio is what we will give you on your CD) and save it with the name `MyFile.tex`.

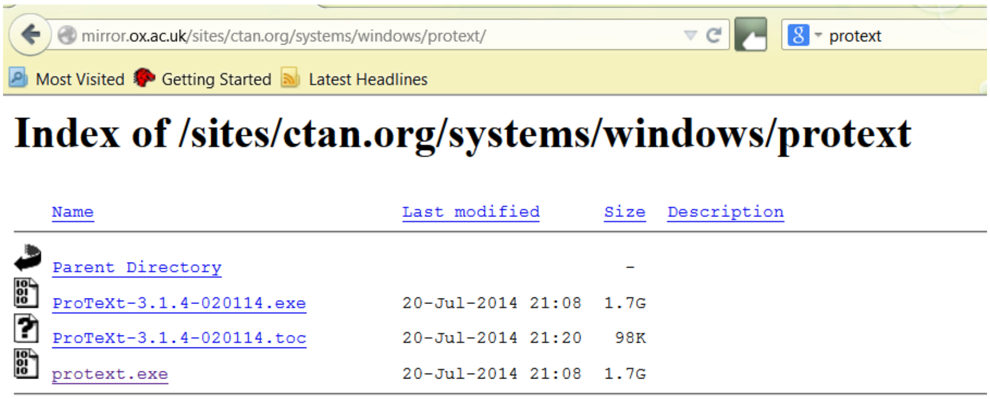
- LaTeX the document (in TeXStudio this is by just clicking an icon). A .pdf| of your document, called `Myfile.pdf`, will be produced.

And that's basically it. I know that you may be thinking 'but Word can do all that, why put myself through all this pain?' Well, Word may be able to produce some or even most mathematics, if you push it hard enough, and if you have equation editor. But how many drop-down menus would you need to use to create even something as simple as the expression $e^{i\pi} = -1$? In LaTeX you just have to type `$e^{i\pi} = -1$`. Much quicker. Perhaps more important is the fact that LaTeX is set up for easy cross-referencing, so you can label and refer back to, for example, equations, in a way that auto-updates when you insert or remove text. There are many other advantages as well, but we'll leave it there as I'm sure you are eager to get started. If you are in the computer room you can skip the next section about installing the software, as it is already installed.

1.5 Installing the software

LaTeX is free mathematical typesetting software developed over many years by the academic community. There are countless forums and websites offering help and advice, and a huge archive of resources, in particular at ctan.org. There are many free distributions of the software and you are welcome to explore them. However we recommend a package called ProTeXt. The reasons for this are that it is fairly simple to install and it comes with a good, reliable and relatively user friendly text editor (TeXStudio).

To install ProTeXt, go to https://www.tug.org/protext/ (or follow the link on the Moodle page for the module). Under the heading 'Download and Install', click on the phrase 'download the self-extracting protext.exe file'. This sends you to a page that looks like this:



mirror.ox.ac.uk/sites/ctan.org/systems/windows/protext/

Index of /sites/ctan.org/systems/windows/protext

Name	Last modified	Size	Description
Parent Directory		-	
ProTeXt-3.1.4-020114.exe	20-Jul-2014 21:08	1.7G	
ProTeXt-3.1.4-020114.toc	20-Jul-2014 21:20	98K	
protext.exe	20-Jul-2014 21:08	1.7G	

Now just click on `protext.exe` to download. It's a large file — based on current UK average broadband download speed, it will take between 1 and 2 minutes to download. When you've downloaded it, simply run it and it will start the installation process. The download comes with full details of how to install the software, and it is short and friendly. But basically you have to first install MiKTeX and then TeXStudio, via a few simple steps through which the manual will guide you. It is not a gigantic program, so shouldn't take up too much of your working memory. And the files you create will be small too.

If you have any difficulties installing the software itself (rather than using it), please contact Nigel Foster (n.foster@bbk.ac.uk) or Awuku Danso (a.danso@bbk.ac.uk). They are the Department's IT officers.

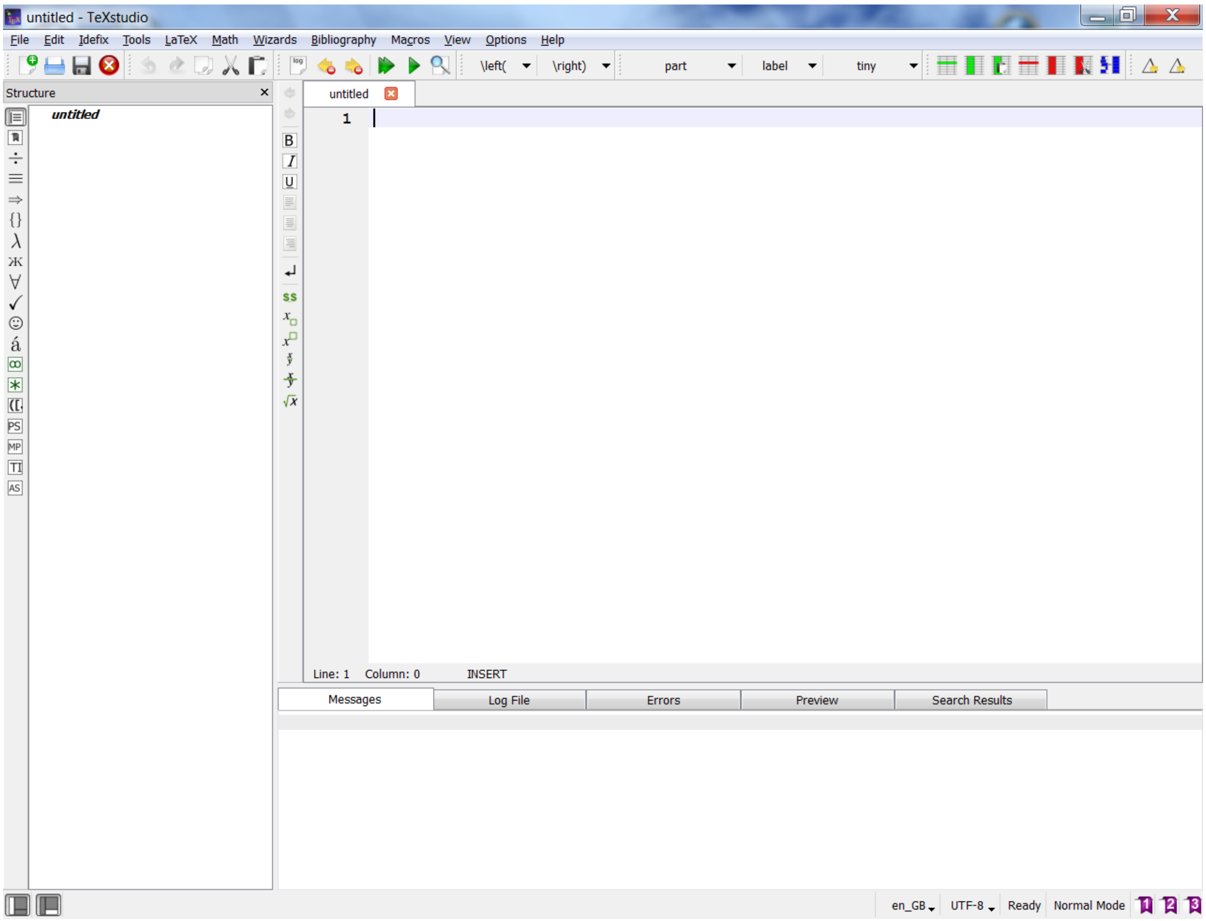
1.6 Using TeXStudio

In this section I will describe how to use TeXStudio, as this is what we are giving you to install at home. However in the 7th floor computer lab at Birkbeck there is also a program called WinEdt, which basically does the same job; some people prefer it, so it's up to you. There are numerous other distributions and software that you can experiment with if you feel so inclined.

Let us assume that you have successfully installed ProTeXt on your computer, or that you are in the computer lab. Then there should be an icon on the desktop like this.

⟵ Double click on this icon!

You'll see a screen with a menu bar across the top. In the top left corner click on 'File', then 'New', *or* just below that click on the 'new file' icon . On the next page is a screenshot of


untitled - TeXstudio
File Edit Idefix Tools LaTeX Math Wizards Bibliography Macros View Options Help
\left(\right) part label tiny
Structure
untitled
untitled
1
Line: 1 Column: 0 INSERT
Messages Log File Errors Preview Search Results
en_GB UTF-8 Ready Normal Mode

what TEXStudio will look like when you have done this.

You'll see a sidebar called 'Structure'. This lists all the chapters, sections and subsections of your document. While this may be useful for longer documents, we don't need it for our little experiment, so if you like you can get rid of it by pressing the × on that sidebar. You can bring it back by clicking on the icon ◧ at the extreme bottom left hand corner of the page.

Having got rid of the Structure sidebar, you will see that you have a blank document, called 'untitled', and a number 1. This is line 1. Type something, such as 'Hello World'. Now let's save this amazing document. Either click 'File', then 'Save As', or click the icon on the menu bar 💾, and at the prompt save it as `myfile`. It will automatically be saved as `myfile.tex` unless you specify otherwise. (You can save in any folder you like. I suggest if you are at home that you create a folder on your computer for all your LATEX documents; at Birkbeck files should saved either to a USB stick or your N drive.)

The name of the document you are working on will now be displayed on a tab at the top of the document. You can have several documents open at once, and clicking on these tabs allows you to move between them.

At this point you are ready to try compiling (or sometimes we say LaTeXing or TeXing) your document. To do this you'll use the single green 'compile' arrow ▶. Click on it.

Oh no! Something terrible has gone wrong! Immediately some error messages will appear in the error bar at the bottom of your screen. When you are working on documents you will regularly make errors, especially at first, and the system will let you know of these and tell you where in the document it thinks the problem is. That's why all the lines are numbered. Our document is currently only one line long, but you can imagine with a document of several hundred or thousand lines, that this would be a very useful function.

OK so what has gone wrong? The error log tells us that there is an error on line 1. We didn't type `\begin{document}`. This was so cataclysmic an error that TeXStudio performed an Emergency stop. What we need to do at this point is correct any errors before attempting to compile again.

In LaTeX, some initial information is required. This is because LaTeX sets up a document differently according to what it is. A book has chapters, an article doesn't. A presentation has slides, and a landscape page format. So we must specify which of these we are producing. The set-up of a document is called the *preamble*. It must include, at minimum, an instruction giving the class of document. The simplest of these is the article class. Later we can add other commands to the preamble. To signal that the preamble is finished we need to formally begin (and end) the document.

So, type the following four lines.

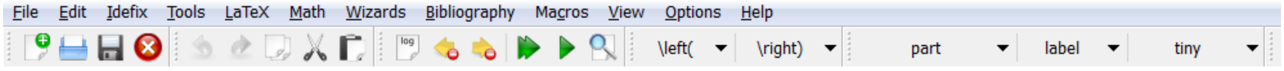
```
\documentclass[a4paper,12pt]{article}
\begin{document}
Hello World
\end{document}
```

Here we have specified that the document is an article to be set in 12 point font on A4 paper. You'll find that TeXStudio is keen to help! When you start typing commands it auto-suggests what you might want, and when you type `\begin{document}`, it helpfully supplies the `\end{document}` for you. Which is nice.

Now we can compile our document again. Press the green arrow ▶. If you have typed the commands correctly, then the error bar will present you with the happy news that the process 'exited normally', which means that a pdf has been created that you can now look at. This is done by pressing the 'view' button 🔍, which is immediately to the right of the 'compile' button. If you are feeling brave, and don't expect any errors, you can compile and view all in one go by pressing the double green arrow 'build and view' ⏩ instead of the compile arrow. That's what you'll probably do most of the time.

Whichever way you do it, the screen will now subdivide and you'll see the pdf of your document (which will be called `myfile.pdf`) on the right hand side of the screen. Well done, you have now produced your first LATEX document!

In the rest of this section I will briefly describe a few of the features of TEXStudio. As ever with new software, the best way in general to learn to use it is to just play with it, pressing buttons to see what they do, hovering over buttons to get more information, and so on.
The top bar looks like this. (I've omitted the symbols at the far right, which are to do with editing tables. We may mention them later; I never use them anyway.)


File Edit Idefix Tools LaTeX Math Wizards Bibliography Macros View Options Help
\left(
\right)
part
label
tiny

File

This menu tab allows you to create new files, open existing files and save files. One useful feature here is 'New from Template'. You can select from various standard document types and you'll be given a document with the bare bones of what you need. So it will have a `\documentclass{}` command, for example. You can also create, open, close and save files using the buttons just below the File tab. Note: the 'Print' command here will print the `.tex` file and *not* the pdf.

Exercise 1. Create and compile a new document called `exercise1.tex` containing the text 'This is some text.'

Edit

This menu tab has all the usual editing tools: undo, redo, copy, cut, paste, find and replace. Buttons for some of these also appear in the editing toolbar immediately underneath.

Idefix

The only things you are likely to use in this drop-down menu are the 'comment' and 'uncomment' options. If you select some text in your document that you think you may not need but don't want to permanently delete, you can 'comment it out', meaning that it stays in the file but doesn't appear in the pdf. You can accomplish this manually by putting a % sign before anything that you don't want to be processed by LATEX. And of course here you can insert comments for yourself. They could be reminders like `%insert more on this topic here %`.

Tools

LATEX does not detect spelling errors! So you are strongly advised to run a spellcheck as a final stage in the preparation of any document. To do this you can hit the 'Check Spelling' option in the Tools drop-down menu. You can also do a word count which ignores commands as obviously they don't contribute to the word count of your final pdf document. This is the 'Analyse Text' option. It is in fact much more powerful than a word count but you can get one out of it by counting all phrases containing one word.

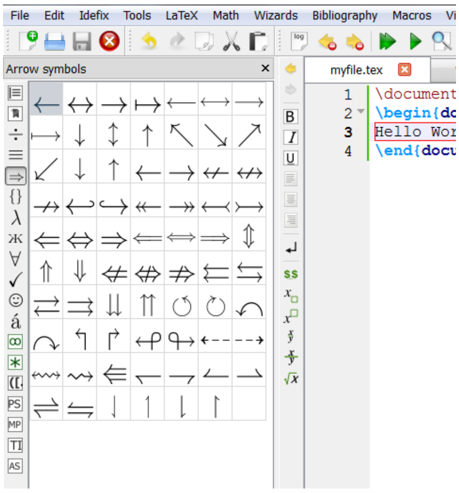
Exercise 2. Add a deliberately misspelled word to `exercise1.tex`. Now run a spellcheck to correct it.

LaTeX and 'Math'

These two drop-down menus have many shortcuts and aides-memoires for common commands. They are useful if you've forgotten (or never knew!) a particular command. But they will slow you down a lot if you use them all the time rather than learning things. TeXStudio already finishes your commands for you so you'll soon get the hang of it.

Vertical Toolbars

You'll see that there are more shortcuts on the left hand side of the screen, for things like subscripts, fractions and surds. If you bring back the 'structure' sidebar (by clicking on the icon ◧ at the extreme bottom left of the screen), you'll see another column of symbols. Clicking on these in turn brings a set of symbols that you can click on to insert the commands for them into your document. For example, here is what appears when you click the ⇒ symbol.



```
\document
\begin{dc
Hello Wor
\end{docu
```

All the arrows a person could wish for!

Again, it will be slow going for you if you don't learn at least the more common of these, rather than finding and clicking on symbols all the time. But for symbols that you use only rarely it is a useful resource. Chapter 3 has a list of common symbols and their commands for reference.

The pdf

There are three choices for viewing your pdf. It will probably depend on the size of your screen. The default setting is that the screen will split within the window, and your pdf and `.tex` files will appear side by side. This is the embedded viewer. The advantage of this is that you can see everything together. The disadvantage is that you may find either your lines when typing the `.tex` document are ludicrously narrow, or the writing on the pdf is too small, or both. In that case you may prefer to have the pdf appear in a separate window: this is the 'windowed viewer' option. You can switch between the embedded and windowed viewer by clicking the icon in embedded mode to get to windowed viewer, and the icon in windowed viewer mode to get back to embedded mode. In either mode you can navigate around the pdf in the usual way, scrolling, using the up/down arrows on the keyboard or even the navigation buttons at the top of the screen.

One extremely useful feature in the embedded and windowed viewer modes is the so-called '**inverse search**' feature. If you are looking at the pdf and you see something that needs correcting, if you hold down the Ctrl key and then left click, you will be taken to the corresponding line of the `.tex` file.

Printing

The most reliable way to print your pdf is to click the red 'external viewer' icon at the top of either the embedded or windowed viewer. This will open the pdf in your standard pdf viewer (usually Adobe Acrobat). You can then print as you normally would. **Caution: you must close the external viewer before compiling again, or you will get an error message!**

1.7 Writing a simple document

In this section we will discuss (briefly) the main types of document, look at sections, subsections, paragraphs and spacing, special characters, text and fonts, titles and footnotes. More complicated things like drawing tables and cross-referencing are dealt with in Chapter 2. We'll also give a very brief mention to mathematics, though that is the subject of Chapter 3.

Three Types of Document

The main three kinds of document you will need to prepare are short documents (for solutions to coursework, Worksheets 1 and 2, the Spring progress report for your dissertation, drafts or summaries of dissertation chapters and similar), presentations (if nothing else, for your final project presentation) and of course book-style longer documents, such as your dissertation.

- For short documents use the *article* document class.
- For presentations use the *beamer* document class
- For your dissertation we have prepared a special Birkbeck dissertation document class. This is the subject of Chapter 5.

Certain commands may have different effects in different classes. For example the first section in an article will be numbered Section 1. But sections in a book are labelled by chapter, so

Section 1.1 and so on. Where differences occur we will try to mention them. The default assumption in Chapters 1 – 3 is that we are in the *article* class. Anything with chapters we will refer to as a 'book'.

In the preamble, the first line is always to specify the document class. For example, an article would begin with the following command.

```
\documentclass[12pt,a4paper]{article}
```

The optional arguments in the square brackets can specify the font and paper size. The allowed font sizes are 10pt, 11pt and 12pt. If you don't specify then you get 10pt font. For a presentation we would type the following.

```
\documentclass{beamer}
```

More on those in Chapter 4.

Sections

Articles (and chapters of books) can be divided into Sections, Subsections and Subsubsections. Anything which is numbered automatically, such as theorems, will be numbered by section for an article, and by chapter for a book. You can change this default setting if you wish, in the preamble. More on this later. To start a new section, simply type

```
\section{Name of Section}
```

So, in these notes, for example, there is a line `\section{Writing a simple document}`. The numbering (in this case 1.4) is done automatically. You can produce a heading of the same size and typeface, but no numbering, by inserting an asterisk.

```
\section*{Name of Section}
```

This would produce a non-numbered section heading. There are also further subdivisions, via the subsection and subsubsection commands.

```
\subsection{Name of Subsection}
\subsubsection{Name of Subsubsection}
```

These give numbered subsections and subsubsections. For non-numbered versions insert an asterisk. I find non-numbered subsections are useful because my sections and subsections are generally short enough to be easily navigable. If your sections are 15 pages long then you might very well want to have numbered subsections. This current subsection's header was produced using the command `\subsection*{Sections}`.

Exercise 3. Go to your document `exercise1.tex`.

1. Create numbered sections, subsections and subsubsections as required, so that the document has subdivisions labelled **1 Introduction, 1.1 Definitions, 1.2 Results, 1.2.1 Theorems**, and **1.2.2 Corollaries**.

2. Add a new numbered section called **Preliminaries**, before **Introduction**. What happens to the numbering – what number, for example, is the **Corollaries** section now given?

3. What happens if you put a subsection right at the beginning of the document before you have started a section?

Paragraphs and Spacing

If you leave a blank line in your `.tex` file, then LaTeX will start a new paragraph, with automatic indentation at the start. (Actually I don't really like indented paragraphs so I put the command `\parindent 0pt` in my preamble.) If you want to leave a blank line in the text you create, you'll need to leave a blank line *and* type \\ and the end of the previous line. You can leave small, medium or large gaps by using the `\smallskip`, `\medskip` and `\bigskip` commands. Below you see the effect of these commands.

The line ends here.
After this line I put a double backslash.

Here follows a small gap.

Here follows a medium one.

And here's a big one.

The commands that produced the above sequence of lines and spaces are as follows.

```
The line ends here.
After this line I put a double backslash.\\

Here follows a small gap.\smallskip\\
Here follows a medium one.\medskip\\
And here's a big one.\bigskip\\
```

You can get an arbitrary vertical space with (for example) `\vspace{1cm}`. You can get a horizontal space with (for example) `\hspace{1cm}`. If you wish to write text right at the end of the line, then you can use the `\hfill` command (similarly `\vfill` puts text at the bottom of the page). So the command `left \hspace{5cm} middle \hfill right` produces the following output text.

left   middle   right

Note Sometimes you may wish to give a paragraph a title (this paragraph is called *Note* as an example). This was done using the command `\paragraph{Note}`, and then writing the text as normal.

It is possible to centre-justify a portion of text by typing `\begin{center}` at the start and `\end{center}` at the end. This is called centering; I'm afraid you do have to use the American spelling.

Exercise 4. Produce an approximation of the following piece of text using centering and the `\hspace` and `\vspace` commands.

12

11 1

10 2

9 3

8 4

7 5

6

Exercise 5. Add a paragraph with the title *Note* to your document.

Creating a Title

Title slides for presentations and title pages of books or dissertations will be covered in Chapters 4 and 5. Here we'll just concern ourselves with creating titles of articles. The required commands are

```
\title{All about Quadrilaterals}
\author{S. Q. Aire}
\date{12 January}
\maketitle
```

The `\author` command can be omitted if you don't need it. If you omit the `\date` command, then LaTeX for some reason assumes that what you really wanted to do was to insert today's date, so it does that! If you want to omit the date, then you need to type `\date{}`. There may be occasions when you feel a 'formal' title takes up too much room on the page, perhaps if your document is only a page long, for example, and/or doesn't need to give author and/or date. In this case I recommend creating something manually like the following.

```
\begin{center}{\Large All about Quadrilaterals\\
S. Q. Aire}
\end{center}
```

Exercise 6. Open your document `exercise1.tex` (or start a new one).

- Give your document a title, author and date.
- Now remove the date from the title.
- Give it a date but no author.
- Now manually create a title.

1.8 Text, Fonts and Special Characters

Special Characters

The following characters have a special meaning in LaTeX.

\ & $ % ~ _ { } # ^

I won't go into all of them just now, though we have already encountered the backslash (\), because it precedes every command. To get a backslash in text, you must type `$\backslash$`. A forward slash, /, has no special role so you can just type it as normal. All the special characters other than the backslash can be obtained by typing a backslash before them. So `\&` gives you &, `\%` gives you %, and so on. It's quite common to forget that % is a special character. If you do this then you'll find a chunk of text missing because, if you remember, the special role of the % sign is to comment out any text that follows it.

I'll mention hyphens here too. There are three lengths possible. The short one, which is just the standard hyphen on the keyboard, should be used when hyphenating a word, such as 'do-gooder'. The second is a dash, obtained by typing two hyphens (`--`), which is used when you type something like May – June. There is also a long dash, which is three hyphens together — it is probably the one you will use least.

Exercise 7. In your document `{exercise1.tex}` or elsewhere, reproduce the following output.

> The national debt of the USA is approximately $16 trillion. It is about 73% of GDP. The USA's credit rating was downgraded in 2011 by the credit ratings agency Standard & Poor's.

Text and Fonts

The size of body text is determined by the optional argument to the `\documentclass` command at the beginning of the preamble. You can specify 10pt, 11pt or 12pt, as we've mentioned. The default is 10pt. Parts of your text can be made tiny, footnote size, small, normal, large, Large to huge. You can use **bold** type. You can also *emphasise* words. Then we have *italic type*, *slanted type* and small caps type. The last two sentences were produced as follows.

```
Parts of your text can be made {\tiny tiny}, {\footnotesize footnote size},
{\small small}, normal, {\large large}, {\Large Large} to {\huge huge}. You
can use {\bf bold} type. You can also {\em emphasise} words. Then we have
{\it italic type}, {\sl slanted type}  and {\sc small caps type}.
```

The `\em` command is the best if you want to italicise something. The reason is that LaTeX is intelligent with this command. If you are in normal text, then the result of this command would produce something like *this*. But if you emphasise something while you are already writing in italics, such as a quotation or the statement of a theorem, the command would reflect that. Thus, for example, consider the text, `` `{\it Do you expect me to {\em talk}?' `No, Mr Bond, I expect you to {\em die}.}' `` This produces: ‘*Do you expect me to* talk*?*’ ‘*No, Mr Bond, I expect you to* die.’ Note the different symbols required to produce left and right quotation marks. For a left quotation mark you need the left dash (usually located on the key to the left of the 1 on a keyboard). For a right quotation mark you need the standard apostrophe. Finally the command for LaTeX is `\LaTeX`.

Exercise 8. Reproduce the following paragraph of text. (Don't worry if your lines are not the same length, and certainly don't try to get a box round it – I'm just interested in the actual words being reproduced in the same typefaces.)

> **Very soon the Rabbit noticed Alice**, as she went hunting about, and called out to her in an angry tone, ‘*Why, Mary Ann, what* are *you doing out here? Run home this moment, and fetch me a pair of gloves and a fan! Quick, now!*’ And Alice was so much frightened that she ran off at once in the direction it pointed to, without trying to explain the mistake it had made. She came upon a neat little house, on the door of which was a bright brass plate with the name ‘W. Rabbit’ engraved upon it.

Accents

If you are using non-English words then you may need accents. Your encyclopædic knowledge of mathematicians like Gödel, Erdős and L'Hôpital may require it. (That sentence was brought to you by the following raw text: `encyclop\ae{}dic knowledge of mathematicians like G\"{o}del, Erd\H{o}s and L'H\^{o}pital`). Because these commands are used rarely, even an old hand like me cannot necessarily remember them all. This is one instance where it is probably quicker to use one of the side menus. In TeXStudio, bring up the left vertical sidebar (if necessary by clicking on the ▣ icon at the extreme bottom left of the screen). Now click on the á symbol. You'll see a full range of accented letters to choose from. When you want one, just click on it and the command will appear in your text. The following table lists just some of the more commonly required accented letters and their corresponding LaTeX commands.

Accented Letter	Command
ë	\"{e}
é	\'{e}
è	\`{e}
ç	\c{c}
à	\`{a}
ö	\"{o}
ô	\^{o}
œ	\oe{}

Sometimes an accent isn't in the list. In the next exercise there is a Vietnamese accent required (ả). When I was writing the exercise I went looking for mathematicians whose names have accented letters, and in the list of Fields medal winners the three in the exercise cropped up. Rather than not include this unusual accent, I decided that it was a good example of how easy it is to find out how to do things, and an example of the kinds of instructions that are put in the preamble to a document (Section 2.2 has much more on this). I Googled 'Vietnamese accents latex'; the first hit told me exactly how to add required characters.

Exercise 9. Open your document `{exercise1.tex}` (or start a new one). In the preamble (the part before `\begin{document}`), add the line `\usepackage[T1,T5]{fontenc}`. This allows you to use many more accented letters. In particular, the Vietnamese letter ả is obtained by typing `\h a`. Now reproduce the following output. (Make sure you get those hyphen lengths right!)

> The name Gauss — if you want to show off — could more correctly be written Gauß. The mathematicans René Thom, Lars Hörmander and Ngô Bảo Châu have all won the Fields medal.

1.9 Basic Mathematics Commands

The whole of Chapter 3 of these notes is devoted to mathematics, and so I won't say much here. But I did want to at least give you the absolute basics so that you can experiment a little at this point. The first and most important thing to learn is that any mathematics should be enclosed in dollar signs. And I mean *any* mathematics. Look at the difference between typing `10-3=7` and `$10-3=7$`. The first gives 10-3=7 and the second gives $10-3=7$ (note the proper length minus sign and better spacing). Moreover when you are referring to, say, a group G or a real number x, these are mathematical terms which are usually italicized. So those two should be contained in dollar signs (so we write `$G$` and `$x$`). If you neglect to do this then you end up with a group G and a real number x. The x in particular looks ugly and not how we want to write variables. If you want to display mathematics in a centred line, then instead of one dollar sign, you should use two. For example, writing `$$10-3=7$$` produces

$$10-3=7.$$

Be careful! If you are finishing a sentence with your displayed equation, you need to put the full stop *inside* the dollar signs with the equation. Otherwise it will just end up at the start of the next line of text, which looks silly. Equations can be numbered, and we will give more detail about that in Chapter 3.

To allow you to get a small idea of the commands available, here are a few mathematical expressions alongside the commands that produce them.

Result	Commands
$\alpha_1 \beta_1 \neq \Gamma - \Delta$	`$\alpha_1 \beta_1 \neq \Gamma - \Delta$`
$\frac{1}{2} \times \frac{2}{3} \geq 0$	`$\frac{1}{2} \times \frac{2}{3} \geq 0$`
$\sin^2 \theta + \cos^2\theta = 1$	`$\sin^2 \theta + \cos^2\theta = 1$`

Exercise 10. In your document `{exercise1.tex}` or elsewhere, reproduce the following mathematical expressions.

- $\lambda_0 + \lambda_1 x^1 + \lambda_2 x^2 > 0$;
- $\frac{2}{3} \times \frac{1}{4} = \frac{1}{6}$;
- $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ (you'll need `\pm` for ± and `\sqrt{?}` for $\sqrt{?}$);
- $\tan^2 \theta \leq 1$ (if cos is `\cos` and $\geq$ is `\geq`, I'll leave you to work out what tan and $\leq$ are!).

Using LaTeX online

LaTeX commands are more and more being incorporated into other software. For example, in Moodle forums and discussion boards, you can use LaTeX mathematics commands. To do this, just type your post, enclosing any mathematics in TWO dollar signs (as if it was a displayed equation). Strangely, this will not produce a displayed equation, but mathematics in the text. If you just use one dollar sign it won't work. I suppose that is because Moodle wants those poor people who are ignorant of LaTeX to be able to use dollar signs as normal without accidentally producing strange mathematical symbols.

You'll find that mathematicians often slip into LaTeX code when emailing each other too, and of course your lecturers will understand (and you'll save space and time) if you write something like `\pm 3` to mean ±3. This can make the difference between sending an incomprehensible email because you can't work out how to make your email text editor produce certain symbols, and getting your point across in such a way that the lecturer can understand you and answer your question. Of course if you have a lot of mathematics to write, you can now simply produce a small but perfectly formed `.pdf` and attach it.

Finally if you are the sort of person who edits Wikipedia pages or writes HTML, you'll find that the commands you've learnt in LaTeX can be incorporated easily into webpages. If you are that sort of person, then you will be more than capable of finding all the relevant information online so I will say no more about it here.

Chapter 2

Progressing with LaTeX

In this chapter we will cover some more advanced topics, including lists, construction of tables, the preamble, numbering and labels (for cross-referencing), environments and other useful commands. Environments are things like theorems, examples and definitions. By the end of the chapter you should be able to produce more or less all of the text formatting, layout and structure that you need. Formatting of mathematics is left for Chapter 3.

2.1 Lists

In this section we will look at lists. There are various kinds of lists, both numbered and un-numbered, that can be created. LaTeX will automatically keep count and nest lists systematically. So, for example, we could have the following set-up, which is started with the command `\begin{enumerate}`.

1. The top numbering is with arabic numerals 1, 2, 3. (one can change this but that's a bit more advanced).

2. Each item in the list is preceded by the command `\item`.

    (a) The next level is letters, so we get (a)

    (b) followed by (b).

        i. After that it's Roman numerals.

        ii. If you are using this many sub-lists, maybe it's time to organise your thoughts more clearly!

    (c) Don't forget you need to type `\end{enumerate}` at the end of each list, so here I have had to type it 3 times in total.

3. I think that's enough enumerated lists.

The commands on the left below generate the text on the right.

```
\begin{enumerate}
\item Vertebrates
       \begin{enumerate}
       \item Birds
             \begin{enumerate}
             \item Penguins
             \end{enumerate}
       \end{enumerate}
\end{enumerate}
```

1. Vertebrates

    (a) Birds

        (i) Penguins

If you want bullets, then you use the `itemize` command.

- Bullet points are not used very much in mathematical writing.

- But on occasion they can be useful.

- When giving a project presentation, short bullet points are better than acres of text.

The following commands illustrate what happens when we use `itemize` instead of `enumerate`.

```
\begin{itemize}
\item Vertebrates
       \begin{itemize}
       \item Birds
             \begin{itemize}
             \item Penguins
             \end{itemize}
       \end{itemize}
\end{itemize}
```

- Vertebrates
    - Birds
        - Penguins

The final type of list I will mention is a catch-all set-up which allows you to specify what the items in a list will be labelled; it is the `trivlist` command. Here is an example: A **group** is a non-empty set, G, together with a map $*$ defined on $G \times G$, satisfying four axioms G0 – G3.

G0 (closure) For all $g, h \in G, g * h \in G$.

G1 (associativity) For all $g, h, k \in G$, $(g * h) * k = g * (h * k)$.

G2 (identity) There is an element $e \in G$, such that for all $g \in G$, $g * e = e * g = g$.

G3 (inverses) For all $g \in G$, there is an element $g^{-1} \in G$, such that $g * g^{-1} = e = g^{-1} * g$.

This is produced with the following commands in the `.tex` file.

```
\begin{trivlist}

\item[{\bf G0}] {\bf (closure)} For all $g, h \in G, g \ast h \in G$.

\item[{\bf G1}] {\bf (associativity)} For all $g, h, k \in G$, $(g \ast h)
\ast k = g \ast (h \ast k)$.

\item[{\bf G2}] {\bf (identity)} There is an element $e \in G$, such
that for all $g \in G$, $g \ast e = e \ast g = g$.

\item[{\bf G3}] {\bf (inverses)} For all $g \in G$, there is an element
$g^{-1} \in G$, such that $g\ast g^{-1} =  e = g^{-1} \ast g$.

\end{trivlist}
```

Exercise 11. Reproduce the following text. (You'll need `\dot{9}` for $\dot{9}$).

Equivalent expressions.

1. (a) 0.5
   (b) $\frac{1}{2}$
   (c) $0.4\dot{9}$
2. 8 o'clock in the evening can be written as:
   (a) 8 pm
   (b) 2000h
   (c) 20:00

Exercise 12. Reproduce the following text. You'll need a couple of mathematical symbols, $\equiv$ (`$\equiv$`) and $\mod n$ (`$\mod{n}$`).

Method for solving a linear congruence $ax + b \equiv c \mod n$.

- Subtract b from both sides to get $Ax \equiv B \mod n$.
  - If $\gcd(A, n)$ does not divide B, then there are no solutions. STOP.
  - If $\gcd(A, n)$ divides B then there are solutions. Continue to next step.
- Divide A, B and n by $\gcd(A, n)$ to get a congruence $kx \equiv l \mod m$ for appropriate k, l, m.
- Reverse the Euclidean algorithm to find u, v with $uk + vm = 1$.
- Then $x \equiv ul \mod m$ is the solution to the original congruence.

2.2 The Preamble

The preamble is the place for global commands. That is, instructions that affect the whole document. It starts of course by specifying the class of document – usually an article. But there are numerous other things we can include. I have described the main four in this section. Note that the first line of the preamble should *always* be the `\documentclass` command.

Packages

Part of what keeps LaTeX such a tight, efficient program is that it doesn't have extraneous features that you never use. This goes back to its early days when computers had much less memory. However there are many functions and features that can be added simply by including bolt-ons called *packages*. If you want to use a given package, you need to add an instruction to that effect in the preamble. The software can then check that the package is installed on your computer. If it isn't, then ProTeXt can auto-install it for you.

We have already seen an example of a package in Section 1.8. Here we wanted to use a Vietnamese accented character. In the preamble we added the line

```
\usepackage[T1,T5]{fontenc}
```

and then when we needed the extra commands provided by the package, we could just use them as normal in the text. You are not likely to need any packages beyond the ones I suggest (and maybe not even them!), but the format for adding them is always the same.

```
\usepackage[optionalargument]{package name}
```

Of course it is perfectly possible to create a complete document without using any extra packages. But there are six packages I use so enough that I just insert them into every document. Usually this is by taking a document I've already written, saving it under the new name, then deleting everything except the preamble.

```
\usepackage{amssymb}
\usepackage{amsmath}
\usepackage{amsfonts}
\usepackage{amsthm}
\usepackage{graphicx}
\usepackage{epstopdf}
```

The first four of these are packages created by the American Mathematical Society. They give extra symbols, mathematics commands, fonts and ways to format theorems. The next two are to do with incorporating graphics into your document, so can be omitted if you don't have any. We'll discuss graphics in more detail in Section 3.4.

Page Setup

You do not need to give any page setup commands in the preamble if you don't want to! For the `\documentclass[a4paper]{article}` class the page size is obviously A4, which is a page 210mm wide and 297mm high. Margins and text width are determined by giving the top margin and text height, the left margin and text width.

By default the top margin is 52mm, the text height is 210 (including the page number at the bottom), meaning that the bottom margin (after the page number) is 35mm. The left margin is 39mm, the text width is 130mm, meaning that the right margin is 41mm.

Any changes you make to the top margin or left margin are in reference to these existing defaults of 52mm for top margin and 39mm for odd side margin. My suggestion is that you try and keep the rough proportions similar to what the clever designers of LaTeX set up. So if you want to add 20mm to your text height, you should take off half that, namely 10mm, from the top margin (these two commands combined will force the loss of 10mm from the bottom margin). This is done using the `\addtolength` command.

```
\addtolength{\topmargin}{-10mm}
\addtolength{\textheight}{20mm}
```

There are commands which allow you to give the absolute value of the textheight, but the advantage of `\addtolength` is that you don't have to remember what the default settings were, as you are just adding and subtracting.

To change the left and right margins and the text width you need to remember that in books usually the odd and even numbered pages are symmetrically formatted, often with a slightly wider 'outside' margin (the right margin on odd numbered pages and the left margin on even numbered pages), and a slightly narrower 'inside' margin. The odd side margin in LaTeX is the left margin on odd numbered pages. The even side margin is the left margin on even numbered pages. So to change the left margins of your document you need to look at both of these. The simplest way is again probably with the `\addtolength` command; an example is below.

```
\addtolength{\oddsidemargin}{-5mm}
\addtolength{\evensidemargin}{-5mm}
\addtolength{\textwidth}{10mm}
```

At this point in the preamble you can also set things like the indentation on paragraphs, the distance between paragraphs, and whether pages are numbered. If you don't want pages to be numbered then use the command `\pagestyle{empty}`. If you want headings automatically produced by LaTeX (such as the title of the document appearing on every page) then you can include `\pagestyle{headings}`. More complicated instructions are not discussed here but you can customise almost infinitely. For paragraphs if you want to change the defaults you can use the commands

`\parindent 5pt` (for example, this sets the indent to 5pt);
`\parsep 5mm` (for example, this sets the gap between paragraphs to 5mm).

LaTeX understands several units of measurement. Points (pt), millimetres (mm), centimetres (cm) and inches (in) are the four you are most likely to want to use.

Exercise 13. In this exercise you will be creating an article and experimenting with formatting. To see the effects you will need at least two pages of text. I suggest cutting and pasting from somewhere, either any old text file you have lying around, or, for example, a chunk of this text. (Don't worry it's just the text of Alice in Wonderland.)

http://www.gutenberg.org/cache/epub/11/pg11.txt

Create an article with at least two pages of text, satisfying the following.

- It should be 11 point font, and A4 paper.
- It should contain three numbered sections.
- The pages should be numbered and have headings.
- The text should be 30mm higher than the default setting, and the topmargin should be 15mm shorter.
- The text should be 20mm wider than the default, and the left margins of both odd and even numbered pages should be 10mm narrower than the default.
- The indentation of paragraphs should be 20mm.

Instructions about Commands

The next part of the preamble should be given over to instructions about commands. This is where you can modify the way LaTeX processes various things like lists, theorems and so on. For example you can specify whether theorems are numbered by chapter or section. You can specify the numbering style of lists. Redesigning lists is not difficult but is probably not something you will need to do. If you do, then simply look online for `\theenumi`. Instructions to do with theorems are covered in Section 2.3.

New Commands

We have already established that LaTeX can do everything, so why on earth would any sane person need new commands? Nearly always it is done to save time. For example, I have the following set of new commands in my preambles.

```
\newcommand{\zz}{\mathbb{Z}}
\newcommand{\qq}{\mathbb{Q}}
\newcommand{\rr}{\mathbb{R}}
\newcommand{\cc}{\mathbb{C}}
```

This is because I use the symbols $\mathbb{Z}$, $\mathbb{Q}$, $\mathbb{R}$ and $\mathbb{C}$ so often that it saves me a lot of time to type `$\rr$` instead of `$\mathbb{R}$` when I want the symbol $\mathbb{R}$. A colleague defines a shorter way of beginning and ending lists.

```
\newcommand{\be}{\begin{enumerate}}
\newcommand{\ee}{\end{enumerate}}
```

Then instead of `\begin{enumerate}` he just has to type `\be`. Much quicker. A final example is that for me the default letter epsilon (given by `$\epsilon$`) is this: ϵ. But I prefer this: ε. The command for that is a bit long: `$\varepsilon$`. So in my preamble I have:

```
\newcommand{\ep}{\varepsilon}
```

meaning to get the symbol ε I just have to type `$\ep$`.

You can define as many of these commands as you like, and copy and paste them from document to document. Sometimes you may get an error message to say that the command is already defined. In that case you'll need to give your command a different name.

Organising your Preamble

It is good practice to put all commands of a similar kind together in the preamble. This makes it easier to find where they are if you want to change them, and also easier to cut and past wholesale when starting a new document. As an example, the preamble for a typical article might go like this.

```
\documentclass[a4paper,12pt]{article}
% % % % % % % % % % % % % % % % %packages
\usepackage{amssymb}
\usepackage{amsmath}
\usepackage{amsfonts}
\usepackage{amsthm}
\usepackage{graphicx}
\usepackage{epstopdf}
% % % % % % % % % % % % % % % % %page setup
\textwidth 170mm
\oddsidemargin -5mm \evensidemargin -5mm \topmargin -5mm \textheight 227mm
% % % % % % % % % % % % % % % % %instructions
\newtheorem{thm}{Theorem}[section]
\newtheorem{lemma}[thm]{Lemma}
% % % % % % % % % % % % % % % % %new commands
\newcommand{\rr}{\mathbb{R}}
\newcommand{\cc}{\mathbb{C}}
```

Remember that the commands beginning `\newtheorem` will be discussed in Section 2.3.

Exercise 14. When I am writing about linear algebra I include the following commands in my preamble.

```
\newcommand{\bu}{\mathbf{u}}
\newcommand{\bv}{\mathbf{v}}
\newcommand{\bw}{\mathbf{w}}
\newcommand{\bo}{\mathbf{0}}
```

Add these to your preamble and then in your document use them to produce the following output. Note that `\sum_{a}^{b}` produces $\sum_a^b$ in a line of text and $\displaystyle\sum_a^b$ in displayed equations.

> Suppose for some a_i, b_j, c_k we have
>
> $$\sum_{i=1}^{l} a_i\mathbf{v}_i + \sum_{j=1}^{m} b_j\mathbf{u}_j + \sum_{k=1}^{n} c_k\mathbf{w}_k = \mathbf{0}.$$
>
> Then $\sum_{i=1}^{l} a_i\mathbf{v}_i + \sum_{j=1}^{m} b_j\mathbf{u}_j = \sum_{k=1}^{n}(-c_k)\mathbf{w}_k$.

2.3 Environments

Environments are parts of the document that have different properties from normal text; they generally sit between commands `\begin{whatever}` and `\end{whatever}`. Lists are a kind of environment – we have the enumerate, itemize and trivlist varieties. Tables are another environment type. The `center` environment is very useful. Displayed equations (another environment type) are centre justified automatically, but we can also make text, or tables, or pictures, appear centrally. (I'm sorry that we are forced to use American spelling, but such is life.) The command

```
\begin{center} {\em To be or not to be, that is the question.}\end{center}
```

produces the following centred quotation.

To be or not to be, that is the question.

Next, we have arrays. These are used when in mathematics mode, such as in the case where we are giving different values to a function. The `array` environment is a kind of 'maths mode' version of the `tabular` environment that is used to produce tables. The following is just an indicative example; don't worry about the detail. Tables are dealt with properly in Section 2.5, and for arrays see Section 3.3.

```
A function $f: \mathbb{R} \rightarrow \mathbb{R}$ is defined as follows.
$$f(x) = \left\{\begin{array}{ll} \sqrt{x} & \mathrm{if}\; x \geq 0\\
                                          0 & \mathrm{otherwise}
                \end{array}
         \right.$$
```

These commands produce the following text.

A function $f : \mathbb{R} \to \mathbb{R}$ is defined as follows.

$$f(x) = \begin{cases} \sqrt{x} & \text{if } x \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

Incidentally the `\;` command that you'll see in the source file inserts space. You could also do this with the `\hspace*{2mm}` command. Don't worry too much about the other commands; as I've said these will be discussed in the relevant sections later.

I suppose I should mention that the way I'm getting all this text that looks like typing is with the `verbatim` environment. Anything typed in this environment comes out exactly as it is typed, with no LaTeXing applied. But I don't suppose you'll need it.

Finally we have the `theorem` environment. This is the environment that covers theorems, lemmas, propositions, corollaries, definitions and anything else that needs numbering. If your document needs any or all of these, you will need to set up these environments in the preamble. You should use the `amsthm` package by inserting the command `\usepackage{amsthm}` in the preamble.

For each object you wish to define you need a line in the preamble.

```
\newtheorem{name}{output}[number by]
```

The name is how you will signify this type of theorem in the raw text. The output is how it will be labelled in the output pdf. The optional [number by] argument tells LaTeX how you would like to number this object – by section, by chapter, and so on. Let's see an example. Every document needs theorems. So we put a line in the preamble specifying what our theorems will be named.

```
\newtheorem{thm}{Theorem}[section]
```

Then to put a theorem in the text we type:

```
\begin{thm}
Some text.
\end{thm}
```

This will result (supposing it is the first theorem in Section 1 of an article) in the following output.

Theorem 1.1. *Some text.*

In the preamble to the document, if you want lemmas, propositions and so on, you'll need to set them up individually so that they are numbered as you wish. Some people want all results to be numbered in sequence Theorem 1, Proposition 2, Example 3, and so on, but others prefer independent numbering: Theorem 1, Proposition 1, Example 1. You can have your objects numbered by chapter, section or even subsection.

For example, in the preamble of this document is a line setting up a Lemma environment.

```
\newtheorem{lemma}[thm]{Lemma}
```

This creates a theorem environment, started by `\begin{lemma}` and ended by `\end{lemma}`, that is numbered with Theorems and named 'Lemma'. Looking below we see that Lemma 2.2 is numbered as a theorem. If instead we had written `\newtheorem{lemma}{Lemma}[section]`, this would change.

Theorem 2.1. *Any group of prime order is simple.*

Lemma 2.2. *Every group of order 15 is cyclic.*

Usually we want theorems, lemmas and so on to be formatted as you have seen above; that is, labelled in bold font and with the text in italics. But there are other objects such as definitions, that we may not wish to italicise. To cater for these the package `amsthm` has three 'styles' of theorem-type object. These are `plain`, `definition` and `remark`. The default setting is `theorem`. To see the difference in formats, suppose we define a new theorem environment called Conjecture. We write the following in the preamble.

```
\theoremstyle{style}
\newtheorem{conjecture}{Conjecture}[section]
```

Here *style* is one of `plain`, `definition` or `remark`. If no style is specified then the default is `plain`. To put a conjecture in the text, we would type the following.

```
\begin{conjecture}
This is some text.
\end{conjecture}
```

The effect of the different styles on the output is shown below. (I've assumed this is an article and this is the first conjecture in Section 1.)

`plain`	**Conjecture 1.1.** *This is some text.*
`definition`	**Conjecture 1.1.** This is some text.
`remark`	*Conjecture 1.1.* This is some text

Note that the theorem style is either the default or the last style specified; you don't have to restate it for every `\newtheorem`. As a guide, I have the following lines included in the preamble for most of my documents.

```
\usepackage{amsthm}
%
\theoremstyle{plain}
\newtheorem{thm}{Theorem}[section]
\newtheorem{conjecture}[thm]{Conjecture}
\newtheorem{cor}[thm]{Corollary}
\newtheorem{lemma}[thm]{Lemma}
\newtheorem{prop}[thm]{Proposition}
%
\theoremstyle{definition}
\newtheorem{example}[thm]{Example}
\newtheorem{defn}[thm]{Definition}
```

Where there are theorems, there are proofs. The `amsthm` package has a proof environment. In the text you can then type the following.

```
\begin{proof}
The proof is an exercise for the reader. \end{proof}
```

This will produce:

Proof. The proof is an exercise for the reader. □

Sometimes the proof of a result is not immediately underneath the statement of that result. In those circumstances it is good form to specify what you are proving. This can be done by inserting an optional argument in square brackets. So for example if there has been some discussion of ancient Greek mathematics following a statement of Pythagoras' Theorem, then when it is time to give the proof, instead of `\begin{proof}`, we could type:

```
\begin{proof}[Proof of Pythagoras' Theorem]
```

This is the outcome.

Proof of Pythagoras' Theorem. Insert your favourite proof here. □

Incidentally if the last line of your proof is a displayed equation then unless you tell it otherwise, LaTeX will stupidly put the QED symbol (a square □) on an empty line underneath the equation. To avoid this just type `\qedhere` at the end of the equation. Then finish the equation (that is, put the two dollar signs) and type `\end{proof}` as normal.

Exercise 15. Create a document with two sections. Set up lemmas, propositions, theorems and corollaries in your preamble in such a way that your document contains the following items.

- Lemma 1.1. *The following holds:* $1 + 1 = 2$.
- Proposition 1.2. *The following holds:* $2 + 1 = 3$.
- Theorem 2.1. *The following holds:* $3 + 1 = 3$.

- Corollary 2.2. *The following holds:* $2 + 2 = 4$.

Then include a proof of Corollary 2.2.

Exercise 16. 1. Alter your preamble commands in Exercise 15 such that your document instead contains the following items.

- Lemma 1.1. *The following holds:* $1 + 1 = 2$.
- Proposition 1.1. *The following holds:* $2 + 1 = 3$.
- Theorem 2.1. *The following holds:* $3 + 1 = 3$.
- Corollary 2.2. *The following holds:* $2 + 2 = 4$.

2. Alter your preamble commands again so that now the items are labelled as follows.

- Lemma 1. *The following holds:* $1 + 1 = 2$.
- Proposition 2. *The following holds:* $2 + 1 = 3$.
- Theorem 3. *The following holds:* $3 + 1 = 3$.
- Corollary 1. *The following holds:* $2 + 2 = 4$.

2.4 Numbering and Labelling

LaTeX, as we have seen, produces a structure which can include numbered chapters (in the case of a book), sections, subsections and so on. It can also number tables, figures, theorems, examples, exercises, equations and many other things. Anything that is numbered by LaTeX can be labelled in the `.tex` file to allow automatic cross-referencing. This is an extremely useful and important tool. It allows you to make changes to your document without worrying that you'll need to go through and check that all the numbers are still right. So you can insert a new section, which will cause all subsequent sections to be renumbered, and if you have cross-referenced using your labels then these cross-references will be automatically updated.

To label something, use the `\label{}` command. So to start this section I typed the following.

```
\section{Numbering and Labelling}\label{numbering}
```

Now I can refer to it in the text by typing, for example,
`This is Section \ref{numbering}.`

That produces the output, 'this is Section 2.4'. There is no need to label everything, by the way, only things you are going to need to refer back to. But if you are going to refer to something you should *always* use the `\label{}` and `\ref{}` commands because then you are protected against your unexpected future decisions to add or remove things at the last minute.

The most likely objects to be cross-referenced are theorems, definitions and similar things. To label them simply insert `\label{myresult}` (or similar) after `\begin{lemma}` (and obviously before `\end{lemma}`). Then to refer back to this lemma type '`by Lemma \ref{myresult}` . . . '.

Tables and Figures are environments that produced numbered Tables and Figures that can therefore can be labelled and cross-referenced. We haven't dealt with those environments yet (see Sections 2.5 and 3.4 for more information), but broadly speaking, the approach is the same as for the theorem environment – insert a `\label{}` command and then cross-refer using `\ref{}`. Equations can also be labelled in this way; there is more on this in Section 3.2.

Exercise 17. In Exercise 15 you created a two-section document containing Lemma 1.1, Proposition 1.2, Theorem 2.1 and Corollary 2.2. Go back to this document and give labels to all these results. Now create the following proof of Corollary 2.2, making sure all the cross-referencing is automatic – in other words don't cheat by writing 'Lemma 1.1', use the proper `\ref` command!

Proof of Corollary 2.2 By Proposition 1.2 we have $2 + 1 = 3$. But Theorem 2.1 states that $3 + 1 = 4$. Therefore $(2 + 1) + 1 = 4$. Since addition is associative, this implies that $2 + (1 + 1) = 4$. Lemma 1.1 states that $1 + 1 = 2$. So, substituting into $2 + (1 + 1) = 4$ we get $2 + 2 = 4$, as required. □

2.5 Tables

There are two environments related to tables: `tabular` and `table`. The `tabular` command is what produces the table, and `table` is used, when required, to give the table a number and caption, and to allow it to be labelled for cross-referencing. Here is a simple table; below it are the commands used to produce it.

right	centre	left
this	this	and
column	one	this
is	is	one
right	centre	is left
justified	justified	justified

```
\begin{center}
\begin{tabular}{|r|c|l|}
\hline right & centre & left\\
\hline this  & this   & and\\
      column & one    & this\\
          is & is     & one\\
       right & centre & is left\\
   justified & justified & justified \\ \hline
\end{tabular}
\end{center}
```

The first command needed is `\begin{tabular}{columns}`. In the {columns} part you will describe the layout of each column. So, for example, {rcl} would mean that you want a right-justified column, followed by a centre-justified column, followed by a left-justified column, whereas {ll} would indicate two left-justified columns. Vertical lines can be drawn by inserting | at appropriate points. Thus in the table above we had {|r|c|l|}, which puts vertical lines before and after each column.

You do not need to specify how many rows the table will have. Within a row, each column entry is separated by the ampersand &. The end of the row is denoted by a double backslash \\. To get horizontal lines we use the `\hline` command. Inserted at the start of a row it inserts a horizontal line above the current row. The final row is finished by the `\end{tabular}` command. But to get a line at the bottom of the table you finish the final row with `\\ \hline \end{tabular}` instead. Table 2.1 gives further examples of the commands. Additionally, though, we have put it into the `table` environment to show you how we can number, label and cross-reference tables.

	1	a	b	ab
1	1	a	b	ab
a	a	1	ab	b
b	b	ab	1	a
ab	ab	b	a	1

Table 2.1: Multiplication table for $\{1, a, b, ab\}$

Table 2.1 was produced with the following commands.

```
\begin{table}[!hbt]
\begin{center}
\begin{tabular}{c|cccc}
& 1 & $a$ & $b$ & $ab$ \\
\hline 1 & 1 & $a$ & $b$ & $ab$ \\
$a$ & $a$ & 1 & $ab$ & $b$ \\
$b$ & $b$ & $ab$ & $1$ & $a$ \\
$ab$ & $ab$ & $b$ & $a$ & 1
\end{tabular}
\caption{Multiplication table for $\{1, a, b, ab\}$}
\label{tab1}
\end{center}
\end{table}
```

Note the optional argument [!hbt]. LaTeX puts tables and figures where it thinks they will look best, not exactly where you have typed the commands for them. But you can (almost) insist where you want them to go. This particular command says ‘I really want you to put the table right here, where I have written it. But failing that you can put it at the bottom of the page, and if it won't fit there you can put it at the top.

It seems to matter to LaTeX that you put the label *after* the caption, so I suggest you do that! If you want the caption to be above the table, then put the `\caption` command after `\begin{table}` but before `\begin{tabular}`.

On occasion you may wish to have entries that span more than one column of a table, or more than one row, or lines that only cover part of the table. For this you will need the `\multicolumn{cols}{pos}{text}` command and the `\cline{i-j}` command. The *cols* argument is a number specifying how many columns should be spanned. The *pos* argument states whether this new merged column should be left, right or centre justified. The final argument, *text*, is the content of the merged column. The whole `\multicolumn` command is placed in the first column of the columns to be merged. For example in the instructions for Table 2.2 below, the second, third and fourth columns in the first row are merged.

	Day				
Time	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	Algebra	Geometry	Topology	Rest	Algebra
Afternoon	Topology	Analysis	Rest	Geometry	Topology
Evening	Rest	Rest	Algebra	Analysis	Rest

Table 2.2: Study Plan

The code that produced Table 2.2 is below. Note the need to put the vertical line | in the `multicolumn` argument, which makes sure that there is no gap in the right hand border of the 'Day' cell.

```
\begin{table}[h!bt]
\begin{center}
\begin{tabular}{|l||c|c|c|c|c|}
\hline & \multicolumn{5}{c|}{Day}\\
          \cline{2-6}
Time &Monday&Tuesday&Wednesday&Thursday&Friday\\
\hline \hline        Morning&Algebra&Geometry&Topology&Rest&Algebra\\
\hline Afternoon&Topology&Analysis&Rest&Geometry&Topology\\
\hline Evening&Rest&Rest&Algebra&Analysis&Rest\\
\hline \end{tabular}
\caption{Study Plan} \label{tab2}
\end{center}
\end{table}
```

Note that double lines (both vertical and horizontal) can be produced. In fact though, Table 2.2 to my mind looks rather ugly and in general the minimalist style of Table 2.1 is often better. But it's up to you.

Exercise 18. Reproduce the following table (the mathematical symbols are `\vee`, `\wedge` and `\Rightarrow`).

		Connectives		
p	q	$p \vee q$	$p \wedge q$	$p \Rightarrow q$
T	T	T	T	T
T	F	T	F	F
F	T	T	F	T
F	F	F	F	T

2.6 Other useful commands

Footnotes

I'm not a great fan of footnotes in mathematical writing. If something is important it should be stated in the main text. If it is not important then why are you saying it in the first place? However, if you do need to include one you should type `\footnote{your text}`. Your footnotes in any chapter will be numbered 1, 2, 3 and so on[1]. For some reason the footnote command doesn't work within the title. To include one there you need to use the `\thanks` command.

Exercise 19. In a new or existing document, create nine footnotes. Now add the command

```
\renewcommand*{\thefootnote}{\fnsymbol{footnote}}
```

to the preamble and LaTeX again. Note the result.

Forced Breaks

LaTeX has been designed to produce professional looking layouts, and for the most part it does a very good job. However sometimes its decisions about when to have a line break or a page break may not be what you want for some reason. You can force line breaks and page breaks with the commands `\linebreak`, `\newline`, `\pagebreak` and `\newpage`. These commands have slightly different effects. The `\linebreak` command stretches the line so that it is still left and right justified, whereas the `\newline` command simply ends the line where you have typed it. It is the same with `\pagebreak` and `\newpage`. Sometimes LaTeX breaks a line between words where you *don't* want it to. For instance it looks silly to write 'Theorem 2.1' and see 'Theorem' on the end of one line and 2.1 at the start of another. Equally, you wouldn't want to see 'G. H. Hardy' spread over two lines. To prevent this (or to correct it if it has occurred) you can insert a tilde (~): `G.~H.~Hardy`. This tells LaTeX to keep these words or numbers together.

Exercise 20. Open a document containing at least two pages of text, for example the one you created for Exercise 13. Insert a `\newpage` command about halfway down the first page. Now try a `\pagebreak` command instead. Look at the difference in outcome. Do a similar experiment with `\linebreak` and `\newline`.

[1] unless you specify otherwise in the preamble, see Exercise 19

Chapter 3

Mathematics

In this chapter we will look in more detail at more of the formatting you will need to produce properly typeset mathematics. Section 3.1 discusses a few of the more common symbols and how to work with them. Section 3.2 looks at numbered and un-numbered equations and the `align` command which allows you to produced nicely aligned arrays of equations. Section 3.3 deals with arrays and matrices. Then we have a look at figures and diagrams in Section 3.4. Some brief advice on writing style for mathematics follows in Section 3.5. Finally at the end of the chapter is a quick reference section for some of the more common mathematical symbols and commands.

3.1 Symbols

We have already remarked that more or less any symbol you could ever need exists in LaTeX. Section 3.6 consists of several tables containing the most common symbols that you might use, and the commands for them. Moreover in TeXStudio the left-hand navigation bars give most of these symbols too. So generally it is easy to find the symbol you need. This section then is more about guidance as to how to use symbols.

Dots

The position of dots matters. For example 9.3 means $9\frac{3}{10}$ but $9 \cdot 3$ means 9×3. The lower dot is just the full stop on the keyboard. To get a centrally located dot you need `\cdot`. The central dot is standard for scalar products (as in $\mathbf{u} \cdot \mathbf{v}$), and common for group actions (as in $g \cdot x$) and as a shorthand for multiplication (as in $9 \cdot 8 \cdot 7$).

Another use for dots is to signify missing elements in lists or strings of various kinds. The convention here is that missing elements of a list be indicated by dots at the bottom of the line, whereas missing elements in a string of objects being combined in some way would be indicated by central dots. We can also have diagonal or vertical dots, which are often used in matrices or other arrays (see Section 3.3). Over the page are some examples of these commands.

$\{1, 2, 3, \ldots, n\}$	`$\{1, 2, 3, \ldots, n\}$`
$1 + 2 + \cdots + n$	`$1 + 2 + \cdots + n$`
$1! = 1$	`$1! = 1$`
$2! = 2 \times 1$	`$2! = 2 \times 1$`
$\vdots \hspace{1.5cm} \ddots$	`$\vdots$ \hspace{1.5cm} $\ddots$`
$n! = n \times \cdots \times 2 \times 1$	`$n! = n \times (n-1) \cdots \times 1$`

Above and Below the Line

We have already seen in these notes several examples of superscripts and subscripts. A subscript is obtained by use of an underscore `_`, and a superscript by use of a circumflex `^`. Unless otherwise instructed only the first character after the underscore or circumflex will be affected by the command, so if you need more than one character in the subscript or superscript, you must enclose all characters in curly brackets. The following examples show what I mean. You must be in mathematics mode to use these commands.

$x^2$	`$x^2$`
$x^2/3$	`$x^2/3$`
$x^{2/3}$	`$x^{2/3}$`
$a_1$	`$a_1$`
$a_{i_1}$	`$a_{i_1}$`
$x^{a_{i_1}}_{i_1}$	`$x^{a_{i_1}}_{i_1}$`

Subscripts and superscripts can be placed next to any symbol. Symbols like integrals, as well as summation, product, union and intersection symbols, all often appear with subscripts or superscripts. These symbols also have the property that they vary in size depending on whether they are in a displayed equation or not. The context in which they appear also determines how the subscripts and superscripts are shown. For example the command `$\int_1^{\infty} x \mathrm{d}x$` results in $\int_1^{\infty} \frac{1}{x}\mathrm{d}x$. But if we display it as an equation by typing `$$\int_1^{\infty} x \mathrm{d}x$$`, we get instead:

$$\int_1^{\infty} \frac{1}{x}\mathrm{d}x.$$

Note that the 'd' in 'dx' is correctly given as a Roman 'd' not an italic 'd'. Note also here that fractions are automatically larger when in displayed equations. The default (larger) style produced for displayed equations is called `displaystyle`. The default smaller style produced for in-line mathematics is called `textstyle`. You can demand that `displaystyle` be used in a line, or that `textstyle` be used in an equation by typing `\displaystyle` or `\textstyle` immediately before your command. Hence

```
$\displaystyle\int_1^{\infty} \textstyle\frac{1}{x} \mathrm{d}x$
```

produces $\int_1^{\infty} \textstyle\frac{1}{x}\mathrm{d}x$ (note that we had to instruct LaTeX to revert back to textstyle for the fraction), and `$$\int_1^{\infty} \textstyle\frac{1}{x} \mathrm{d}x$$` produces

$$\int_1^{\infty} \textstyle\frac{1}{x}\mathrm{d}x.$$

Here are some more examples of the `textstyle` and `displaystyle` forms of various symbols.

Expression	`textstyle`	`displaystyle`
`\sum_{r=1}^n r^2`	$\textstyle\sum_{r=1}^n r^2$	$\displaystyle\sum_{r=1}^n r^2$
`\prod_{k \leq n} x_k`	$\textstyle\prod_{k \leq n} x_k$	$\displaystyle\prod_{k \leq n} x_k$
`\lim_{x\rightarrow \infty} e^{-x}`	$\textstyle\lim_{x\rightarrow \infty} e^{-x}$	$\displaystyle\lim_{x\rightarrow \infty} e^{-x}$
`\bigcap_{A \in \mathcal{A}} A`	$\textstyle\bigcap_{A \in \mathcal{A}} A$	$\displaystyle\bigcap_{A \in \mathcal{A}} A$
`\bigcup_{n \in \zz^+} [-n,n]`	$\textstyle\bigcup_{n \in \mathbb{Z}^+} [-n,n]$	$\displaystyle\bigcup_{n \in \mathbb{Z}^+} [-n,n]$

Incidentally in this table, to fit the displayed mathematics in, I had to increase the amount of space allotted to the rows. To do this I used the command

```
\renewcommand{\arraystretch}{1.6}
```

immediately before the table, and then reset it immediately afterwards with

`\renewcommand{\arraystretch}{1}`.

Occasionally you may wish to place a symbol directly above or below another symbol, for example writing above an arrow. For this we use the overset and underset commands. For example, the command `$A \overset{f}{\longrightarrow} B$` produces $A \overset{f}{\longrightarrow} B$. The command `$A \underset{f}{\longrightarrow} B$` produces $A \underset{f}{\longrightarrow} B$. For each of these the main symbol appears second and the annotation to it (the thing that will be overset or underset) is given first.

Delimiters

Delimiters are symbols, usually appearing in pairs, that enclose expressions. We can have rounded ( ), curly { }, square [ ] and angled ⟨ ⟩ brackets, each of which have particular meanings and uses in mathematics. We will look at each of these in turn.

Rounded Brackets These are used of course in normal text, but in the mathematical context tend to be reserved for co-ordinates, for row and column vectors and matrices, and for permutations. Usually you will be able to produce them simply by using the left and right brackets on your keyboard. However sometimes this isn't desirable, for example if enclosing a large symbol such as $\sum$ in brackets, you want the brackets to be large enough to enclose it. Compare $(\frac{n^2+1}{3n-7})$ with $\left(\frac{n^2+1}{3n-7}\right)$. To obtain the large brackets you type `\left(` and `\right)` respectively. This works for all delimiters (I think!), even ones that don't have an obvious right and left, for example modulus signs. So `\left|\frac{2}{7}\right|` gives $\left|\frac{2}{7}\right|$.

Curly Brackets These are used for sets, and also to define functions in arrays – but we'll look at arrays later in Section 3.3. A pitfall here is that as we know commands in LaTeX often put arguments in curly brackets. Therefore LaTeX treats them just as holders of information. Hence to really get curly brackets in your text you must type `\{` and `\}`. Again if you want curly brackets that automatically adjust to be large enough for the text they contain, then you can use `\left\{` and `\right\}`.

Square Brackets These are used for closed intervals on the real line, for equivalence classes and sometimes in expressions where there are already lots of rounded brackets and a square bracket looks less confusing. Again we can employ `\left[` and `\right]` where necessary.

Angled Brackets These are usually used in the context of a set generating a group or vector space. You should used the dedicated symbols $\langle$ and $\rangle$ rather than lazily writing 'less than' ($<$) or 'greater than' ($>$) symbols because the dedicated symbols look better and avoid confusion.

Here are some examples of these delimiters in use.

$[0,1]$	`[0,1]`	
$\{\frac{1}{2},\frac{1}{3}\}$	`\{\frac{1}{2}, \frac{1}{3}\}`	— doesn't look very good
$\left\{\frac{1}{2},\frac{1}{3}\right\}$	`\left\{\frac{1}{2}, \frac{1}{3}\right\}`	— that's better
$\langle x : x^5 = 1\rangle$	`\langle x: x^5 = 1\rangle`	

Other things to Note

Negation Symbols like $=$ and $\in$ have negations $\neq$ (`\neq`) and $\notin$ (`\notin`). A few other negations, providing you have the `amssymb` package in your preamble, are obtained by adding the letter n before the command, as in $\ncong$ (`\ncong`) and $\nless$ (`\nless`). If you try that and it doesn't work you can use the catch-all command `\not`. This command strikes a line through whatever immediately follows it. So `$\not\equiv$` produces $\not\equiv$.

Space Sometimes, marvellous as LaTeX is, you may want to tweak the space allocated in a mathematical expression. The following commands give a small amount of positive or negative space. For complete control you can of course use the `\hspace` command, as in the last example.

`\int \! \int`	$\int \! \int$
`\int \int`	$\int \int$
`\int \,\int`	$\int \,\int$
`\int \;\int`	$\int \;\int$
`\int \quad \int`	$\int \quad \int$
`\int \qquad \int`	$\int \qquad \int$
`\int \hspace{15mm} \int`	$\int \hspace{15mm} \int$

Trigonometric Functions Since letters typed in maths mode by default come out in italic, we need to take care when using functions like sin, cos and tan. Table 3.8 at the end of the chapter lists the functions to which this applies. The basic rule is that instead of typing `$cos \theta$`, for example, you should type `$\cos \theta$`. There may be occasions when you need to use a function for which there is not a predefined command. Suppose you want to look at the least common multiple (lcm). You could type `$\mathrm{lcm}$` whenever you use it in an equation, or you could define a new command in the preamble if you will be using it a lot, for example the following.

```
\newcommand{\lcm}{\mathrm{lcm}}
```

Normal Text in Maths Mode Occasionally you will need to produce a few words of normal text in Maths mode. This is best done using the `\text` command. If you try to do it with `\mathrm` or similar, you'll find that words are run together and it looks awful. Compare the following effects.

`$\{x \in X: x < a for all a \in A\}$`	$\{x \in X: x < a for all a \in A\}$
`$\{x \in X: x < a \mathrm{for all} a \in A\}$`	$\{x \in X: x < a \mathrm{for all} a \in A\}$
`$\{x \in X: x < a \text{for all} a \in A\}$`	$\{x \in X: x < a \text{for all} a \in A\}$
`$\{x \in X: x < a \text{ for all } a \in A\}$`	$\{x \in X: x < a \text{ for all } a \in A\}$

Colons At the risk of accusations of perfectionism (!), I'll make a small point about the use of colons. If you need to define a function, as in $f\colon A \rightarrow B$, you need to use `\colon` rather than the keyboard character : to get the spacing right. Writing `f:A\rightarrow B` produces $f : A \rightarrow B$. This is spaced as if you are trying to express the ratio of 'f' to '$A \rightarrow B$', whereas the `\colon` moves the resulting colon a little closer to the f.

Exercise 21. Start a new document called `ExCh3.tex`. We will work on this document throughout the chapter.

- Use the `\maketitle` command to give your document a title (*Exercises from Chapter 3*) and an author (you!) but no date.
- Make sure that in the preamble you instruct LaTeX to use the packages `amsmath`, `amsfonts`, `amssymb` and `amsthm`.
- Create a Section 1, called *Symbols*, containing the text below. (Don't worry if you have different text width and hence different linebreaks.)

Groups Let G be a group and X a set. We say that G acts on X if for all $g \in G$ there is a map $g \colon X \to X$ such that the following hold.

1. For all $x \in X$ we have $1_G \cdot x = x$;
2. For all $g_1, g_2 \in G$ and $x \in X$ we have $(g_1 g_2) \cdot x = g_1 \cdot (g_2 \cdot x)$.

Limits Using the algebra of limits we can deduce that

$$\lim_{n\to\infty}\left(\frac{2n^2+3n+7}{5n^2+2n+3}\right) = \lim_{n\to\infty}\left(\frac{2+3\cdot(\frac{1}{n})+7\cdot(\frac{1}{n^2})}{5+2\cdot(\frac{1}{n})+3\cdot(\frac{1}{n^2})}\right) = \frac{2}{5}.$$

Sets For each w in W there is a set of vectors $N(w)$ with the property that for all $x, y \in W$ we have $N(xy) = \left(N(y) \setminus [-y^{-1}\cdot N(x)]\right) \dot{\bigcup}\, y^{-1}\left(N(x) \setminus N(y^{-1})\right).$

Exercise 22. Create a new command in your preamble. It should have the effect that when you type `\tr` in maths mode, the letters 'tr' (for trace) should appear in roman font. When you have done that, use it to produce the following text in Section 1 of your document `ExCh3.tex`.

Let A be an $n \times n$ matrix. Then the *trace* of A, denoted $\mathrm{tr}(A)$, is the sum of the entries on the main diagonal of A. It can be shown that for all $n \times n$ matrices A and B we have $\mathrm{tr}(AB) = \mathrm{tr}(BA)$.

Exercise 23. Create a new section(Section 2) in `ExCh3.tex` called *An Interesting Function.* Reproduce the following text in that section.

For a positive integer x we define $g(x)$ to be $\frac{1}{2}x$ if x is even, and $g(x) = 3x + 1$ if x is odd. For example:

$$42 \underset{g}{\longrightarrow} 21 \underset{g}{\longrightarrow} 64 \underset{g}{\longrightarrow} 32 \underset{g}{\longrightarrow} \cdots \underset{g}{\longrightarrow} 1.$$

We can define the following subset S of positive integers.

$$S = \{x \in \mathbb{Z}^+ : g^n(x) = 1 \text{ for some } n \in \mathbb{Z}^+\}$$

Conjecture We conjecture that $S = \mathbb{Z}^+$.

3.2 Equations

This section is about displayed mathematics. If you just want to display one equation centrally on a line then you can use the double dollar signs I've mentioned. However I've read while producing these notes that using `$$` is actually an old fashioned short cut, and that modern young up-to-the-minute LaTeXers always use `\[ . . \]` instead of double dollar signs. So maybe you should too. This is all very well but for more complicated expressions, such as multi-line equations and numbered equations, we need to look at a set of environments developed for these purposes. They are the `equation`, `multline` and `align` environments.

Before getting into details, note that in articles equations will be numbered (1), (2), (3) and so on. In books (or your dissertation), they will be numbered within chapters. In this current book we are in Chapter 3, so we have Equations (3.1) and (3.2) as the first two numbered equations in the chapter. Of course you can customise the numbering so that a different rule is followed in your document. If in an article you would like equations numbered by section, for example, then you can include the following command in your preamble.

```
\numberwithin{equation}{section}
```

The `equation` environment

The command `\begin{equation} \label{einstein} E = mc^2 \end{equation}` produces a numbered equation.

$$E = mc^2 \tag{3.1}$$

By giving it a label we can refer back to it in the text. There are two ways of doing this. You could write `Equation \eqref{einstein}` or `Equation (\ref{einstein})`. They both produce the same effect, namely 'Equation (3.1)'. The standard `\ref` command only provides the number, which is why with this option you must add the brackets yourself. If you want your equation not to be numbered you can type `\begin{equation*} E = mc^2 \end{equation*}`. This is consistent with (for example) the distinction between numbered and unnumbered sections (`section` and `section*`). Then we would just get the following output.

$$E = mc^2$$

The `multline` environment

Equation (3.2) was produced using the `\multline` command, as shown below.

```
\begin{multline} \label{multex}
\sum_{r=1}^{12} r = 1 + 2 + 3 + 4 + 5
+ 6 + 7 + 8\\
+ 9 + 10 + 11 + 12 = 78
\end{multline}
```

$$\begin{multline}\sum_{r=1}^{12} r = 1+2+3+4+5+6+7+8 \\ +9+10+11+12 = 78 \tag{3.2}\end{multline}$$

Again we could have an unnumbered version using `\begin{multline*}` and `\end{multline*}`. This environment is useful for long expressions. It is much easier for the reader to absorb such expressions when they are not just included in lines of text.

Equation (3.2) is a slightly artificial example; usually when we want to break lines in an expression it is because it is in the middle of a calculation over many lines. For such situations we need the `align` environment.

The `align` environment

With a calculation spanning several lines, or indeed several equations displayed together, the correct method is to align them so that the equals signs are at the same position on the line. Naturally LaTeX will do this for you automatically in the `align` environment. There is the flexibility to number every line, no lines or just some lines. Here are some examples.

```
\begin{align}
\sin^2\theta + \cos^2\theta
& = 1 \label{cos}\\
\sec^2\theta - \tan^2\theta
& = 1 \label{tan}
\end{align}
```

$$\begin{align}\sin^2\theta + \cos^2\theta &= 1 \tag{3.3}\\ \sec^2\theta - \tan^2\theta &= 1 \tag{3.4}\end{align}$$

Notice that we have put a label on each line so that we can refer back to Equations (3.3) and (3.4) individually. The next example has no numbered lines.

```
\begin{align*}
\pm\sqrt{b^2 - 4ac}
& = \pm\sqrt{6^2 - 4\cdot (-2) \cdot 8}\\
& = \pm\sqrt{36 + 64}\\
& = \pm\sqrt{100} \\
& = \pm 10
\end{align*}
```

$$\begin{align*}\pm\sqrt{b^2 - 4ac} &= \pm\sqrt{6^2 - 4\cdot(-2)\cdot 8}\\ &= \pm\sqrt{36+64}\\ &= \pm\sqrt{100}\\ &= \pm 10\end{align*}$$

In the next example we have just numbered the last line.

```
\begin{align}
\pm\sqrt{b^2 - 4ac}
& = \pm\sqrt{6^2 -
4\cdot (-2) \cdot 8} \nonumber\\
& = \pm\sqrt{36 + 64} \nonumber\\
& = \pm\sqrt{100} \nonumber\\
& = \pm 10 \label{ten}
\end{align}
```

$$\begin{aligned}\pm\sqrt{b^2-4ac} &= \pm\sqrt{6^2-4\cdot(-2)\cdot 8}\\ &= \pm\sqrt{36+64}\\ &= \pm\sqrt{100}\\ &= \pm 10 \qquad (3.5)\end{aligned}$$

By adding further '&' signs you can create arrays of equations. This can be useful if you have simultaneous equations to solve. Here is an example.

$$\begin{aligned} a+b &= 2 & b+c &= 5 & c+d &= 7\\ d+e &= 9 & e+f &= 11 & f+a &= 7\end{aligned}$$

This was produced using the following commands.

```
\begin{align*}
a + b & = 2 & b + c & = 5 & c + d & = 7 \\
d + e & = 9 & e + f & = 11 & f + a & = 7
\end{align*}
```

There may be occasions when you wish to split a line inside a calculation. For that the simplest way is just to start a new line and leave a `\quad` space. If you are numbering every line you'll need to insert a `\nonumber` command to avoid both halves of your split line being numbered. (There is a dedicated environment, the `split` environment, for this, but all it does is the no-number part, which you don't need anyway most of the time as generally you'll be using `align*` rather than `align`.) Here's an example of creating a split line manually.

```
\begin{align*}
(x - y)(x^2 + xy + y^2)
& = x^3 + x^2y + xy^2 \\
& \quad - x^2y - xy^2 - y^3\\
& = x^3 - y^3
\end{align*}
```

$$\begin{aligned}(x-y)(x^2+xy+y^2) &= x^3+x^2y+xy^2\\ &\quad -x^2y-xy^2-y^3\\ &= x^3-y^3\end{aligned}$$

Finally the `align*` environment can be useful when you wish to justify steps of your argument.

```
\begin{align*} e^{i\theta}
&= \cos\theta + i\sin\theta
&& \text{(by Theorem 7)}\\
e^{i\pi} &= \cos\pi + i \sin \pi
&& (\text{setting } \theta = \pi)\\
e^{i\pi} & = -1
\end{align*}
```

$$\begin{aligned} e^{i\theta} &= \cos\theta + i\sin\theta && \text{(by Theorem 7)}\\ e^{i\pi} &= \cos\pi + i\sin\pi && (\text{setting } \theta=\pi)\\ e^{i\pi} &= -1\end{aligned}$$

Exercise 24. In your document `ExCh3.tex` create a new section (it should be Section 3) called *Equations*. Now reproduce the following text, including the same numbering that is given here. Note that there is no LaTeX command `\cosec` as the Americans usually write 'csc' for cosec. So you'll have to make your own arrangements!

Newton found a link between force, mass and acceleration.

$$F = ma$$

There are also five equations of motion for constant acceleration a. Here s is the displacement at time t, u is initial speed and v is the speed at time t.

$$\begin{aligned}
v &= u + at \tag{3.1}\\
s &= \tfrac{1}{2}(u+v)t \tag{3.2}\\
v^2 &= u^2 + 2as \tag{3.3}\\
s &= ut + \tfrac{1}{2}at^2 \tag{3.4}\\
s &= vt - \tfrac{1}{2}at^2 \tag{3.5}
\end{aligned}$$

There are three trigonometric identities which can be derived from each other.

$$\begin{aligned}
\sin^2\theta + \cos^2\theta &= 1 \tag{3.6}\\
\sec^2\theta(\sin^2\theta + \cos^2\theta) &= \sec^2\theta \notag\\
\tan^2\theta + 1 &= \sec^2\theta \tag{3.7}\\
\cot^2\theta(\tan^2\theta + 1) &= \cot^2\theta\sec^2\theta \notag\\
1 + \cot^2\theta &= \mathrm{cosec}^2\theta \tag{3.8}
\end{aligned}$$

Exercise 25. In your document `ExCh3.tex` you should now have eight numbered equations. If you have not done so, give each of them a label, and then use the commands `\eqref` or `\ref` to produce the following paragraph of text.

Equations (3.1) and (3.2) are obtained by using the actual meaning of the letters u, v, a, s and t. But Equations (3.3), (3.4) and (3.5) can be deduced purely algebraically from (3.1) and (3.2). Similarly, Equation (3.6) can be proved using Pythagoras' Theorem and the definitions of sine and cosine. Then Equations (3.7) and (3.8) follow easily by algebraic manipulation.

Exercise 26. Go back to the un-numbered equation '$F = ma$' in your document and this time number it – it will then be Equation (3.1). Check that the paragraph produced in Exercise 25 is still correct – in other words the references are all to the correct equations. This is the sort of sneaky thing I will be doing with the `.tex` files you submit as coursework!

3.3 Arrays and Matrices

The array environment is essentially a tabular environment for mathematics. It can align rows and columns of mathematics text, and is very versatile. The array environment is only allowed in maths mode, so in the example below it is included in an equation, but it could be just between dollar signs, or in the align environment, or similar. Here is an example.

```
\begin{equation*}
f(x) =
\left\{
   \begin{array}{ll}
       \sqrt{x} & \text{if } x \geq 0\\
        0 & \mbox{otherwise}
   \end{array}
\right.
\end{equation*}
```

$$f(x) = \left\{ \begin{array}{ll} \sqrt{x} & \text{if } x \geq 0\\ 0 & \mbox{otherwise} \end{array} \right.$$

You'll see the array has two left-justified columns. Note also that only the left angled bracket is used. Because LaTeX gets worried if left parentheses are not closed by right parentheses, we insert a 'dummy' right parenthesis. The command `\right.` accomplishes this.

Arrays can also be used to produce matrices. But for simple matrices there are some dedicated commands which give you less control but are quicker. The commands are matrix, bmatrix, Bmatrix, pmatrix, vmatrix, Vmatrix and smallmatrix. For each of these you do not have to specify how many columns or rows there are; you can just get typing. All columns are centre justified and you don't have the functionality of putting any vertical lines. Which is mostly fine for simple examples. The different commands (except for smallmatrix) specify what kind of delimiter (bracket) goes around the matrix. The smallmatrix command produces a small matrix which can be used in a line. Here are some examples.

```
$\begin{matrix}
1 & 2 \\ 3 & 4
\end{matrix}$
```

$$\begin{matrix} 1 & 2 \\ 3 & 4 \end{matrix}$$

```
$\begin{bmatrix}
1 & 2 \\ 3 & 4
\end{bmatrix}$
```

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

```
$\begin{Bmatrix}
1 & 2 \\ 3 & 4
\end{Bmatrix}$
```

$$\begin{Bmatrix} 1 & 2 \\ 3 & 4 \end{Bmatrix}$$

```
$\begin{pmatrix}
1 & 2 \\ 3 & 4
\end{pmatrix}$
```

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$$

```
$\begin{vmatrix}
1 & 2 \\ 3 & 4
\end{vmatrix}$
```

$$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix}$$

```
$\begin{Vmatrix}
1 & 2 \\ 3 & 4
\end{Vmatrix}$
```

$$\begin{Vmatrix} 1 & 2 \\ 3 & 4 \end{Vmatrix}$$

```
$\begin{smallmatrix}
1 & 2 \\ 3 & 4
\end{smallmatrix}$
```

$\begin{smallmatrix} 1 & 2 \\ 3 & 4 \end{smallmatrix}$

```
$\left(\begin{smallmatrix}
1 & 2 \\ 3 & 4
\end{smallmatrix}\right)$
```

$\left(\begin{smallmatrix} 1 & 2 \\ 3 & 4 \end{smallmatrix}\right)$

Of these, the commands you are most likely to use are `pmatrix` and `smallmatrix`. However, there will be occasions when these quick commands do not produce the optimal outcome. An example of this is for matrices featuring negative numbers, or symbols, when left-justified or right-justified columns can be preferable. Below, for comparison, you can see a 3 × 3 matrix produced using the `pmatrix` and `array` commands. The `array` version is clearly superior. The final version illustrates the possibility, in the `array` environment, of including vertical and horizontal lines.

```
$\begin{pmatrix}
1 & 0 & \alpha\\
0 & -1 & \alpha^{-1}\\
0 & 0 & \alpha^2
\end{pmatrix}$
```

$$\begin{pmatrix} 1 & 0 & \alpha\\ 0 & -1 & \alpha^{-1}\\ 0 & 0 & \alpha^2 \end{pmatrix}$$

```
$\left(\begin{array}{crl}
1 & 0 & \alpha\\
0 & -1 & \alpha^{-1}\\
0 & 0 & \alpha^2
\end{array}\right)$
```

$$\left(\begin{array}{crl} 1 & 0 & \alpha\\ 0 & -1 & \alpha^{-1}\\ 0 & 0 & \alpha^2 \end{array}\right)$$

```
$\left(\begin{array}{cr|l}
1 & 0 & \alpha\\
0 & -1 & \alpha^{-1}\\
\hline 0 & 0 & \alpha^2
\end{array}\right)$
```

$$\left(\begin{array}{cr|l} 1 & 0 & \alpha\\ 0 & -1 & \alpha^{-1}\\ \hline 0 & 0 & \alpha^2 \end{array}\right)$$

One final special kind of array that has its own command is the binomial coefficient $\binom{n}{r}$; this is produced with the command `$\binom{n}{m}$`.

Exercise 27. In Section 3 of `ExCh3.tex` create this text: $g(x) = \begin{cases} \frac{1}{2}x & \text{if } x \text{ is even;} \\ 3x+1 & \text{if } x \text{ is odd.} \end{cases}$

Exercise 28. In your document `ExCh3.tex` use the appropriate matrix commands to produce the following matrices: $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$, $\begin{pmatrix} p & q \\ r & s \end{pmatrix}$, $\left(\begin{smallmatrix} 1 & 0 \\ 0 & 1 \end{smallmatrix}\right)$, and $\begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$.

Exercise 29. In your document `ExCh3.tex` create the matrices $\begin{pmatrix} 0 & 1 & -1 \\ 1 & 2 & 3 \end{pmatrix}$ and $\left(\begin{array}{cc|c} 1 & 0 & * \\ 0 & 1 & * \\ \hline * & * & 1 \end{array}\right)$.

3.4 Figures and Diagrams

There are two aspects to the question of including graphics in documents. The first is getting them into the document; the second is actually creating them.

Importing Graphics

It is possible to include pictures and diagrams in your LaTeX document if they are in one of the following formats: `pdf`, `eps`, `png`, `jpg`, and `gif`. To do this, in the preamble to your document, you should insert the following line.

```
\usepackage{graphicx}
```

If you need to use `.eps` files then you also need the `epstopdf` package. But I cannot think of a case where you would be using a programme that can create `.eps` files but not `.pdf` files, so you are not likely to need this.

At the point in the document where you want your picture to appear, you can simply type

```
\includegraphics{mypicture.pdf}
```

(or `mypicture.eps` or `mypicture.jpg` or whatever file type your picture is). This will plonk your picture straight into the text, which usually isn't what you want! At the least you'll probably want to display it:

```
\begin{center}
\includegraphics{mypicture.pdf}
\end{center}
```

You'll often need to tweak pictures, for example scaling or rotating them. To do this you can use the following example optional arguments in square brackets.

```
\includegraphics[scale=0.5]{mypicture.pdf}
\includegraphics[width=45mm]{mypicture.pdf}
\includegraphics[height=3cm]{mypicture.pdf}
\includegraphics[angle=45]{mypicture.pdf}
\includegraphics[angle=90,scale=0.5]{mypicture.pdf}
\includegraphics[width=0.5\textwidth]{mypicture.pdf}
```

Note that, for example, the command `width=45mm` scales the picture so that its width is 45mm while preserving the aspect ratio. If you specify both width and height at the same time then you risk stretching your figure, because to satisfy both instructions at the same time the program may have to scale by a different amount horizontally than it does vertically. The `angle=45` command will result in rotation *anticlockwise* through 45 degrees. The final command specifies that the picture be exactly half the width of the text.

Finally, for longer documents, it's good practice to label and number your figures. If you do this then you can refer back to them in the text by number. Figures are placed by LaTeX on the page where they will look best, so for example not right at the bottom of a page with only one line of text under them. Notice the `[hbt]` argument after the `\begin{figure}` in the text below. As in the section on tables, the `[hbt]` argument is used to give instructions about where the figure should go. In this case, it is indicating my preference that the figure should be inserted, in order of preference, 'here' in the text (that is, exactly where I've put it), but failing that at the bottom, then the top, of the current page.

```
\begin{figure}[hbt] \begin{center}
\includegraphics{mypicture.pdf}
\caption{My lovely picture}
\label{mypic}
\end{center} \end{figure}
```

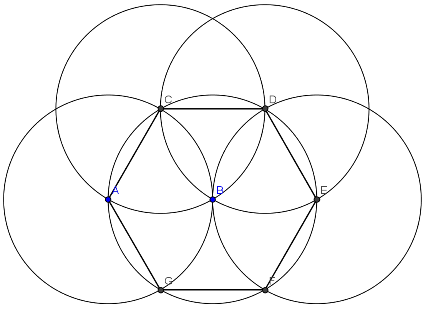
Having created a proper figure, as you might expect, you can refer back to it in the text by number. So you can type 'Figure `\ref{mypic}` shows', and this will produce the text 'Figure 1 shows' (if it's the first figure in your document of course!). There is more detail on including figures in the useful page here:

http://en.wikibooks.org/wiki/LaTeX/importing_Graphics

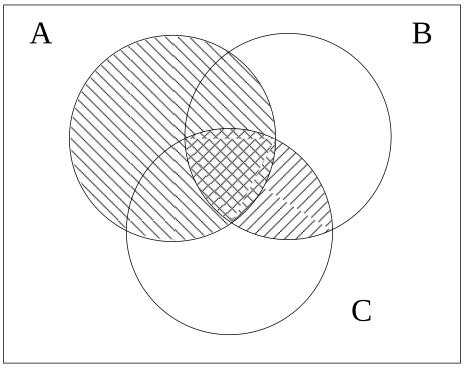
Creating Graphics

You may not need to create graphics for your dissertation, but if you do, there are several ways to do it, and we'll very briefly discuss some of them here. You can then go and explore the various options for yourself if and when you need them.

- Geogebra (www.geogebra.org) is a lovely, free program that allows you to construct and play with graphs, geometric diagrams and so on. You can create text labels for objects and export the finished results as `.eps`, `.pdf` or `.png` files. The following picture is an example of what can be produced very easily.

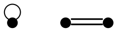


- WinFig (or xfig for mac users) is a LaTeX-compatible graphics program, mainly for drawing diagrams. It isn't free but is very cheap to buy. It works OK though can sometimes be frustrating. Here is an example of a Venn diagram produced using WinFig; as you can see it's not brilliant!



- Paint, as in the free tool that comes with Windows. I guess if you're desperate you could try it!

- Maple/Matlab are powerful pieces of software for doing mathematics. They can both plot graphs and are available in the department computer room. They have extensive tutorial and help support, so after a bit of experimentation you'll be able to produce graphs such as the following (much more complicated things are possible but you'll need to work that out for yourselves). By right clicking on the plot in the Maple worksheet you can save it as a `.pdf` file.

- LaTeX itself can be used to draw pictures. They can be small pictures, even appearing within a line of text, like this graph: . Here are the commands required to produce the graph.

```
\unitlength 0.7mm \linethickness{0.6pt}
\begin{picture}(5,5)(-2,-1.7)
```

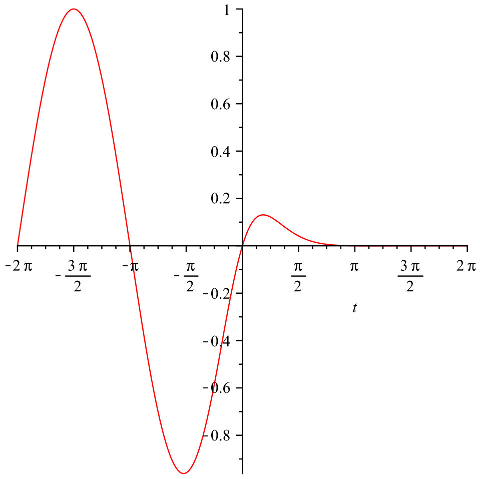


Figure 3.1: A Maple Picture

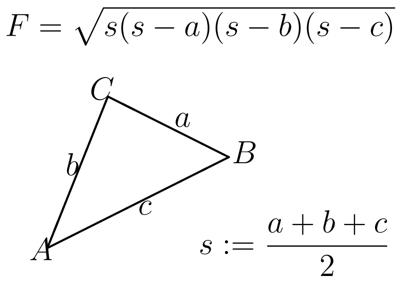
```
\put(0,0){\circle*{2.00}} \put(0,2){\circle{3}}
\end{picture}
%
\unitlength 0.7mm \linethickness{0.6pt}
\begin{picture}(13,5)(-2,-1.7)
\put(0,0){\circle*{2}} \put(8,0){\circle*{2}}
\put(1,0.7){\line(1,0){6}} \put(1,-0.3){\line(1,0){6}}
\end{picture}
```

Alternatively the pictures you draw can be full size diagrams incorporating text. I've taken the following diagram and commands from the '*Not so short introduction to LaTeX*', which was one of the documents in the recommended reading list and can be downloaded from the Moodle page for this module (or just by searching online – it's freely available). Chapter 5 of that book is devoted entirely to producing graphics in LaTeX, so I suggest you read it!

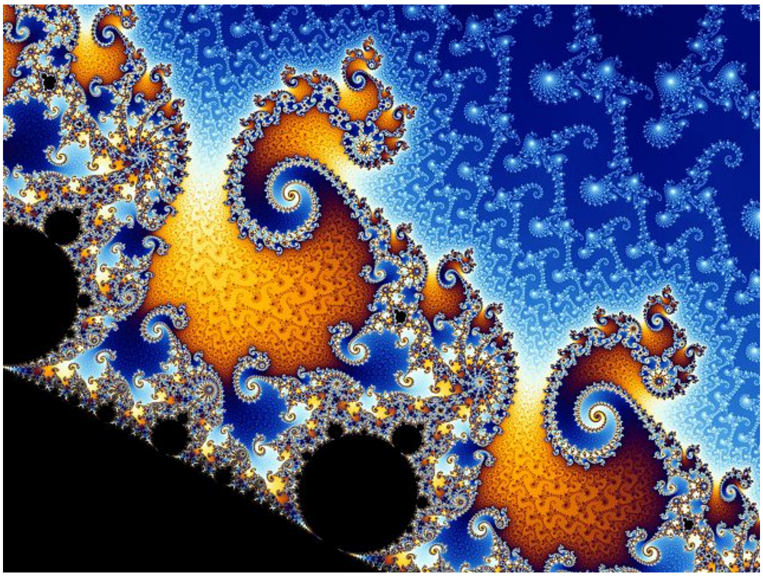
```
\begin{center}\setlength{\unitlength}{0.8cm}
\begin{picture}(6,5)
\thicklines
\put(1,0.5){\line(2,1){3}}
\put(4,2){\line(-2,1){2}}
\put(2,3){\line(-2,-5){1}}
\put(0.7,0.3){$A$}
\put(4.05,1.9){$B$}
\put(1.7,2.95){$C$}
\put(3.1,2.5){$a$}
\put(1.3,1.7){$b$}
\put(2.5,1.05){$c$}
```

```
\put(0.3,4){$F= \sqrt{s(s-a)(s-b)(s-c)}$}
\put(3.5,0.4){$\displaystyle s:=\frac{a+b+c}{2}$}
\end{picture}
\end{center}
```

This set of instructions produces the picture below.



- Finally, you can of course include photographs or other colour images, as these tend to be in `.jpg` format. You should be careful not to breach copyright if you are using images from books or the web, of course. The following is a (non-copyrighted) `.jpg` of the Mandelbrot set.



Exercise 30. Experiment with importing graphics, following the guidance below.

- Create a new section (Section 4) in your document `ExCh3.tex`, called *Pictures*. Include the relevant package commands in the preamble for including graphics.

- Include a picture in Section 4. For example `TrigGraph.pdf` is Figure 3.1 from this section; it can be downloaded from the Moodle page for this module. Specify that the picture should be scaled to 20%.

- Turn the picture you've imported into a figure, with a caption, and label it, for example with the command `\label{graph1}` or something similar.
- Include the sentence '*Figure 1 is the graph* $y = \frac{\sin(x)}{(1+(e^x)^2)}$.'
- Now import the picture four more times, creating captioned, labelled figures each time (so you end up with five figures in total). The first variation on Figure 1 should be 8cm wide. The second one should be 4cm high. The third should be both 8cm wide and 4cm high (look at the distortion that is created). The fourth should be half the size of Figure 1 and rotated 90 degrees anticlockwise.
- Add some text which describes each figure, making sure to use the `\ref{}` command. For example, '*Figure 2 is Figure 1 scaled to be 10cm wide*'.
- Finally, change the order of your figures with a bit of cutting and pasting, and make sure that the text still refers to the correct figures.

3.5 Good Mathematical Writing

So far we have concentrated mostly on simply processing your mathematics and text with LaTeX. There are whole books on good writing and I do not intend to write another one. In this section I will content myself with ten tips for making your mathematics easier to read and understand.

1. Think about structure. In a long report or dissertation, you should have chapters, sections and probably subsections. A good structure might be to have an introductory chapter setting up notation, terminology, basic concepts and results, then a chapter for each specific topic. Sections can split up the topic of a chapter further. Each new thought requires a new paragraph. The structure should be natural and not feel forced or arbitrary.

2. The page layout should not be too dense. This means that you should avoid having very narrow margins, and acres of uninterrupted text. Display equations rather than shoehorning lots of mathematics into lines. Start new paragraphs when necessary.

3. Define any notation you use if there is the slightest room for doubt about what it could mean, or if a fairly competent undergraduate might not recognise it. So you don't need to define $\mathbb{Z}$ and $\mathbb{R}$, for example, but if using $\mathbb{N}$ you should state for the record whether you are using it to mean the set of positive integers or the set of non-negative integers.

4. In the mathematics itself, pay attention to detail. Avoid death by subscript. If your notation requires something horrid like $x_{i_{j_k}}$, then it is not good notation! Avoid using symbols that look too similar to each other. For example the Greek letters *upsilon* and *nu* both look rather like each other and like the letter v in maths mode: υ, ν, v. So it would be foolhardy to use them together.

5. Follow convention. Variables are usually x, y, z. Constants are usually a, b, c. Scalars are often λ and μ. Vectors are usually $\mathbf{u}, \mathbf{v}, \mathbf{w}$. Complex numbers are usually z or w. There are subject specific conventions too. Groups are usually G, H. Normal subgroups are often N and K. Try to avoid using notation that normally means something else. So if you have a group G and want to consider an arbitrary subgroup, don't call that subgroup G' because this is fairly standard notation for the commutator subgroup of G. Similarly you should probably avoid calling anything but the identity matrix I and, if there are complex numbers floating about, using i as anything other than the square root of minus one is bound to lead to trouble.

6. Use the proper tools. If you want angled brackets, for example, then use them. Don't use the less than and greater than symbols. This is not mere pedantry. Using the wrong symbols can cause confusion. For example the expression $< x_i | i < n >$ is hard to decipher, whereas $\langle x_i | i < n \rangle$ is much easier.

7. Use the numbering, labelling and cross-referencing functionality provided by LaTeX. Avoid saying things like 'by the lemma above'. There may be several previous lemmas to which you could be referring. This also goes for lazily writing `Lemma 1` (for example) rather than `Lemma \ref{lemma1}`. You are a hostage to fortune when you go back and add, delete or move something in the editing process. But only number the equations to which you will refer back. In particular there is usually no need to number every single line of a long calculation. Mostly you should use the `align*` environment here.

8. Abbreviations should be avoided. This includes things like e.g., i.e., etc., wlog, wrt, iff, $\Rightarrow$, $\Leftrightarrow$, $\therefore$ and $\because$, though at a push QED is probably acceptable. While these are often used informally (and by lecturers on the whiteboard) they are not correct in a formal document.

9. Do not break off in the middle of a proof to state and prove a supplementary result. Before embarking on a proof you should have proved all the required lemmas and propositions that are needed to establish your main theorem and can then reference them in the proof. If a proof is very long, consider proving some parts of it separately (beforehand) as lemmas.

10. Treat mathematical symbols as part of the text, and do not overuse them. It is much easier for the reader to see '*Let x and y be positive integers*' than '*Let $x \in \mathbb{Z}^+, y \in \mathbb{Z}^+$*'. You should also make sure that you are producing grammatical sentences, even where mathematical symbols are used. You can test this by reading it to yourself. Here is a bad sentence: '*Let $x \in S$, $x > 7$.*' This reads, '*let x in S, x is greater than* 7'. What you really want to say is: '*let x be an element of S such that x is greater than 7*'. This could be slightly shortened to '*let x be an element of S such that $x > 7$*. A similar example is '*Let $A \subseteq B$ be a subset*', which reads '*Let A be a subset of B be a subset*'! Better to write '*let A be a subset of B*'. Do your best to avoid starting a sentence with a mathematical symbol. This is considered bad form!

3.6 Quick Reference

The tables in this handy ‘cut out and keep’ guide were originally prepared by David Carlisle at Manchester University, and he kindly shared them online. One or two of the more unusual symbols require the package `amssymb`.

α	`\alpha`	θ	`\theta`	o	`o`	τ	`\tau`
β	`\beta`	ϑ	`\vartheta`	π	`\pi`	υ	`\upsilon`
γ	`\gamma`	γ	`\gamma`	ϖ	`\varpi`	ϕ	`\phi`
δ	`\delta`	κ	`\kappa`	ρ	`\rho`	φ	`\varphi`
ϵ	`\epsilon`	λ	`\lambda`	ϱ	`\varrho`	χ	`\chi`
ε	`\varepsilon`	μ	`\mu`	σ	`\sigma`	ψ	`\psi`
ζ	`\zeta`	ν	`\nu`	ς	`\varsigma`	ω	`\omega`
η	`\eta`	ξ	`\xi`				

Γ	`\Gamma`	Λ	`\Lambda`	Σ	`\Sigma`	Ψ	`\Psi`
Δ	`\Delta`	Ξ	`\Xi`	Υ	`\Upsilon`	Ω	`\Omega`
Θ	`\Theta`	Π	`\Pi`	Φ	`\Phi`		

Table 3.1: Greek Letters

$\pm$	`\pm`	$\cap$	`\cap`	$\diamond$	`\diamond`	$\oplus$	`\oplus`
$\mp$	`\mp`	$\cup$	`\cup`	$\bigtriangleup$	`\bigtriangleup`	$\ominus$	`\ominus`
$\times$	`\times`	$\uplus$	`\uplus`	$\bigtriangledown$	`\bigtriangledown`	$\otimes$	`\otimes`
$\div$	`\div`	$\sqcap$	`\sqcap`	$\triangleleft$	`\triangleleft`	$\oslash$	`\oslash`
$\ast$	`\ast`	$\sqcup$	`\sqcup`	$\triangleright$	`\triangleright`	$\odot$	`\odot`
$\star$	`\star`	$\vee$	`\vee`	$\lhd$	`\lhd`	$\bigcirc$	`\bigcirc`
$\circ$	`\circ`	$\wedge$	`\wedge`	$\rhd$	`\rhd`	$\dagger$	`\dagger`
$\bullet$	`\bullet`	$\setminus$	`\setminus`	$\unlhd$	`\unlhd`	$\ddagger$	`\ddagger`
$\cdot$	`\cdot`	$\wr$	`\wr`	$\unrhd$	`\unrhd`	$\amalg$	`\amalg`
$+$	`+`	$-$	`-`				

Table 3.2: Binary Operation Symbols

$\hat{a}$	`\hat{a}`	$\acute{a}$	`\acute{a}`	$\bar{a}$	`\bar{a}`	$\dot{a}$	`\dot{a}`	$\breve{a}$	`\breve{a}`
$\check{a}$	`\check{a}`	$\grave{a}$	`\grave{a}`	$\vec{a}$	`\vec{a}`	$\ddot{a}$	`\ddot{a}`	$\tilde{a}$	`\tilde{a}`

Table 3.3: Math mode accents

$\leq$	\leq	$\geq$	\geq	$\equiv$	\equiv	$\models$	\models
$\prec$	\prec	$\succ$	\succ	$\sim$	\sim	$\perp$	\perp
$\preceq$	\preceq	$\succeq$	\succeq	$\simeq$	\simeq	$\mid$	\mid
$\ll$	\ll	$\gg$	\gg	$\asymp$	\asymp	$\parallel$	\parallel
$\subset$	\subset	$\supset$	\supset	$\approx$	\approx	$\bowtie$	\bowtie
$\subseteq$	\subseteq	$\supseteq$	\supseteq	$\cong$	\cong	$\Join$	\Join
$\sqsubset$	\sqsubset	$\sqsupset$	\sqsupset	$\neq$	\neq	$\smile$	\smile
$\sqsubseteq$	\sqsubseteq	$\sqsupseteq$	\sqsupseteq	$\doteq$	\doteq	$\frown$	\frown
$\in$	\in	$\ni$	\ni	$\propto$	\propto	$=$	=
$\vdash$	\vdash	$\dashv$	\dashv	$<$	<	$>$	>
$:$	:						

Table 3.4: Relation Symbols

$\leftarrow$	\leftarrow	$\longleftarrow$	\longleftarrow	$\uparrow$	\uparrow
$\Leftarrow$	\Leftarrow	$\Longleftarrow$	\Longleftarrow	$\Uparrow$	\Uparrow
$\rightarrow$	\rightarrow	$\longrightarrow$	\longrightarrow	$\downarrow$	\downarrow
$\Rightarrow$	\Rightarrow	$\Longrightarrow$	\Longrightarrow	$\Downarrow$	\Downarrow
$\leftrightarrow$	\leftrightarrow	$\longleftrightarrow$	\longleftrightarrow	$\updownarrow$	\updownarrow
$\Leftrightarrow$	\Leftrightarrow	$\Longleftrightarrow$	\Longleftrightarrow	$\Updownarrow$	\Updownarrow
$\mapsto$	\mapsto	$\longmapsto$	\longmapsto	$\nearrow$	\nearrow
$\hookleftarrow$	\hookleftarrow	$\hookrightarrow$	\hookrightarrow	$\searrow$	\searrow
$\leftharpoonup$	\leftharpoonup	$\rightharpoonup$	\rightharpoonup	$\swarrow$	\swarrow
$\leftharpoondown$	\leftharpoondown	$\rightharpoondown$	\rightharpoondown	$\nwarrow$	\nwarrow
$\rightleftharpoons$	\rightleftharpoons	$\leadsto$	\leadsto		

Table 3.5: Arrow Symbols

$\ldots$	\ldots	$\cdots$	\cdots	$\vdots$	\vdots	$\ddots$	\ddots
$\aleph$	\aleph	$\prime$	\prime	$\forall$	\forall	∞	\infty
$\hbar$	\hbar	$\emptyset$	\emptyset	$\exists$	\exists	$\Box$	\Box
$\imath$	\imath	∇	\nabla	$\neg$	\neg	$\Diamond$	\Diamond
$\jmath$	\jmath	$\surd$	\surd	$\flat$	\flat	$\triangle$	\triangle
ℓ	\ell	$\top$	\top	$\natural$	\natural	$\clubsuit$	\clubsuit
$\wp$	\wp	$\bot$	\bot	$\sharp$	\sharp	$\diamondsuit$	\diamondsuit
$\Re$	\Re	$\Vert$	\\\|	$\backslash$	\backslash	$\heartsuit$	\heartsuit
$\Im$	\Im	$\angle$	\angle	∂	\partial	$\spadesuit$	\spadesuit
$\mho$	\mho	$.$	.	$\vert$	|		

Table 3.6: Miscellaneous Symbols

$\sum$	`\sum`	$\bigcap$	`\bigcap`	$\bigodot$	`\bigodot`
$\prod$	`\prod`	$\bigcup$	`\bigcup`	$\bigotimes$	`\bigotimes`
$\coprod$	`\coprod`	$\bigsqcup$	`\bigsqcup`	$\bigoplus$	`\bigoplus`
$\int$	`\int`	$\bigvee$	`\bigvee`	$\biguplus$	`\biguplus`
$\oint$	`\oint`	$\bigwedge$	`\bigwedge`		

Table 3.7: Variable-sized Symbols

`\arccos`	`\cos`	`\csc`	`\exp`	`\ker`	`\limsup`	`\min`	`\sinh`
`\arcsin`	`\cosh`	`\deg`	`\gcd`	`\lg`	`\ln`	`\Pr`	`\sup`
`\arctan`	`\cot`	`\det`	`\hom`	`\lim`	`\log`	`\sec`	`\tan`
`\arg`	`\coth`	`\dim`	`\inf`	`\liminf`	`\max`	`\sin`	`\tanh`

Table 3.8: Log-like Symbols

<table>
<tr><td>$($</td><td><code>(</code></td><td>$)$</td><td><code>)</code></td><td>$\uparrow$</td><td><code>\uparrow</code></td><td>$\Uparrow$</td><td><code>\Uparrow</code></td></tr>
<tr><td>$[$</td><td><code>[</code></td><td>$]$</td><td><code>]</code></td><td>$\downarrow$</td><td><code>\downarrow</code></td><td>$\Downarrow$</td><td><code>\Downarrow</code></td></tr>
<tr><td>$\{$</td><td><code>\{</code></td><td>$\}$</td><td><code>\}</code></td><td>$\updownarrow$</td><td><code>\updownarrow</code></td><td>$\Updownarrow$</td><td><code>\Updownarrow</code></td></tr>
<tr><td>$\lfloor$</td><td><code>\lfloor</code></td><td>$\rfloor$</td><td><code>\rfloor</code></td><td>$\lceil$</td><td><code>\lceil</code></td><td>$\rceil$</td><td><code>\rceil</code></td></tr>
<tr><td>$\langle$</td><td><code>\langle</code></td><td>$\rangle$</td><td><code>\rangle</code></td><td>$/$</td><td><code>/</code></td><td>$\backslash$</td><td><code>\backslash</code></td></tr>
<tr><td>$\vert$</td><td><code>|</code></td><td>$\Vert$</td><td><code>\|</code></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 3.9: Delimiters

$\rmoustache$	`\rmoustache`	$\lmoustache$	`\lmoustache`	$\rgroup$	`\rgroup`	$\lgroup$	`\lgroup`
$\arrowvert$	`\arrowvert`	$\Arrowvert$	`\Arrowvert`	$\bracevert$	`\bracevert`		

Table 3.10: Large Delimiters

$\widetilde{abc}$	`\widetilde{abc}`	$\widehat{abc}$	`\widehat{abc}`
$\overleftarrow{abc}$	`\overleftarrow{abc}`	$\overrightarrow{abc}$	`\overrightarrow{abc}`
$\overline{abc}$	`\overline{abc}`	$\underline{abc}$	`\underline{abc}`
$\overbrace{abc}$	`\overbrace{abc}`	$\underbrace{abc}$	`\underbrace{abc}`
$\sqrt{abc}$	`\sqrt{abc}`	$\sqrt[n]{abc}$	`\sqrt[n]{abc}`
f'	`f'`	$\frac{abc}{xyz}$	`\frac{abc}{xyz}`

Table 3.11: Some other constructions

Chapter 4

Presentations

This chapter is about preparing presentations using LaTeX. As part of your dissertation module, you will be giving two presentations. The first is a short, informal one (the *Preliminary presentation*) at the end of the Autumn Term in your second year. For this you may well choose (or indeed have chosen!) to simply write on the whiteboard, though some people do prefer having everything written in advance on slides, even for a short presentation. The main presentation is a different matter. This is a 20 minute final presentation of your project, to be given shortly after you submit your finished dissertation. Lecturers and fellow students will be present, and you will wish to give a polished performance. This chapter is written with that presentation in mind.

The main tool used for preparing LaTeX presentations is the `beamer` package. In the first section of this chapter we will start by creating a very simple presentation. In subsequent sections we will look at creating a title page, choosing 'themes' (which determine colour schemes and so on), using the 'Birkbeck' theme, slide layout, effects such as gradual reveal, and guidelines for good presentation design. The aim here is to give you a brief overview, enough so that you can prepare a competent presentation. As ever, LaTeX is almost infinitely customisable. Very full documentation about the `beamer` class is given in the *Beamer User Guide*. At 245 pages it really does tell you everything you could want to know. It is freely available online and also on the Moodle page for this module.

4.1 A simple presentation

The following commands produce a presentation consisting of a single slide.

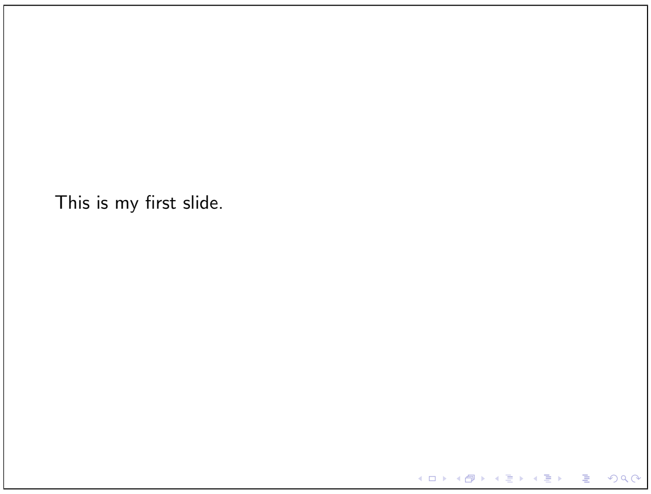
Preamble	`\documentclass{beamer}`
	`\usepackage{amsfonts,amsmath,amssymb}`

Begin Document	`\begin{document}`

A slide	`\begin{frame}`
	`This is my first slide.`
	`\end{frame}`

End Document	`\end{document}`

As you can see, slides are produced as ‘frames’ and are created in the `frame` environment. The resulting document is shown over the page.



This is my first slide.

Notice that the font is a sans serif font (called computer modern). Fonts such as this are easier to read in presentations and their clean lines make for a better looking slide. It is possible to alter the size and typeface but not without effort. We will look briefly at this in Section 4.3. At the bottom of the slide there are various symbols. These are navigation tools that are present in the default beamer style. We'll discuss them when we have a slightly longer document to navigate through.

To create more slides you simply add more frames. Adding the following text to the simple presentation above will create a second slide containing the text ‘This is my next slide.’

```
\begin{frame}
This is my next slide.
\end{frame}
```

Exercise 31. Create a presentation called `myslides.tex`, consisting of four slides each containing one line of text.

Frames may be given titles (and even subtitles) as shown in Example 4.1. You will also see that standard LaTeX commands work here, but the results are slightly different. Theorems, for example, are *not* numbered (or, to be more precise, the numbers are not shown).

Example 4.1. The following commands will produce a frame of output.

```
\begin{frame}
\frametitle{Fractions don’t exist}

\begin{theorem}
The smallest positive number is 1.
```

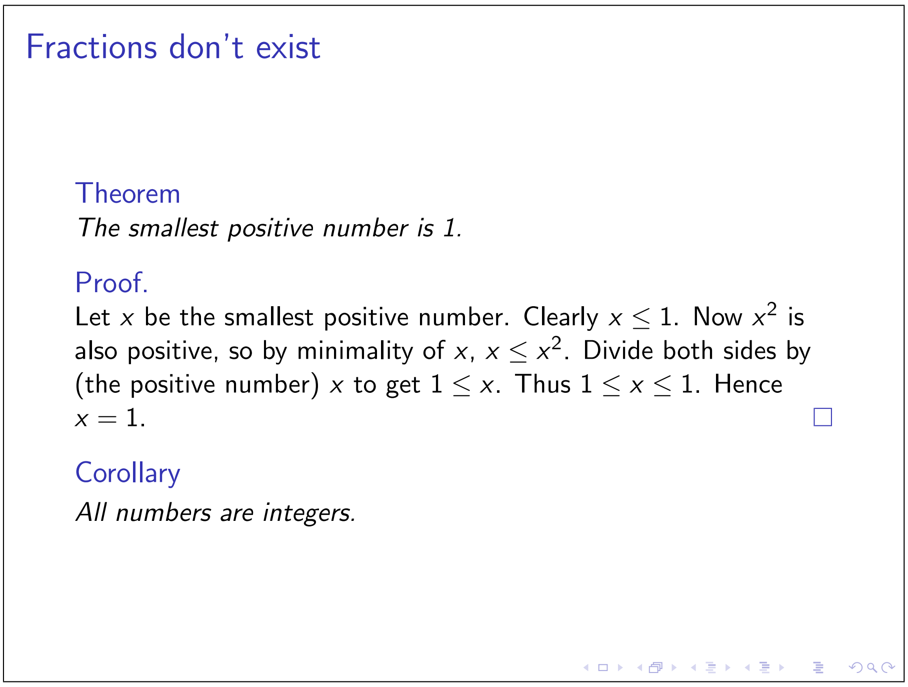
```
\end{theorem}

\begin{proof}
Let $x$ be the smallest positive number. Clearly $x \leq 1$. Now $x^2$ is also
positive, so by minimality of $x$, $x \leq x^2$. Divide both sides by (the
positive number) $x$ to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x=1$.
\end{proof}

\begin{corollary}
All numbers are integers.
\end{corollary}

\end{frame}
```

The above input creates the following frame.



Fractions don't exist

Theorem

The smallest positive number is 1.

Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

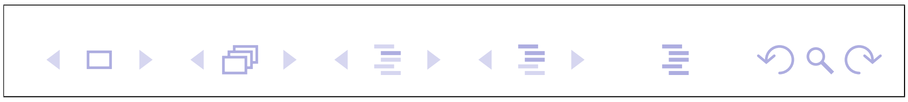
All numbers are integers.

You may be looking at a black and white printout, in which case note that the title and the words *theorem, proof* and *corollary* are blue here. That is the default beamer style.

We could have added a subtitle using the command `\framesubtitle{This is a lie}`, or similar.

Exercise 32. In your presentation `myslides.tex` or elsewhere, add titles to your pages, and subtitles to two of the pages. Add a new first page which is the page created in Example 4.1.

Here is a closer view of the navigation symbols on the slides.



Working left to right, the symbols represent slides, frames, subsections and sections. Clicking to the left or right of each symbol causes you to jump backward or forward one slide, frame, subsection or section respectively. (The difference between a slide and a frame is that in theory it is possible to have a frame over-run into more than one slide. This is best avoided as many of the commands, such as gradual reveal and titling, won't work. So for our purposes slides and frames are the same.) The final symbols are undo, search and redo.

You can nagivate your way around the final pdf document by pressing the up and down arrow keys on your keyboard. For a short presentation you will have so few slides that this will suffice and you may not wish to go to the trouble of dividing your document into sections. The usual reason for making these subdivisions in a standard article is that we are numbering things and cross-referring. We also have different sizes of headings and so on. But in a presentation it is best to avoid numbering completely. No-one will remember what 'Theorem 2.1' was. For this reason the commands `\section` and `\subsection` do not have the same effect in the beamer class. They do not create headings, for example. In a document without sections most of these navigation tools then become redundant, and so they have been omitted from the Birkbeck package introduced in Section 4.4.

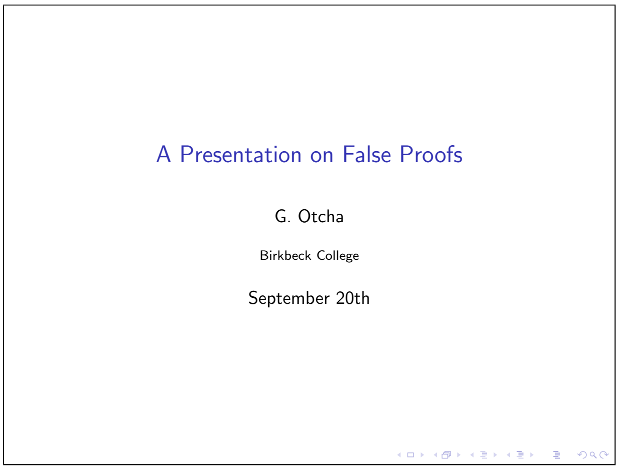
4.2 Creating a Title Page

Your presentation needs a title page. As with titles in articles and other LaTeX documents, this is achieved by stating the title, author, date and so on, and then issuing a command to produce the title. Here it is `\titlepage` rather than `\maketitle`.

After `\begin{document}` the following commands will produce the title page shown on the right.

```
\title{A Presentation on False Proofs}
\author{G.~Otcha}
\institute{Birkbeck College}
\date{September 20th}

\begin{frame}
\titlepage
\end{frame}
```



A Presentation on False Proofs

G. Otcha

Birkbeck College

September 20th

Note that if you have a very long title, author or date, you can have an optional argument in square brackets with a short version. For example

```
\date[20th September]{Just after six o'clock on the twentieth day of September}
```

You would do this if your presentation theme (see the next section) shows the title, date or author at the top or bottom of each frame.

Exercise 33. Add a title page to your document `myslides.tex`.

4.3 Themes

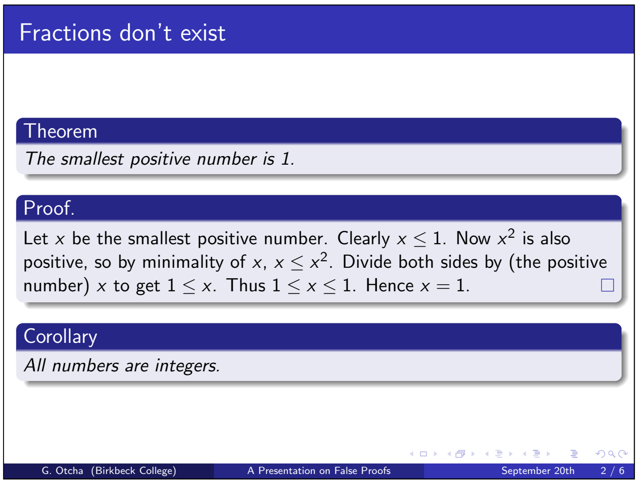
The style of a presentation is called a *theme*. If nothing is specified in the preamble, then the default theme is used. It has a white background, blue headings, no left or right sidebars, and small navigation buttons at the bottom of the page. There are many ways in which you can change the style of your presentation. The most major change is the presentation theme, but you can also vary colour schemes and choice of font within that. It is possible to change individually almost any detail of the slide and presentation structure, but there is no real need to do this unless you wish to. More or less you will simply choose a presentation theme and colour scheme from the available options.

Presentation Themes

These are wholesale specifications for every aspect of a presentation: colour scheme, the symbols used for lists, the font, what sidebars are shown, and so on. Presentation Themes are named after cities. An example is `madrid`. To specify a theme include the line (for example) `\usetheme{Madrid}` in the preamble. If you do not specify a theme then the default theme will be used. For a list of available presentation themes see the *Beamer User Guide*, which is available online, including on the Moodle page for this module. Maura Paterson has designed a Birkbeck Presentation Theme which is the subject of the next section.

On the next page you see the slide from Example 4.1. The only change is the addition of a `\usetheme` command to the preamble. The page on the left results from the command `\usetheme{Madrid}`. The page on the right results from the command `\usetheme{Warsaw}`.

Note that Warsaw shows section and subsection titles at the top of the page. Also note if you are looking at a black and white printout that the colour scheme for these is blue.



Fractions don't exist

Theorem

The smallest positive number is 1.

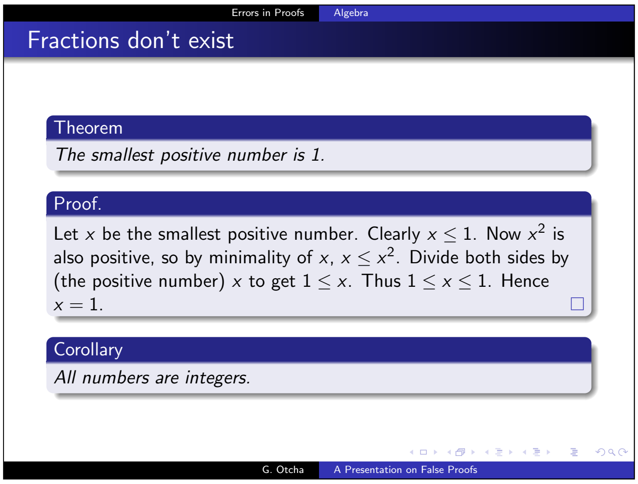
Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

All numbers are integers.

G. Otcha (Birkbeck College) A Presentation on False Proofs September 20th 2 / 6



Errors in Proofs Algebra

Fractions don't exist

Theorem

The smallest positive number is 1.

Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

All numbers are integers.

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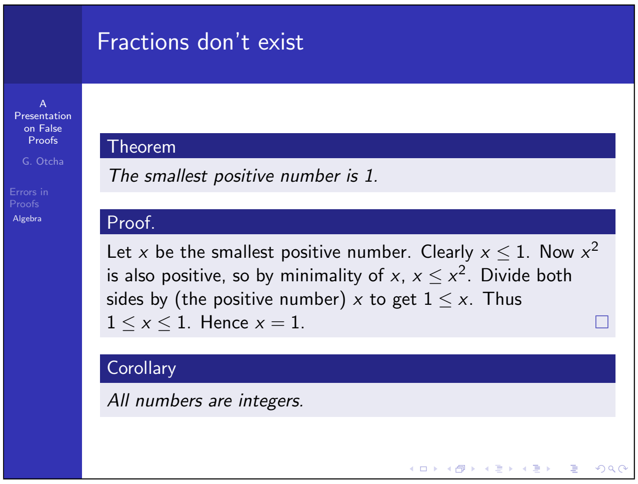
Colour Themes

A colour theme only controls the colour palette of the presentation. If no command is given, the default colour theme for your chosen presentation theme will be used. To specify a colour theme include *after* choosing your main theme, the line (for example) `\usecolortheme{seagull}`. **Note: color has the American spelling!** The `seagull` theme, for example, creates various greys for the backgrounds. Below you will see the sample page from Example 4.1. The page on the left results from the command `\usetheme{Berkeley}` in the preamble. The page on the right results from inserting into the preamble the command `\usetheme{Berkeley}` followed by the command `\usecolortheme{albatross}`.



A Presentation on False Proofs

G. Otcha

Errors in Proofs

Algebra

Fractions don't exist

Theorem

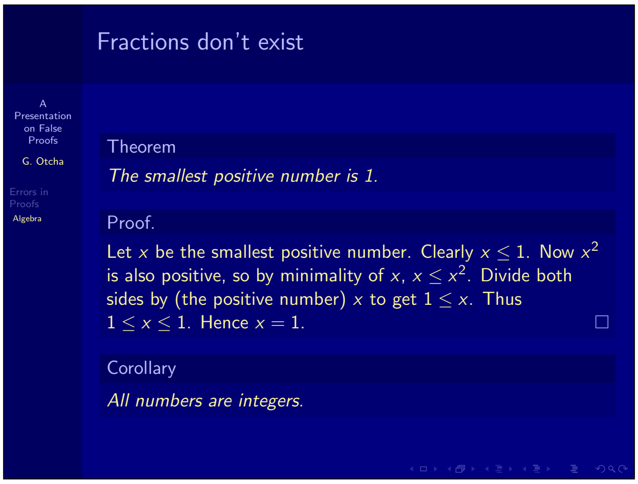
The smallest positive number is 1.

Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

All numbers are integers.



A Presentation on False Proofs

G. Otcha

Errors in Proofs

Algebra

Fractions don't exist

Theorem

The smallest positive number is 1.

Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

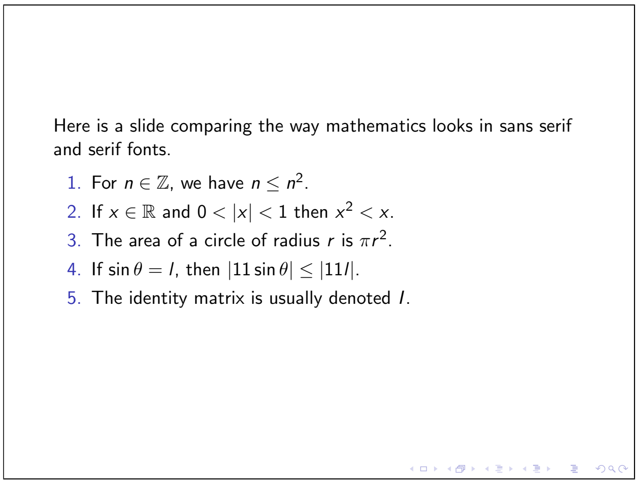
All numbers are integers.

Beamer colour themes are mostly named after flying animals, such as beetle, dove, fly. It is also possible to dictate precise colour changes, such as the colour of one sidebar. However you then risk picking colours that look awful together! Again, for a list of standard colour themes see the *Beamer User Guide*.

Exercise 34. Modify your presentation `myslides.tex` as follows. Firstly create at least one section and at least one subsection. This is done with the usual `section` and `subsection` commands, which should be placed between frames. Then experiment with the presentation themes `Madrid`, `Frankfurt`, `Copenhagen` and `Antibes`, and the colour themes `albatross`, `dove`, `spruce` and `beetle`.

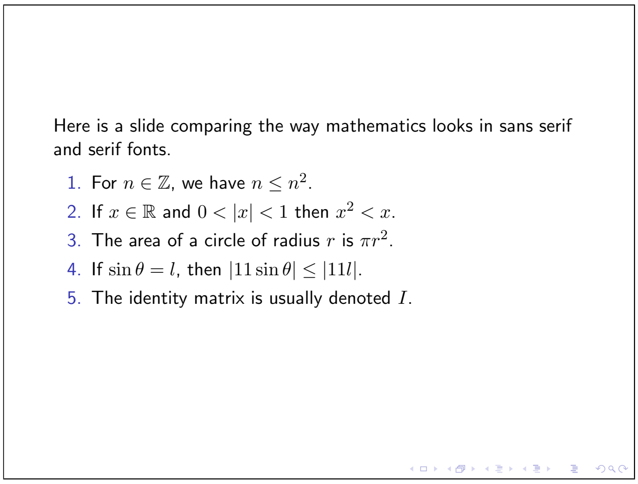
Font Themes

Obviously these themes specify fonts. It is unlikely that you will need to alter standard settings very much, but there are one or two commands here that may be of use. We have remarked that the text in presentations is by default sans serif. This is mostly fine except that in mathematics we are so used to seeing serif fonts that it is often easier on the eye to typeset mathematics in this way. To achieve serif mathematics while retaining the rest of the document in sans serif font, add the line `\usefonttheme[onlymath]{serif}` to the preamble after specifying your theme. Over the page you will see, for comparison, two slides; the one on the right makes use of the `\usefonttheme[onlymath]{serif}` command. The page on the left does not. While consistency of typeface is usually desirable, you may feel that, depending on the content of your presentation, the introduction of serifs for mathematics may well be worthwhile.



Here is a slide comparing the way mathematics looks in sans serif and serif fonts.

1. For $n \in \mathbb{Z}$, we have $n \leq n^2$.
2. If $x \in \mathbb{R}$ and $0 < |x| < 1$ then $x^2 < x$.
3. The area of a circle of radius r is πr^2.
4. If $\sin\theta = l$, then $|11 \sin\theta| \leq |11l|$.
5. The identity matrix is usually denoted I.



Here is a slide comparing the way mathematics looks in sans serif and serif fonts.

1. For $n \in \mathbb{Z}$, we have $n \leq n^2$.
2. If $x \in \mathbb{R}$ and $0 < |x| < 1$ then $x^2 < x$.
3. The area of a circle of radius r is πr^2.
4. If $\sin\theta = l$, then $|11 \sin\theta| \leq |11l|$.
5. The identity matrix is usually denoted I.

Inner and Outer Themes

Inner themes alter things that happen inside a frame. That is, in the body of the slide rather than any sidebars, borders, headers and footers. You can change symbols used for lists, the way in which theorems are shown (in a box or not, for example) and other things. Outer themes govern page layout – the style and contents of any headers, footers and sidebars. For the most part you are likely to be happy with the set-up of whatever presentation theme you use. See the *Beamer User Guide* for more information.

Remember that the rationale for choosing given themes, or elements of themes, is ease of comprehension. Any changes you make should be justifiable in terms of making the talk easier to follow.

4.4 A Birkbeck Presentation

Maura Paterson has designed a special Birkbeck package for presentations which is available for Birkbeck students and staff to use. To do so, you will need to download the following files from Moodle.

```
bbklogo.jpg
beamerthemebbk2.sty
```

You should be sure to save these files in the same directory as the presentation for which you will be using them.

Maura has also give permission for you to access the `.tex` file of a presentation she prepared on her research, using the Birkbeck theme. The file is called `khoptalk.tex` and again you can download it from Moodle or the computer lab.

To use the Birkbeck theme, you will need to insert the following lines into your preamble.

```
\usetheme{bbk2}
\usefonttheme{structurebold}
\usepackage{graphicx}
```

You can include the Birkbeck logo in your title page too. The following is a basic document that uses the Birkbeck theme, and which you can modify as you wish.

Preamble

```
\documentclass{beamer}
\mode<presentation>
\usetheme{bbk2}
\usefonttheme[onlymath]{serif}
\usepackage{graphicx}
```

Begin Document

```
\begin{document}
```

Title Page

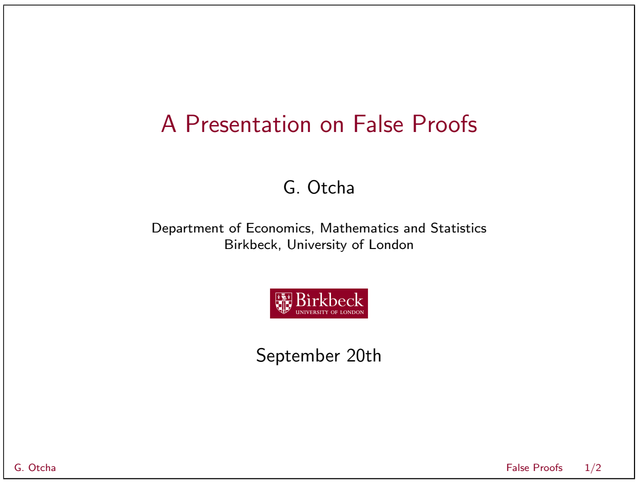
```
\title[False Proofs]{A Presentation on False Proofs}
\author{G.~Otcha}
\institute[Birkbeck College]
{Department of Economics, Mathematics and Statistics\\
 Birkbeck, University of London\\ \vspace{0.7cm}
\includegraphics[width=2cm]{bbklogo}}
\date{September 20th}
\begin{frame}\titlepage\end{frame}
```

A slide	`\begin{frame}`
	`\frametitle{Summary of Results}`
	`My research is fascinating.`
	`\end{frame}`

End Document	`\end{document}`

Exercise 35. Create a presentation using the Birkbeck theme, by modifying your `myslides.tex` presentation accordingly (or starting from scratch).

You will have noticed that the Birkbeck logo is in fact inserted manually into the title page, so that even using the Birkbeck presentation theme, you are not compelled to use the logo, nor indeed to mention the word 'Birkbeck' anywhere. The job of the theme is to set up the look of the slides. The colour scheme uses Birkbeck college colours (dark red, essentially) and sets up the structure of slides. You will see below the title page and a sample slide from a presentation using the Birkbeck theme. The nagivation symbols are omitted on the grounds that they are not useful during a short talk, and section headings are not shown. What is shown is the author's name and the current slide number. This gives both you and the audience a feel for how far through the talk you are. If you have three minutes to go and are on slide 3 of 15, you may see some worried faces!



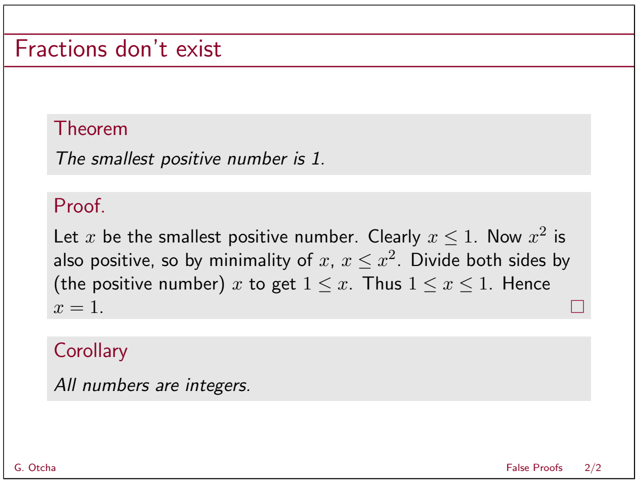
A Presentation on False Proofs

G. Otcha

Department of Economics, Mathematics and Statistics
Birkbeck, University of London

September 20th

G. Otcha False Proofs 1/2



Fractions don't exist

Theorem

The smallest positive number is 1.

Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

All numbers are integers.

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The title page commands would work in other presentation themes too of course. As a final possibility, if you are feeling brave you may modify the style file `beamerthemebbk2.sty` to create different results.

Note: For reasons that I do not understand, occasionally when a new frame is added LaTeX takes more than one attempt to realise that the total number of slides has gone up. So you may add a slide, LaTeX your work and see that it is labelled slide 6/5 or something similarly ridiculous. This will fix itself on the next running of LaTeX but always check the page numbering when you have finished preparing the presentation.

4.5 Creating Slides

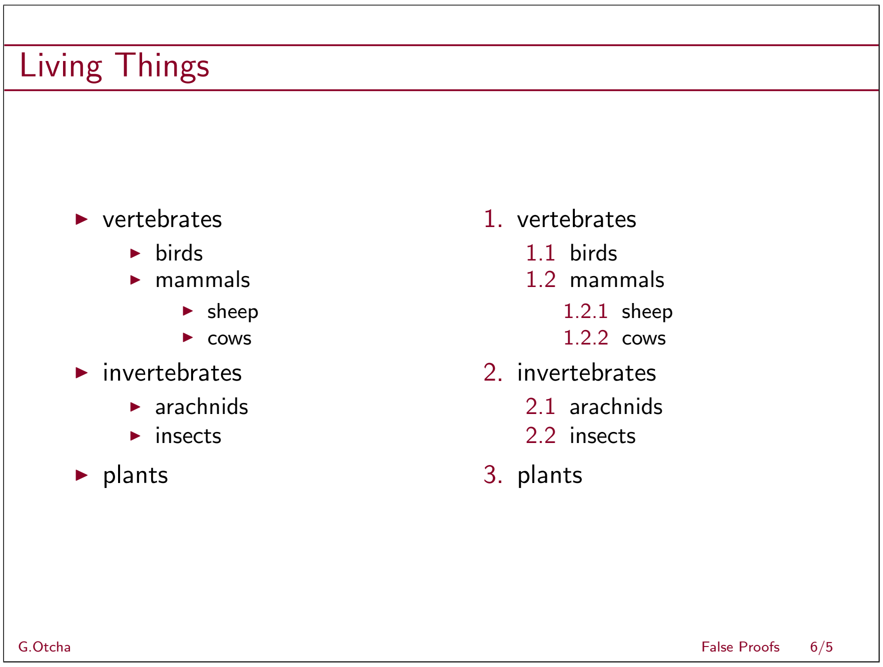
Having established the overall look of your presentation with presentation and colour themes, it is now time to think about the content of, and layout within, the slides themselves. Broadly speaking, standard LaTeX commands work more or less as expected. There are a few exceptions. You can create as many slides (frames) as you like. If you write too much text in any one frame, it will overspill to another slide, and you'll need to add another frame when you spot this. The command `\frametitle{Title}` will give your slide a title; if you don't want that slide to have a title, just omit this command.

Numbering

We have already remarked that theorems, examples and other environments that are numbered by LaTeX will not appear to be numbered in a presentation. People won't remember things by number. If you want to refer back to a result you have stated, it is sensible to either give it a name (for example Lagrange's Theorem, or 'The Main Theorem') or to restate it when required. Hopefully in a short presentation you will only have a handful of results and will be able to distinguish easily between them.

Lists

For the most part it is not necessary to have numbered lists. But the `enumerate` environment will produce them for you, should you so desire. For bulleted lists, which is what you are likely to need, you can use the `itemize` environment as usual. On a slide, lists are often a useful and clear way of getting information across. Below is a sample slide from a presentation prepared in the Birkbeck theme. The `itemize` environment has been used on the left; the `enumerate` environment on the right.



Living Things

- vertebrates
  - birds
  - mammals
    - sheep
    - cows
- invertebrates
  - arachnids
  - insects
- plants

1. vertebrates
   1.1 birds
   1.2 mammals
      1.2.1 sheep
      1.2.2 cows
2. invertebrates
   2.1 arachnids
   2.2 insects
3. plants

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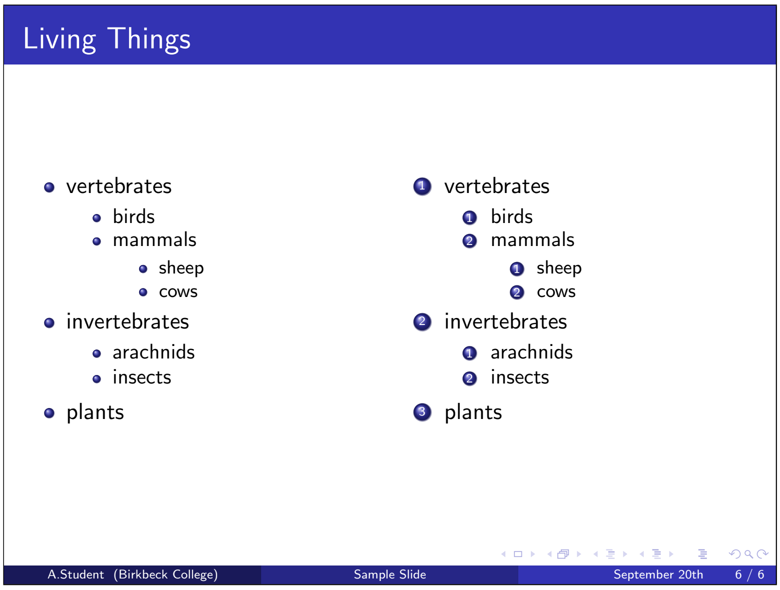
Items in sublists of each type are shown in a smaller font size. The symbol indicating items in an itemized list is always the same, a triangle, but the placement on the frame, and the size of the text, clearly indicates list level. In the enumerated list on the right, you will see that the numbering is 1, 1.1, 1.1.1 and so on. In other presentations the symbols differ. You can experiment, and of course as ever all these things can be changed if you try hard enough. As an example of a different theme's treatment of lists, the following is the same sample frame, but using the presentation theme `Madrid`.



Living Things

- vertebrates
  - birds
  - mammals
    - sheep
    - cows
- invertebrates
  - arachnids
  - insects
- plants

1. vertebrates
   1. birds
   2. mammals
      1. sheep
      2. cows
2. invertebrates
   1. arachnids
   2. insects
3. plants

A.Student (Birkbeck College) Sample Slide September 20th 6 / 6

Emphasis

The `\em` command does work, but since we have colour available to us, you may prefer to use the `\alert` command. The default setting is that it turns the selected text red. So to highlight the phrase 'at least one' in the following sentence, you would use the following raw tex.

```
Every cubic equation has \alert{at least one} real solution.
```

Figures and Tables

The `\includegraphics` command works in Beamer as with standard documents. You will need to think about the way in which you show pictures. Think carefully about whether you need to label figures and give them titles. After all you will be there explaining what the diagrams are at the time. Similar advice goes for tables. Note that any placement options for figures and tables will be ignored by Beamer. It simply places figures and tables as they are put in the text. This is because slides contain so little material that specifying 'top', 'here' or 'bottom' is not so vital. The outcome is that you have more control. You can place text next to figures or tables using the `columns` environment, which we are about to discuss. It is possible to include sounds, film clips and animations too, but I do not expect many of you to need this option, which requires the `multimedia` package. See the *Beamer User Guide* for more information.

Columns

It can be useful to divide the page, or parts of the page, up into columns, probably at most two. This is done using the following commands.

```
\begin{columns}
\begin{column}{0.45\textwidth}
whatever you want in your first column
\end{column}

\begin{column}{0.45\textwidth}
whatever you want in your second column
\end{column}
\end{columns}
```

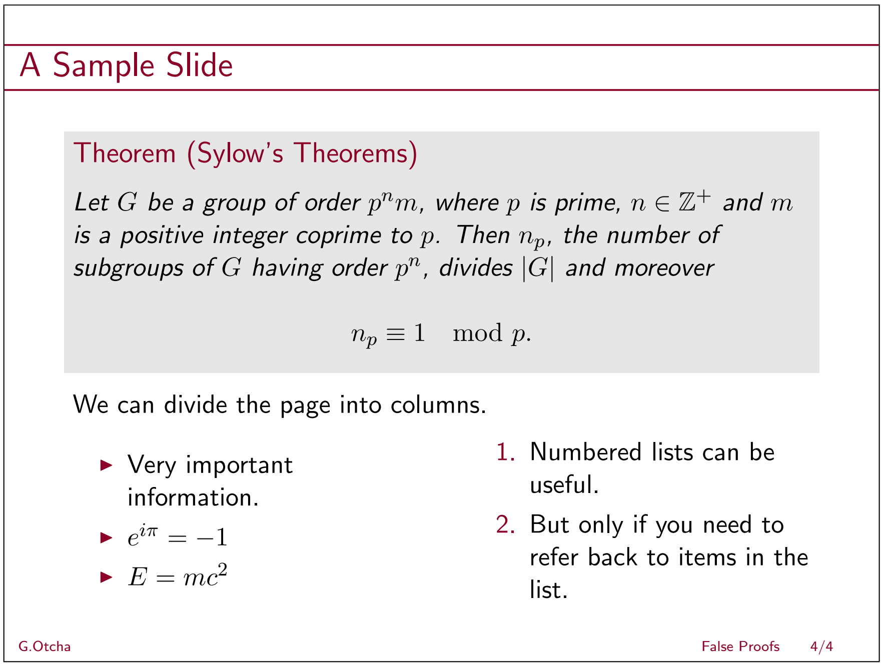
The width of the column is defined in this example to be slightly less than half the width of the text, though you can specify an exact width if you wish, in millimetres (mm), centimetres (cm), inches (in) or points (pt). As long as the total width of your combined columns does not exceed the total textwidth, anything goes.

The columns environment is flexible in that a frame can contain parts with different numbers of columns.

Example 4.2. The following text outputs a frame with a theorem (across the whole page) followed by two columns of text.

```
\begin{frame}\frametitle{A Sample Slide}
\begin{theorem}[Sylow's Theorems]
Let $G$ be a group of order $p^nm$, where $p$ is prime, $n \in \mathbb{Z}^+$
and $m$ is a positive integer coprime to $p$. Then $n_p$, the number of
subgroups of $G$ having order $p^n$, divides $|G|$ and moreover

\[n_p \equiv 1 \mod{p}.\]
\end{theorem}

We can divide the page into columns.

\begin{columns}
  \begin{column}{0.45\textwidth}
  \begin{itemize}
    \item Very important information.
    \item $e^{i\pi} = -1$
    \item $E=mc^2$
  \end{itemize}
  \end{column}
  \begin{column}{0.45\textwidth}
  \begin{enumerate}
    \item Numbered lists can be useful.
    \item But only if you need to refer back to items in the list.
  \end{enumerate}
  \end{column}
\end{columns}

\end{frame}
```

Here is the resulting output.



A Sample Slide

Theorem (Sylow's Theorems)

Let G be a group of order $p^n m$, where p is prime, $n \in \mathbb{Z}^+$ and m is a positive integer coprime to p. Then n_p, the number of subgroups of G having order p^n, divides $|G|$ and moreover

$$n_p \equiv 1 \mod p.$$

We can divide the page into columns.

- Very important information.
- $e^{i\pi} = -1$
- $E = mc^2$

1. Numbered lists can be useful.
2. But only if you need to refer back to items in the list.

G.Otcha False Proofs 4/4

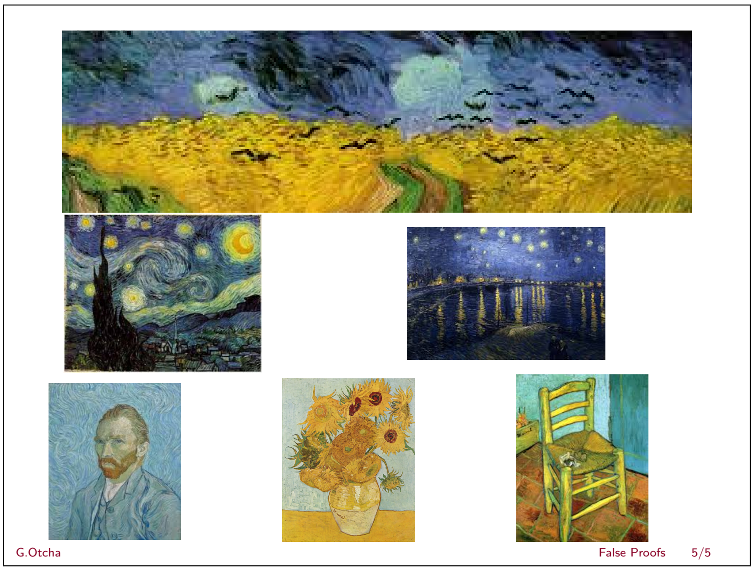
Each column is essentially a (small) page in its own right. This has the consequence that commands like `\textwidth`, when used in a column, reference the width of the text *in the column*, not the whole page. This affects things like the specification of widths for included graphics. Consider the following commands for a column.

```
\begin{column}{0.5\textwidth}
\includegraphics[width=.5\textwidth]{picture.pdf}
\end{column}
```

This would produce a column half the width of the frame. The picture inside that column would be half the width of the *column*, which means it would be a quarter of the width of the page.

A final observation about this sample slide: notice that the theorem is given a name (Sylow's Theorems). The name is formatted as part of the title of the theorem. To achieve this the relevant command was `\begin{theorem}[Sylow's Theorems]`.

Exercise 36. In your presentation `myslides.tex` use the columns environment to add a frame containing six figures (any pictures you like). One figure on the top, two figures below and three below that. It might look something like the slide below.



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4.6 Effects

In this section we will look at two main effects: overlays, where you reveal different parts of your slide at different times, and transition effects, which govern the way one frame changes to the next. Remember that any effect should enhance what you are saying, not distract from it.

Overlays and Gradual Reveal

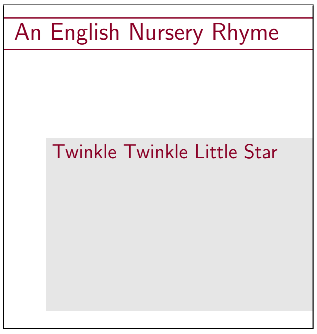
Just as in a powerpoint presentation, you can reveal the information on your slides gradually. The sequence of gradually changing slides is called the set of *overlays*. A single frame may consist of several overlay slides. As with all effects, you shouldn't do it just because you can, but sometimes it can be useful to only show part of an argument, to keep the audience focused on what is being discussed at that moment.

There are two main ways to produce overlays. The simplest is the `\pause` command. You simply insert this command wherever you want a pause in the text. Then during the presentation you just hit the page down, or enter, key, to proceed to the next point.

Example 4.3. The following sample frame uses the pause command. It will consist of four overlay slides.

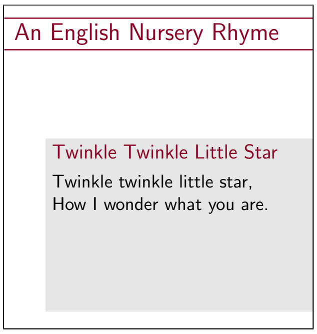
```
\begin{frame}
\frametitle{An English Nursery Rhyme}
\begin{block}{Twinkle Twinkle Little Star}\pause
Twinkle twinkle little star,\\
How I wonder what you are.\pause\\
Up above the world so high,\\
Like a diamond in the sky.\pause \\
Twinkle twinkle little star,\\
How I wonder what you are.\end{block}
\end{frame}
```

The `block` environment here is a theorem-like environment allowing you to give your own titles. It allows you to give headings in the manner of section titles. Below, from left to right, are the four slides that make up the sample frame. I have only shown the top left hand part of each slide here to make the writing more clearly visible.



An English Nursery Rhyme

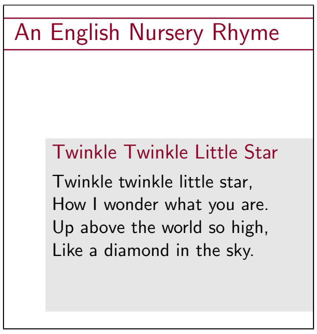
Twinkle Twinkle Little Star



An English Nursery Rhyme

Twinkle Twinkle Little Star

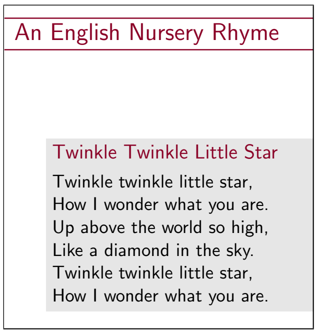
Twinkle twinkle little star,
How I wonder what you are.



An English Nursery Rhyme

Twinkle Twinkle Little Star

Twinkle twinkle little star,
How I wonder what you are.
Up above the world so high,
Like a diamond in the sky.



An English Nursery Rhyme

Twinkle Twinkle Little Star

Twinkle twinkle little star,
How I wonder what you are.
Up above the world so high,
Like a diamond in the sky.
Twinkle twinkle little star,
How I wonder what you are.

For many situations, the `\pause` command will suffice. For full versatility you can use overlay specifications, which will enable you to state on exactly which slides a given element appears. An overlay specification is a list, in angled brackets, of slide numbers. Consider the following.

```
\begin{frame}
\begin{itemize}
\item<1-> Euclid
\item<1-3,5> Newton
\item<3-> Gauss
\item<2,4> Euler
\end{itemize}
\end{frame}
```

This frankly stupid frame consists of five slides. Euclid is shown from slide 1 onwards, Newton is shown on slides 1, 2, 3 and 5. Gauss is shown from slide 3 onwards. Euler is shown on slides 2 and 4. Try it!

Exercise 37. Use overlay specifications to create a list of three items whose first item is visible on the first and third slides, whose second item is visible on the second and third slides, and whose third item is visible only on the third slide.

Example 4.4. Overlay specifications can be applied not just to items of lists, but also to text by using `\uncover< >`. For example the following input produces a frame which uncovers three sentences of text one at a time.

```
\begin{frame}
\uncover<2->{This sentence is shown from the second slide.}
\uncover<1->{This sentence is shown on all slides.}
\uncover<3->{This sentence is shown from the third slide.}
\end{frame}
```

Exercise 38. Input the text from Example 4.4 and see the effect. Note how text that is not currently 'uncovered' has space left for it on all slides.

A final useful command that works with overlay specifications is the `\alert` command. Typing something like

```
\alert<3-4>{even integer}
```

will cause the phrase 'even integer' to be emphasised (coloured red) on slides 3 and 4, and appear normally on all other slides. A variant on this is *alert specifications*. Within the overlay specification you may state that the relevant element is to be alerted on at most one slide. For example in the following slide the item *n is even and composite* appears from the third slide onwards and is highlighted in the third slide (but not in any other slide).

```
\begin{frame}
\frametitle{Cases to consider}
\begin{itemize}
\item<1- |alert@1> $n=2$
\item<2- |alert@2> $n$ is an odd prime
\item<3- |alert@3> $n$ is even and composite
\item<4- |alert@4> $n$ is odd and composite
\end{itemize}
\end{frame}
```

Transition

The default transition from one frame to the next is simply replacement — one frame disappears and is instantly replaced by the next one. However, other more exuberant transitions are available. Use them sparingly, of course. It's a talk, not a fireworks display! There are some effects, such as dissolve, which may be appropriate to indicate something like time passing. So, for example, you may have a series of illustrations showing iterations of a fractal design, then dissolve to a next frame showing the 'finished' fractal. That would be an effective and helpful use of a special transition. But if your statement of the Goldbach conjecture folds itself up into an origami bird and flies off the screen, that is harder to justify (though if you can do that I would probably be quite impressed in spite of myself).

There are several transition effects. Each is used in the same way. As an example, consider the *wipe* effect (this sweeps one frame away with a horizontal line moving from top to bottom gradually replacing it with the next). If you wish the transition from frame k to frame $k+1$ to use the wipe effect, then after the line \begin{frame} that starts frame $k+1$, insert the line

```
\transwipe
```

Note: I have found that these effects are only visible in the external (adobe acrobat) pdf viewer, and moreover it has to be in full screen mode.

You can change the duration of these effects — the default is 1 second. To cause the wipe effect to last 0.3 seconds, you would use the command

```
\transwipe[duration=0.3]
```

For some of the effects you can specify the direction in which the effect proceeds. So for the wipe effect the default is that the screen is wiped with a horizontal line moving downwards from top to bottom. You may change the direction using the option [direction=], with the number 0, 90, 180 or 270. For example

```
\transwipe[direction=180]
```

causes the frame to be wiped by a vertical line moving from right to left. The full list of effects is as follows.

Command	Effect
\transblindshorizontal	like horizontal blinds being closed
\transblindsvertical	like vertical blinds being closed
\transboxin	old frame collapses to a point in the centre
\transboxout	new frame emerges as a growing box from the centre
\transdissolve	old frame dissolves into new
\transglitter	dissolve combined with wipe left to right
\transsplithorizontalin	new slide replaces old from top and bottom
\transsplithorizontalout	new slide spreads from central horizontal line
\transsplitverticalin	new slide replaces old from left and right
\transsplitverticalout	new slide spreads from central vertical line
\transwipe	new slide sweeps away old from top to bottom

Exercise 39. Add transition effects to a presentation. Experiment with duration and direction of different effects.

4.7 Printing your presentation

You are likely to want to print out your presentation so that you can read it over, make notes on it and have a hard copy in case of some technical disaster. But if you simply print the pdf of your presentation as it stands, there is likely to be a problem. Any frame that has been gradually revealed using the `\uncover` or `\pause` commands, or overlay specifications, is created by producing a new pdf page for each overlay. So, for example, a list whose six items have been revealed one by one will result in six pages of output. What we need is a way to suppress these overlay commands. That way is by adding the option 'handout' to the document class.

```
\documentclass[handout]{beamer}
```

and changing the 'mode' (if this command is in your document) from `\mode<presentation>` to `\mode<handout>`. If your background colour on frames is white, then it can help to distinguish slides by tweaking it slightly for the handouts, even if you change nothing else. To accomplish this, you can add an option specification to the handout mode.

```
\mode<handout>{\setbeamercolor{background canvas}{bg=black!5}}
```

The effect of this is that the background colour changes from white to a very pale grey.

When printing a handout you will typically wish to print at least two and probably four frames on each page. The easiest way of doing so is probably to use the package `pgfpages` in your preamble as follows:

```
\usepackage{pgfpages}
\pgfpagesuselayout{4 on 1}[a4paper,border shrink=5mm,landscape]
```

Instead of 4 on 1 you can just print 2 pages on 1, and then you should remove the 'landscape' option. A sample page of a printout with four frames on each page, is shown on the final page of this chapter.

Exercise 40. Create a version of your `myslides` presentation that uses the handout overlay specifications. You might wish to choose a different colour and/or presentation theme for the handout. Now print (or at least get a print preview of) your presentation.

4.8 Ten Guidelines for a Good Presentation

1. Get the length right. One slide per minute is already pushing it. Better to plan something around ten to fifteen slides at most for a 20 minute presentation. Of course you will practice it and you should ruthlessly cull anything that doesn't fit. If you are running short of time, omit slides rather than simply speaking faster!

2. The amount of material on any one slide should not be large. If your text doesn't fit on the slide, take this as a sign that you need to redesign or reword the slide. Do not take

it as a sign that you should remove all spacing and have five columns just to wedge it in.

3. Avoid numbering things unless there is a good reason. In this list the points are numbered to emphasise the fact that there are ten of them. That may well not be a sensible reason!

4. Choose a sensible presentation theme. All information on all slides should be useful in some way.

5. Try to avoid including long calculations, detailed tables or other text that requires close and careful reading. In a presentation you are usually trying to give the big picture, rather than elucidate all the detail. Your dissertation may well contain complex formulae, and large tables of data, but a table with, say, 7 rows and 8 columns contains over 50 entries; no-one can take that information in, unless your talk consists entirely of that one slide.

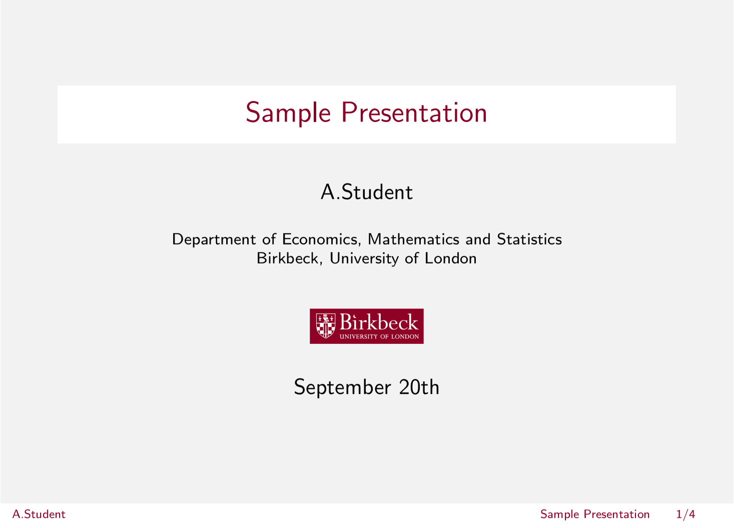
6. Don't introduce too much new notation. People cannot remember it. If your first slide says 'let G be a group, p a prime, q a power of p, r a positive integer, H a subgroup of G, N a normal subgroup of G, set $K = H \cap N$, $k = |K|$, $a \in G$, $b \in H$, $c \in N$ and $d \in K$' then you, and the audience, are doomed. Either people will just stop listening, or you will be plagued with interruptions as people ask 'what was K again?'

7. It is useful to have a final page that says something like, 'The End' or 'Thank you' or your email address, or similar. It signals the end of the talk without that embarrassing tailing off that can occur, where it gradually becomes clear to the audience, and you, that you have said everything you are going to say.

8. Practice your talk, out loud. That swanky Greek letter you used — can you remember whether it's a zeta or an eta? One of the great things about LaTeX is that you have to know the name of Greek letters in order to type them. But what about $\bowtie$ or $\sim$. Are you going to refer to them in your talk as 'bowtie' and 'sim'? You also need to know how to pronounce, at least roughly, the names of any famous mathematicians you mention. If in doubt, ask your supervisor. If they don't know, then you are probably safe to get it wrong! Otherwise, get it right.

9. Prepare for disaster. If you lose your USB stick, would you be able to cope? Make sure you have a printed copy of the talk so that in an emergency you could give an abbreviated version of the talk on a whiteboard. Better, make sure you have backed up your talk onto either a second USB stick, or email it to yourself so you can access it online. And of course turn up in good time so that you can make sure your talk is set up on the computer, and you are not out of breath or flustered.

10. Prepare for questions. Try and think of the sort of questions you may get asked, and prepare answers. If you are asked something you don't know, it isn't a disaster. Try and give some sort of a response, which could range from 'I don't know the answer in general but if $n = 3$ the answer is this.' to 'I know that was mentioned in Jones's book, I can't recall the exact result but research has been done in that area', or similar. Sometimes you may just have to say you don't know, but there is often something that you can say, however small.



Sample Presentation

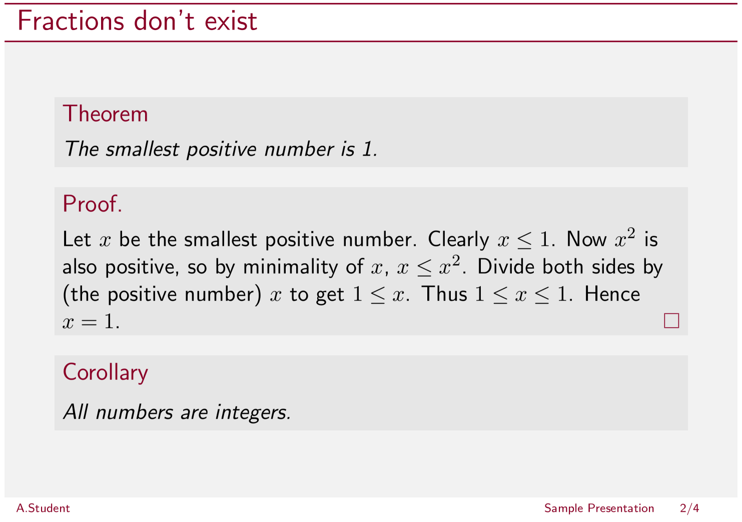
A.Student

Department of Economics, Mathematics and Statistics
Birkbeck, University of London

Birkbeck UNIVERSITY OF LONDON

September 20th

A.Student Sample Presentation 1/4



Fractions don't exist

Theorem

The smallest positive number is 1.

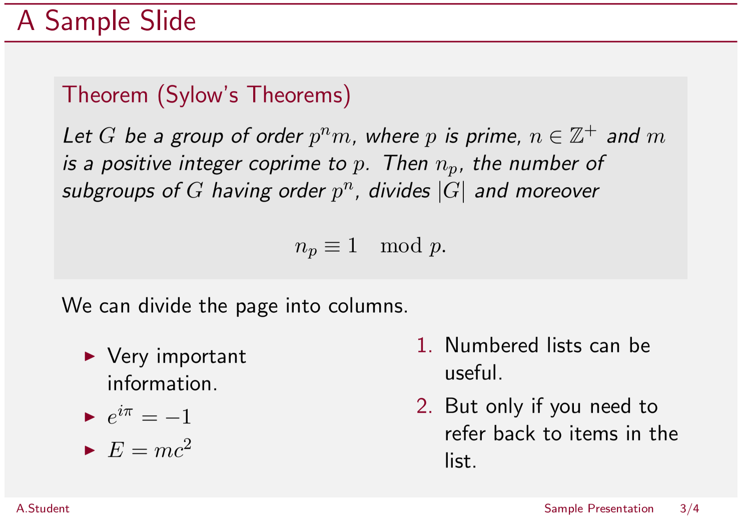
Proof.

Let x be the smallest positive number. Clearly $x \leq 1$. Now x^2 is also positive, so by minimality of x, $x \leq x^2$. Divide both sides by (the positive number) x to get $1 \leq x$. Thus $1 \leq x \leq 1$. Hence $x = 1$. □

Corollary

All numbers are integers.

A.Student Sample Presentation 2/4



A Sample Slide

Theorem (Sylow's Theorems)

Let G be a group of order $p^n m$, where p is prime, $n \in \mathbb{Z}^+$ and m is a positive integer coprime to p. Then n_p, the number of subgroups of G having order p^n, divides $|G|$ and moreover

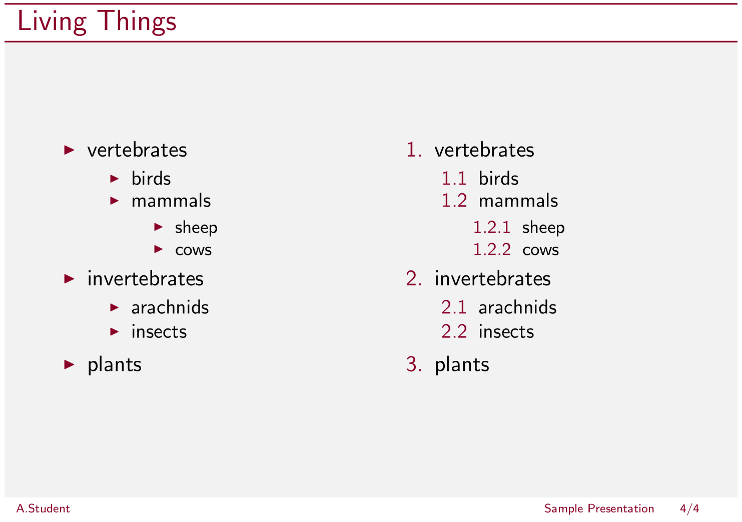
$$n_p \equiv 1 \mod p.$$

We can divide the page into columns.

- Very important information.
- $e^{i\pi} = -1$
- $E = mc^2$

1. Numbered lists can be useful.
2. But only if you need to refer back to items in the list.

A.Student Sample Presentation 3/4



Living Things

- vertebrates
  - birds
  - mammals
    - sheep
    - cows
- invertebrates
  - arachnids
  - insects
- plants

1. vertebrates
   1.1 birds
   1.2 mammals
      1.2.1 sheep
      1.2.2 cows
2. invertebrates
   2.1 arachnids
   2.2 insects
3. plants

A.Student Sample Presentation 4/4

Chapter 5

Dissertations

A dissertation is a rather longer document than we have worked with so far, but after your practice with writing articles, producing the actual content will not require many new skills. The main new things to get to grips with will be the document classes, such as `book`, that allow for chapters, and the creation of a title page, abstract, declaration, table of contents and bibliography. As with presentations, we have a Birkbeck project package for dissertations that you have the option of using. It sets up many of the format requirements for you.

5.1 Layout of a Dissertation

There are several things that need to be included in your dissertation, however you choose to prepare it. When you start your dissertation module you will receive a formal list of requirements, but as a guide the following rules will need to be observed.

- Your dissertation must be typed.
- It must be on white A4 paper, single sided.
- It must be at least 10 point and at most 12 point font.
- Lines must be at least 1.5 spaced and at most double spaced.
- Margins must be at least 30mm.
- Pages must be numbered.
- There must be a title page including the title of the dissertation and your name.
- There must be an abstract.
- There must be a declaration stating that the work is your own.
- There must be a bibliography.

Other things, such as a table of contents, are optional but highly desirable. Although not a formal requirement, you will of course wish to divide your dissertation into well-organised chapters, containing sections and maybe subsections. You will label these chapters and sections, as well as theorems, figures, tables, relevant equations and so on, so that you can refer back to them. This is done in the same way as discussed in earlier chapters.

Word Count

As you may recall, your dissertation should be between 6,000 and 10,000 words. This is a wide range, to reflect the fact that a project heavy in calculation would have relatively few words compared to a more discursive dissertation. Please don't count your words by hand! TEXstudio has a tool that counts words – and it doesn't count the words used in commands, so it is just what is required. Go to Tools, click on Analyse Text, and then on Count. It will give, as well as a word count, a frequency analysis of words used. But what you care about is word count. I have just checked and in the first four chapters of these notes there are 24,841 words. Which means 1,000 words would cover about 3 single-spaced pages on average. Of course your project is going to be double spaced, which will make it look much more impressive!

5.2 Choice of Document Class

There are several choices of document class, but the two I will talk about are `report` (in conjunction with the Birkbeck style file) and `book`.

The 'Report' Class

This is the simplest document class that produces chapters. There are no headers, and the footer is a central page number. The assumption is that the report is being printed on single sided paper and so there is no difference in format between odd and even numbered pages. The `\maketitle` command produces a separate title page with the title, author and date as usual. To use the `report` class, the first line of your preamble should be `\documentclass{report}`. Or in fact, more likely you would type `\documentclass[a4paper,12pt]{report}`. But we can do better than this.

The Birkbeck Project Style

We have prepared a style file `bbkproject.sty` that you can use in conjunction with the `report` class. The style file can be downloaded from the Moodle page for this module. It sets up the structure of the document so that you can create a title page, abstract, declaration and table of contents, the line spacing is correct, the margins are the right size and so on. The page design reflects the fact that we would like the dissertation to be submitted single sided. That means all page numbers are on the top right. You do not need to look at the contents of the `bbkproject.sty` file unless you wish to. To use the Birkbeck project package `bbkproject`, the first two lines of your preamble should be:

```
\documentclass[a4paper,12pt]{report}
\usepackage{bbkproject}
```

Of course you must have the file `bbkproject.sty` in the same folder as your dissertation.

With this package the headers and footers are set up as follows.

- No header or footer on the title page.
- On the first page of each chapter, and for the abstract, declaration and table of contents, there are no headers and the footer is just the page number.
- No difference between odd and even numbered pages, because the dissertation is supposed to be single sided.
- Header of standard page: on the left the current chapter number and title; on the right, the page number.
- Footer of standard page: on the right the current section number and title.

There are other advantages to using this package: it is easy to produce the abstract and declaration that are required. Moreover the margins and line spacing are set up as per guidelines. Finally a table of contents is automatically produced. However it is certainly not compulsory to use this package.

The 'Book' Class

The `book` class is another class that produces chapters. These notes have been produced using the `book` class. It expects that the outcome will be viewed in book form — pages printed on both sides, so that odd and even numbered pages are formatted separately. A chapter always begins on an odd numbered page (the right hand page of a book). That means if your Chapter 1 ends on page 9 say, then page 10 will be left blank so that Chapter 2 can begin on page 11. For your dissertation the `book` class is not optimal, because you are asked to produce a single-sided document, but you may wish to use it in future. Headers and footers are set up as follows.

- No header or footer on the title page
- Title, contents and chapters begin on odd numbered pages.
- On the first page of each chapter, and for the abstract, declaration and table of contents, there are no headers and the footer is just the page number.
- Header of standard even numbered (left hand) page: page number on left, Chapter number and name in upper case text on the right. No footer.
- Header of standard odd numbered (right hand) page: page number on right, section number and name in upper case text on the left. No footer.

- Left margin of even numbered page is wider than right margin. Right margin of odd numbered page is wider than left margin.

Headers and footers can be altered using the `fancyhdr` package. Since we are supplying a Birkbeck package already, I will not go into detail about doing this. But to give you an idea of the sort of thing that can be done, look at the headers and footers of these notes. The relevant commands from the preamble are as follows.

```
\documentclass[12pt,a4paper]{book}
\usepackage{fancyhdr}

\pagestyle{fancyplain}
\addtolength{\headwidth}{\marginparsep}
\addtolength{\headwidth}{\marginparwidth}
\addtolength{\headheight}{2.5pt}
\renewcommand{\chaptermark}[1]{\markboth{
                              \scriptsize Chapter \thechapter : #1}{}}
\renewcommand{\sectionmark}[1]{\markright{\scriptsize \thesection : #1}}
\lhead[\fancyplain{}{\thepage}]{\fancyplain{}{\rightmark}}
\rhead[\fancyplain{}{\leftmark}]{\fancyplain{}{\thepage}} \cfoot{}
\chead[\fancyplain{}{\textsc{\scriptsize Writing Mathematics}}]
{\fancyplain{}{\textsc{\scriptsize Writing Mathematics}}}

\textwidth 170mm \oddsidemargin -4mm \evensidemargin -6mm
\textheight 227mm \topmargin -5mm
```

You will see commands like `\lhead`, which deals with the left hand side of the header, giving instructions for odd numbered and even numbered pages. The default in this package is that the header is underlined, unlike using the `book` class on its own. I **do not** expect you to be conversant with all of this. But you are welcome to explore the `fancyhdr` package if you wish.

5.3 Title Page, Abstract, Declaration

In this section we will look at how to produce a title page, abstract and declaration, focusing mainly on how this is done in files using the `bbkproject` package.

The Title Page

Example 5.1. If using `bbkproject`, insert the following lines into your preamble.

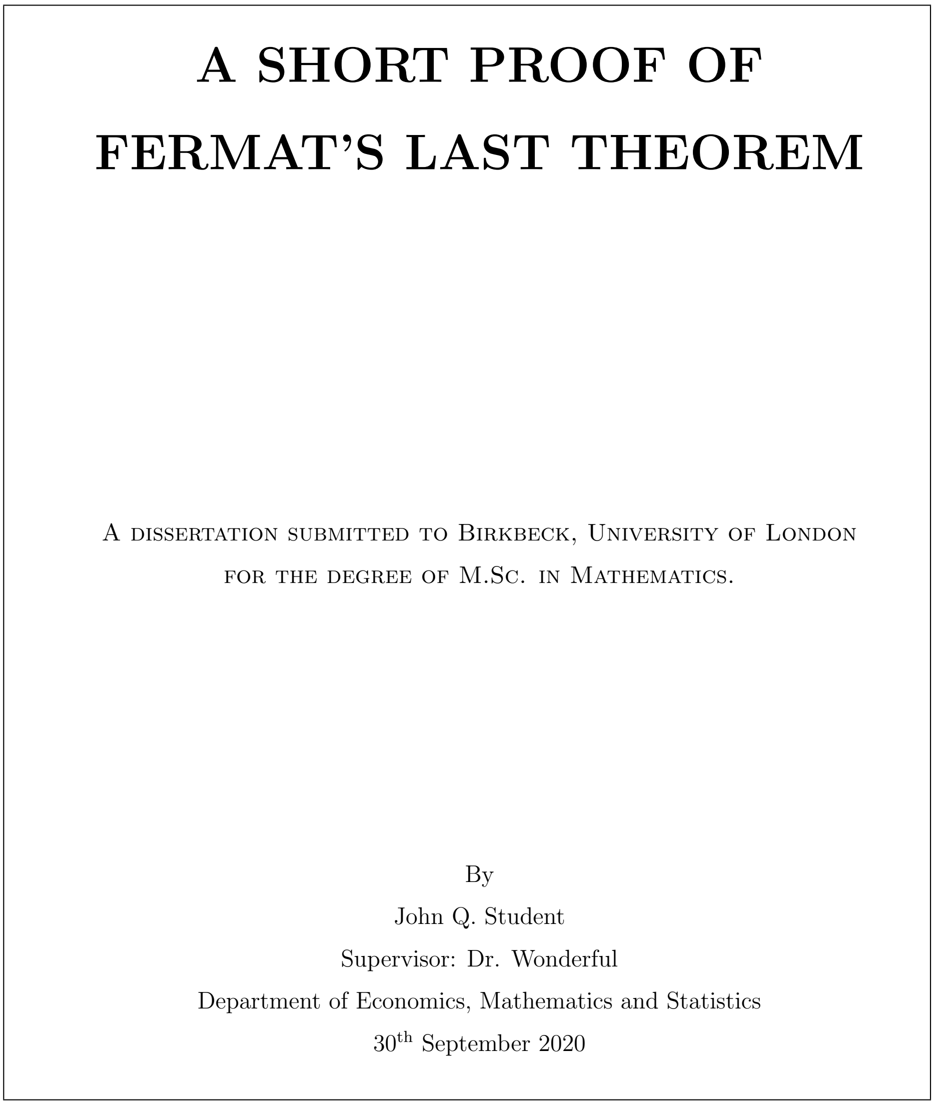
```
\subject{Mathematics}
\degree{M.Sc.}
\thesis{dissertation}
\title{A Short Proof of Fermat's Last Theorem}
```

```
\author{John Q. Student}
\supervisor{Dr. Wonderful}
\department{Department of Economics, Mathematics and Statistics}
\submissiondate{$30^{\mathrm{th}}$ September 2020}
\institution{Birkbeck, University of London}
```

Then when you are ready to begin the document, type the following.

```
\begin{document}
\maketitle{}{}{}
```

Note the three empty pairs of brackets! These brackets can have contents, which we will discuss shortly. But leaving them empty as we have done creates the title page as we want it, as shown below.



A SHORT PROOF OF FERMAT'S LAST THEOREM

A DISSERTATION SUBMITTED TO BIRKBECK, UNIVERSITY OF LONDON FOR THE DEGREE OF M.SC. IN MATHEMATICS.

By

John Q. Student

Supervisor: Dr. Wonderful

Department of Economics, Mathematics and Statistics

30^{th} September 2020

Exercise 41. Create a document called `ch5report.tex` (or similar). Start a practice dissertation using the `bbkproject` package. Create a title page substituting your own made-up title, supervisor and so on for the ones used in Example 5.1 above.

Exercise 42. Create a document called `ch5book.tex` (or similar). This time start a practice dissertation using the document class `book`. Create a title page.

If you are **not** using the `bbkproject` package, then you can create a title page with Title, Author and Date with the standard `\maketitle` command.

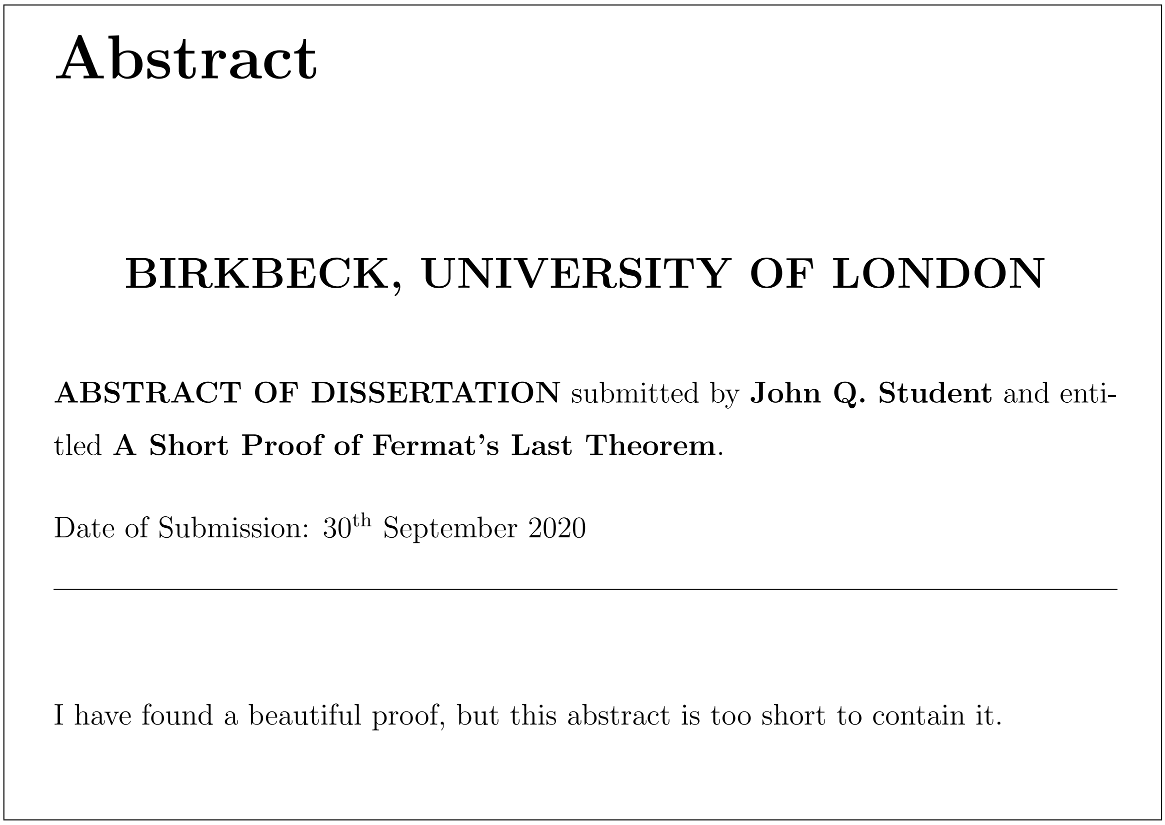
The Abstract

Your dissertation must have an abstract. This is a short (around one page) summary of what you have done. It is important because it allows the Programme Director to assign the most appropriate second examiner, and it allows the two internal examiners and the external examiner to assess your ability to give a clear summary of the scope and results of your project.

In the `bbkproject` package, insert your abstract in the third argument of the `\maketitle` command. As an example, the command

```
\maketitle{}{}{I have found a beautiful proof,
     but this abstract is too short to contain it.}
```

produces, in conjunction with the preamble commands from Example 5.1, the following abstract page.



Abstract

BIRKBECK, UNIVERSITY OF LONDON

ABSTRACT OF DISSERTATION submitted by **John Q. Student** and entitled **A Short Proof of Fermat's Last Theorem**.

Date of Submission: 30th September 2020

I have found a beautiful proof, but this abstract is too short to contain it.

If you are not using the bbkproject package, then you can create an abstract using the command

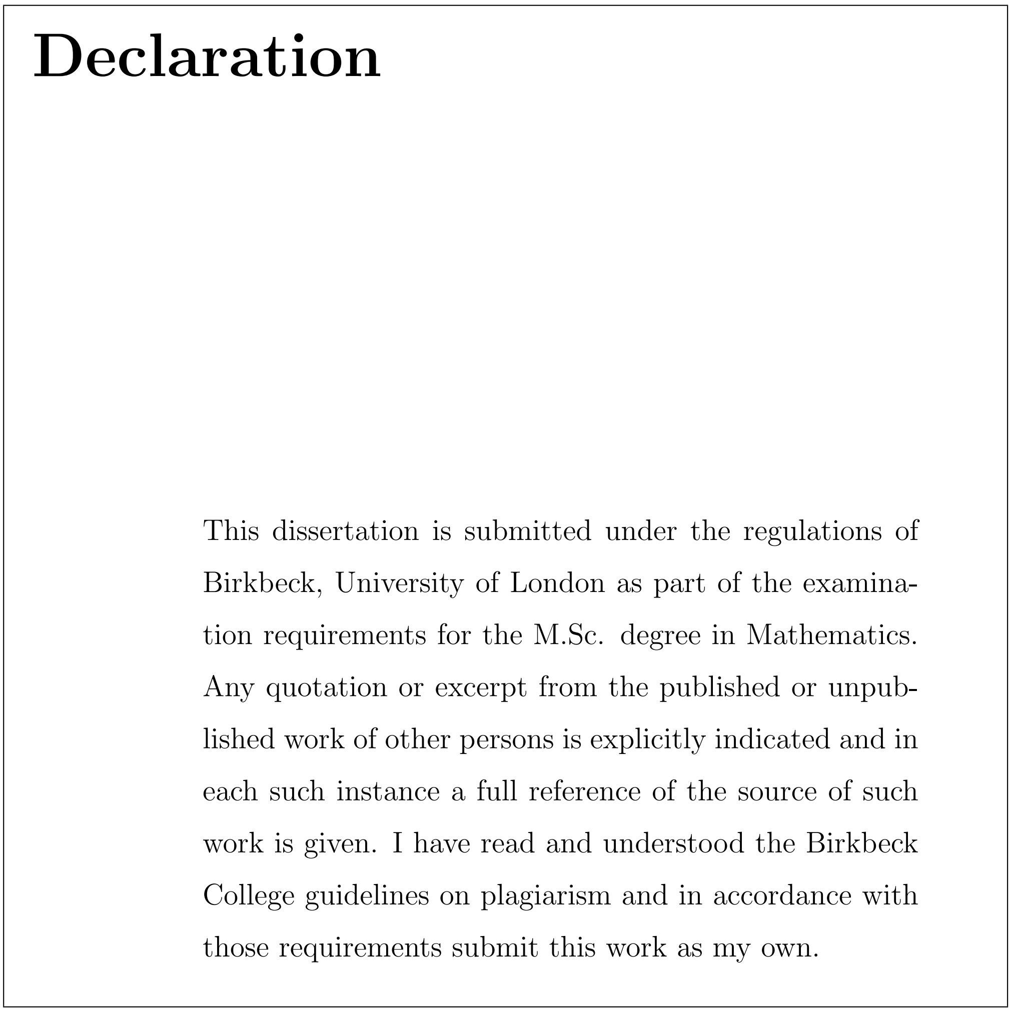
```
\chapter*{Abstract}
```

and then typing your abstract. But it won't have all the nice layout above.

Exercise 43. Add an abstract to your document ch5report.tex, which you created in Exercise 41 using the bbkproject package. Next, add an abstract to your document ch5book.tex, which you created in Exercise 42 using the book document class.

The Declaration

Another necessary component of your dissertation is the declaration that you are aware of plagiarism rules, have read them, and that you have not plagiarised. You need to include the text of the declaration when you submit your dissertation. If you are using the bbkproject package, then the declaration is automatically included, as shown.



Declaration

This dissertation is submitted under the regulations of Birkbeck, University of London as part of the examination requirements for the M.Sc. degree in Mathematics. Any quotation or excerpt from the published or unpublished work of other persons is explicitly indicated and in each such instance a full reference of the source of such work is given. I have read and understood the Birkbeck College guidelines on plagiarism and in accordance with those requirements submit this work as my own.

If you are not using the `bbkproject` package, you can create a page with the declaration on by using the command

```
\chapter*{Declaration}
```

and then typing the words of the declaration. They will not be nicely centred on the page though. This can be achieved using the `\minipage` command, which we will describe in more detail in Section 5.5.

5.4 Table of Contents

LaTeX has the ability to generate a table of contents automatically from the chapter, section and subsection structure. If you are using the `bbkproject` package, a table of contents will be automatically generated after your title page. It is a good thing to have and you need to think carefully about your reasons for not wanting one, should you decide to omit it.

There is one decision you need to make, and that is about the depth of your table of contents. It will show chapters, and sections within chapters, and subsections too unless you specify otherwise. My view is that while showing chapters and sections is helpful, it is not necessary to go down to the level of subsections and subsubsections. I therefore suggest inserting the command

```
\setcounter{tocdepth}{1}
```

into your preamble. Depth 0 is the highest level – for the case of a book or report, that is chapters. Depth 1 is the next level, here sections. Depth 2 is subsections and so on. By specifying depth 1, we say that the table of contents should list chapters and sections but no smaller subdivisions. This will work with or without the `bbkproject` package. If you are not using the `bbkproject` package, a table of contents will not automatically appear. If you want one, you need to type the command

```
\tableofcontents
```

after the `\maketitle` command.

If your dissertation has lots of tables or lots of figures, or both, you might want to have a list of tables and/or a list of figures. Some books do this. One case where this might be useful for the reader is if you have tables summarising all the data about some different cases. So maybe you have some investigation to do with prime numbers, and a table at the end of Chapter 2 with information about the case $p = 2$, one at the end of Chapter 3 with information about the case $p \equiv 1 \mod 4$ and then a final one about the case $p \equiv 3 \mod 4$. Then the reader could find these tables quickly by looking for the page references in the list of tables. You will need to make a judgement as to whether it helps the reader to have these lists. To insert them if using the `bbkproject` package, you use the first two arguments of the redefined `\maketitle{}{}{}`

command. By this stage of course your third argument is likely to contain your abstract. A summary of the outcomes is given in the table below.

First two arguments	List of Figures?	List of Tables?
`\maketitle{}{}{}`	no	no
`\maketitle{yes}{}{}`	yes	no
`\maketitle{}{yes}{}`	no	yes
`\maketitle{yes}{yes}{}`	yes	yes

If you are not using the `bbkproject` package, then you can insert lists of figures and tables by adding one or both of the following commands after your `\maketitle` command.

```
\listoffigures
\listoftables
```

5.5 Chapters

Once you have your title, abstract, declaration and (at this point empty) table of contents, it's time for the first chapter. As with sections, subsections and other subdivisions, to begin a chapter called, say, 'Introduction' you simply type:

```
\chapter{Introduction}
```

If this is the first chapter, then the result will be a new page headed as follows.

Chapter 1

Introduction

For many choices of document class the name of the current chapter will be shown at the head of the page. For this reason, if the name of the chapter is long, you may need to have a shorter version for display in the page header. This is done with an optional argument.

```
\chapter[Introduction]{An Introduction to Some of the Terminology Required}
```

The short title 'Introduction' would then appear in the header (if this is specified by your choice of document class and package), and the full long title would be given at the start of the Chapter and in the Table of Contents.

The content of the chapters is written like any LaTeX document. You can cross-reference within and between chapters with the `\ref` command. You will need to be careful with your choice of labels. The longer your document gets the easier it is to accidentally use the same label twice. Doing this will cause an error message about 'multiply defined labels'. Ideally you would be systematic about your labelling so that it is easy for you to remember what you have called things.

Exercise 44. Give you document `ch5report.tex` a Chapter 1. Add sections and subsections so that Chapter 1 has Section 1.1, 1.2 and 1.3, and subsections 1.1.1 and 1.1.2. Put a few paragraphs of text in each section (cut and pasted from some other document to save time if you like), so that each section is more than one page. Now copy and paste your Chapter 1 to your document `ch5book.tex`. Observe what the headers and footers are for each page in the two documents.

Exercise 45. Now we have some content we can talk about the table of contents. Insert the relevant commands to your documents `ch5report.tex` and `ch5book.tex` so that they have tables of contents that show chapters and sections, but not subsections.

Exercise 46. Insert at least one numbered figure and at least one numbered table into your documents. Then in each document create a list of tables and a list of figures. (You can uncreate them afterwards if you like!)

Structuring your Dissertation

How many chapters should you have? How long should they be? How many subsections in each chapter? These are difficult questions to answer. But as a broad guide, a dissertation of 8,000 words might have between three and five fairly short chapters. The first could be introductory, setting up the notation, background to the problem being discussed, elementary results that are needed from undergraduate mathematics and a brief summary of the structure of the rest of the dissertation, something like the following paragraph.

In Chapter 2 we will discuss the case $p = 2$; in Chapter 3 we deal with the case $p \equiv 1 \mod 4$ and in Chapter 4 we will look at $p \equiv 3 \mod 4$. Chapter 5 summarises the results and looks at possible future research.

You will probably write the technical chapters first, and add needed notation and elementary results to Chapter 1 as you go along. Then you can write the final summary chapter, and after that you can finish by tidying up Chapter 1 so that it has a coherent tour through all the notation and definitions that you need.

Using minipage

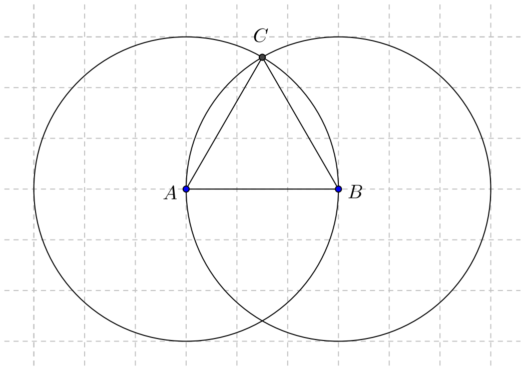
When you are producing a long document, particularly one that involves the use of a lot of figures, data or tables, or one that involves writing down algorithms, computer programs or other list-like things that you would like to accompany with commentary, it can be useful to have a column-like structure available. This can also be helpful if you are producing tables where the entries are sentences rather than numbers or single items. For these scenarios, the `minipage` environment is very useful. I have used it many times in these notes where I was showing some commands on the left and their effect on the right.

As you might guess, the effect of `minipage` is to produce a miniature page. So it will produce left-justified text that breaks into lines. You can import figures, draw tables and so on. The next few examples illustrate the sorts of uses that might be relevant.

Example 5.2. Here we have a sequence of steps in a mathematical construction. We wish to show the steps on the left and the final outcome (produced using the free package GeoGebra) on the right. We can set what proportion of the text width will be given over to each minipage. First, here is the result.

To construct an equilateral triangle:

- Draw points A and B.
- Draw a circle centre A, radius $|AB|$.
- Draw a circle centre B, radius $|AB|$.
- Let C be one of the intersection points of the two circles.
- The triangle ABC is equilateral.



Here are the commands used to produce that result.

```
\begin{minipage}{0.5\textwidth}
{\bf To construct an equilateral triangle:}
\begin{itemize}
\item Draw points $A$ and $B$.
\item Draw a circle centre $A$, radius $|AB|$.
\item Draw a  circle centre $B$, radius $|AB|$.
\item Let $C$ be one of the intersection points of the two circles.
\item The triangle $ABC$ is equilateral.
\end{itemize}
\end{minipage} \begin{minipage}{0.5\textwidth}
\includegraphics[width=\textwidth]{ch5fig5.pdf}
\end{minipage}
```

Example 5.3. In this next example we have a table whose entries are sentences, so we wish to have normal text wrapping. The table concerns whether a prime number p can be expressed as the sum of two squares.

$p = 2$	$p \equiv 1 \mod 4$	$p \equiv 3 \mod 4$
$p = 2$ is clearly the sum of two squares, because $2 = 1^2 + 1^2$.	It can be demonstrated that p is always the sum of two squares. For example if p is 5 we have $5 = 1^2 + 2^2$. If $p = 13$ then $13 = 3^2 + 2^2$.	p can never be the sum of two squares. This is because a square number is congruent to 0 or 1 modulo 4. Hence the sum of two squares is congruent to 0, 1 or 2.

The commands that produce this table are shown over the page.

```
\begin{center}
  \begin{tabular}{|l|l|l|}
  \hline
  $p = 2$ & $p \equiv 1 \mod{4}$ & $p \equiv 3 \mod{4}$\\
  \hline
    \begin{minipage}{0.2\textwidth}
       $p=2$ is clearly the sum of two squares, because $2 = 1^2 + 1^2$.
    \end{minipage}
  &
    \begin{minipage}{0.3\textwidth}
       It can be demonstrated that $p$ is always the sum of two squares.
       For example if $p$ is $5$ we have $5 = 1^2 + 2^2$.
       If $p=13$ then $13 = 3^2 + 2^2$.
    \end{minipage}
  &
    \begin{minipage}{0.4\textwidth}
       $p$ can never be the sum of two squares.
       This is because a square number is congruent to $0$ or 1 modulo 4.
       Hence the sum of two squares is congruent to $0$, $1$ or 2.
   \end{minipage}
  \\ \hline
  \end{tabular}
\end{center}
```

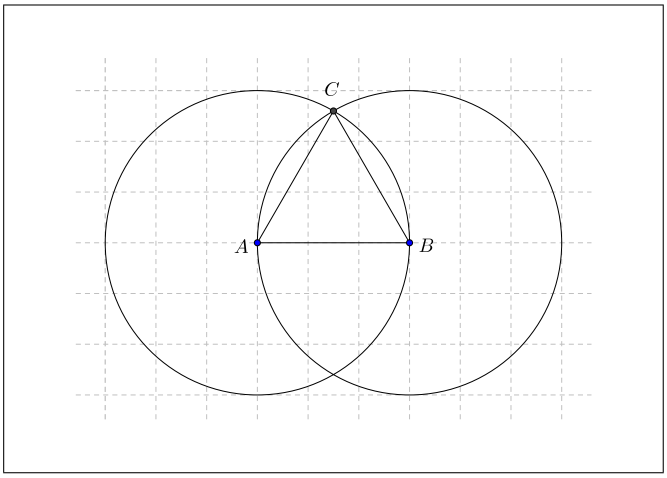
We can also put a border round text or figures, or a whole minipage, if we wish, using the `\framebox` command. Altering the penultimate line of the commands in Example 5.2 to

```
\framebox{\includegraphics[width=\textwidth]{ch5fig5.pdf}}
```

would result in the following outcome. I think it actually looks less good, but sometimes it may be helpful.

To construct an equilateral triangle:

- Draw points A and B.
- Draw a circle centre A, radius $|AB|$.
- Draw a circle centre B, radius $|AB|$.
- Let C be one of the intersection points of the two circles.
- The triangle ABC is equilateral.



Exercise 47. Use the minipage environment to produce a figure on the left, with some text on the right.

Exercise 48. Use the minipage environment to create a table with four columns, of different widths, each containing a paragraph of text.

5.6 Creating a Bibliography

At the end of your dissertation you will list the references you have used. I'll show you two ways of doing this. The first is fairly workmanlike but gets the job done. The second, described in Section 5.7 takes slightly longer initially but is more versatile in the long run.

To get your bibliography then, the first method is to use the following LaTeX commands. They should go after the end of your final chapter.

```
\begin{thebibliography}{99}
\bibitem{bright} I.~M.~Bright. {\em My favourite Theorems},
 Madeup University Press (2006).
\bibitem{mersenne} http://www.MersennePrimes.com
\end{thebibliography}
```

The result will be the following, appearing on a new page.

Bibliography

[1] I. M. Bright.*My favourite Theorems*, Madeup University Press (2006).

[2] http://www.MersennePrimes.com

When you talk about a reference in the text, you will then type something like '*Fermat's Last Theorem is discussed in detail in Chapter 3 of* `\cite{bright}`'. That will appear in the document as '*Fermat's Last Theorem is discussed in detail in Chapter 3 of [1].*

Alternatively, you may include more detail in the square brackets. If you type '*Fermat's last Theorem is discussed in detail in* `\cite[Ch. 3]{bright}`', it will appear in the document as '*Fermat's Last Theorem is discussed in detail in [1, Ch. 3]*'.

Your references should be listed in order. There are three main possible conventions.

- **Alphabetical Order of Author** This is the preferred ordering in most mathematics books and journal articles, and the suggested one for you. For websites where the authorship may not be known, they should be listed within the alphabetical order, but by the name of the site. So here we have M for MersennePrimes, which goes after B for Bright. For multiple authored books or journals, the first listed author (usually alphabetically first) determines the position. The advantages of this convention are that it is easy to understand and use, you can add in new items in the correct places as you use them, and you don't have to worry about where they are first referenced in the text.

- **Chronological order of publication** This is easy to understand, but difficult to find items, means items by the same author are not necessarily adjacent, and you can get into trouble with different editions of a book and websites, which are constantly updated so have no meaningful publication date. The only time where chronological order could come into play is if you have several papers or books by the same author. Then alphabetical order can't help you and it is standard practice to put them in chronological order, oldest first.

- **Order in Which they Appear in the Dissertation** Some people like this because it seems to make sense that your first reference should be to reference 1, your second to reference 2 and so on. But the main disadvantage is that whenever you rearrange your text, which tends to happen quite a lot, you risk changing the order in which you cite your references. So you would need to manually check each time that you haven't changed the order. That is asking for trouble! It also means someone looking for a particular name or book (rather than a number) in the list of references will have a hard time finding it.

You will see that the references are labelled with numbers [1], [2] and so on. If you would rather use another system, such as an abbreviated form of the author's name and the year of publication, then you can do this too with an optional argument to `\bibitem`. So, for example,

```
\bibitem[BR06]{bright} I.~M.~Bright.{\em My favourite Theorems},
 Madeup University Press (2006).
```

produces [BR06] instead of [1] for the label of the item, and when it is cited in the text with `\cite{bright}` the reference will be to [BR06].

Bibliography items should be written consistently. For a book, give the authors first, then the title in italics, including edition number if relevant, then the publisher and finally the year of publication in brackets. For a journal article, give the authors, then title, then journal title (using standard abbreviations such as J. Algebra for 'Journal of Algebra'), then the volume, number and pages on which the article appeared, followed finally by the year of publication. With e-journals usually the number of pages is listed rather than a start and end page. If you cite any websites you should be as specific as you can with the URL, name of author if known, but of course there is no publication year.

Example 5.4. Here is the bibliography from Sarah Hart's PhD thesis, as an example. Note that if you produce a bibliography in the `article` document class, rather than in `book` or `report`, it will call it 'References', rather than 'Bibliography'.

[1]. N. Bourbaki. *Groupes et Algèbres de Lie*, Chapitres IV, V and VI, Masson, Paris (1981).

[2]. B. Brink and R.B. Howlett. *A finiteness property and an automatic structure for Coxeter groups*, Math. Ann. 296, 179–190 (1993).

[3]. B. Brink. *The Set of Dominance Minimal Roots*, School of Mathematics and Statistics, University of Sydney, Preprint (1995).

[4]. R.W. Carter. *Conjugacy Classes in the Weyl Group*, Compositio. Math. 25, 1–59 (1972).

[5]. R.W. Carter. *Simple Groups of Lie Type*, Wiley Interscience (1972).

[6]. A.M. Cohen. *Recent Results on Coxeter Groups*, for ASI on Polytopes, 18 pages (1993).

[7]. H.S.M. Coxeter. *Discrete Groups generated by reflections*, Ann. of Math. 35, 588–621 (1934).

[8]. H.S.M. Coxeter. *The Complete Enumeration of finite groups of the form* $R_i^2 = (R_iR_j)^{k_{ij}} = 1$, J. London Math. Soc. 10, 21–25, (1935).

[9]. H.S.M. Coxeter and W.O.J. Moser. *Generators and Relations for Discrete Groups*, Springer-Verlag, Fourth Edition (1980).

[10]. V.V. Deodhar. *On the Root System of a Coxeter Group*, Comm. Algebra 10(6) 611–630 (1982).

[11]. M. Dyer. *Reflection Subgroups of Coxeter Systems*, J. Algebra 135, 57–73 (1990).

[12]. D.B. Epstein et al. *Word Processing in Groups*, Jones and Bartlett, Boston (1992).

[13]. M. Geck and G. Pfeiffer. *On the Irreducible Characters of Hecke Algebras*, Adv. in Math. 102, 79–94 (1993).

[14]. M. Geck, S.Kim and G. Pfeiffer. *Minimal Length Elements in Twisted Conjugacy Classes of Finite Coxeter Groups*, to appear in J. Algebra.

[15]. R.B. Howlett, P.J. Rowley and D.E. Taylor. *On Outer Automorphism Groups of Coxeter Groups*, Manchester Centre for Pure Mathematics Preprint (1996).

[16]. J.E. Humphreys. *Reflection Groups and Coxeter Groups*, Cambridge studies in advanced mathematics, 29 (1990).

[17]. D.L.Johnson. *Word Growth of Coxeter Groups*, LMS Lecture Note Series 252 ‘Geometry and Cohomology in Group Theory’, 188–189 (1998).

[18]. I.G. Macdonald. *The Poincaré Series of a Coxeter Group*, Math. Ann. 199, 161–174 (1972).

[19]. R.W. Richardson. *Conjugacy Classes of Involutions in Coxeter Groups*, Bull. Austral. Math. Soc. 26, 1–15 (1982).

Exercise 49. Create a bibliography of three items in your practice dissertation (either one). Cite page 5 of the first item, Theorem 2 of the second and Section 4 of the third.

The advantages of creating a bibliography in this way are that it's easy, you don't need a separate file (as the method in Section 5.7 does), and you have complete control over the formatting. The disadvantages are that when you add new items you need to insert them in the correct place, getting your alphabetical ordering (or whatever) correct, it's easy to be inconsistent about whether you use initials or full names, and that if you decide to change the order from chronological to alphabetical or vice versa it is very time-consuming. Also, housekeeping like removing references you once needed but now don't, has to be done manually. If only there was a way of automating some of this....

5.7 Using BibTeX to Manage Your Bibliography

A convenient way of managing your references is through the use of BibTeX. This involves collecting all your references in a .bib file that is separate from your main .tex file. BibTeX then allows you to automatically create a bibliography through a simple command. There are several advantages to this approach:

- You can collect together references for as many resources as you like because only the ones that you cite directly will appear in the bibliography.
- This means if you are writing more than one document on a particular topic you only need to create a single .bib file, because it can be used to create appropriate bibilographies for each separate documents if required.
- Many journal websites and resources such as dblp allow you to export references for papers directly in the required format, making it easier to create the .bib file.
- By changing a single command you can change the formatting of your bibliography (for instance you could switch it from being in alphabetical order to being in order of citation).

Creating the .bib file

You can create your .bib file using TEXStudio. Open a blank document and save it as `mybibliography.bib` (or similar). Now you need to include an entry for each reference. (The order in which you create these entries does not matter.) The precise formatting depends on the nature of the reference: available BibTeX options include:

- `article`
- `book`
- `inbook` (used when referencing a single chapter, for example)
- `inproceedings` (used for conference papers)
- `mastersthesis`
- `misc` (for references that don't fit the other options)

- phdthesis
- techreport

The following is an example of how you would create a BibTeX entry for an article:

```
@article{ssandrs,
  author    = {Robert J. McEliece and
               Dilip V. Sarwate},
  title     = {On Sharing Secrets and {R}eed-{S}olomon Codes},
  journal   = {Commun. {ACM}},
  volume    = {24},
  number    = {9},
  pages     = {583--584},
  year      = {1981}
 }
```

It includes fields for all the essential information. To cite this reference from within a document you would use the command

```
 \cite{ssandrs}.
```

Note that the authors' first names have been included in the entry here. If we decide later that we only want initials to be used in our bibliography we do not have to change the .bib file, BibTeX can adjust this automatically with a different choice of bibliography style (See Section 5.7). One other point to note is that all titles will appear in the bibliography with the words after the first word all beginning with lower case letters. In this example, we want the words "Reed-Solomon" to be capitalised, since they are names. By placing the parentheses around the R and the S we can ensure they appear as capitals in the final bibliography.
The various different types of entries have slightly different fields. Here is an example of a `book` entry:

```
@book{lidl,
 author = {R.~Lidl and H.~Niederreiter},
 title = {Finite Fields},
 year = {1997},
 edition = {2nd},
 isbn = {0-521-39231-4},
 series = {Encyclopedia of Mathematics and its applications},
 Volume = {20},
 publisher = {Cambridge University Press},
 address = {Cambridge, UK},
}
```

Details for all of the available options for each type can easily be found online.

Finding BibTeX Entries Online

Often it is possible to obtain suitably formatted BibTeX entries online, from journal websites, databases or similar. For example, suppose I wish to include an entry for the article "Practical Minimalist Cryptography for RFID Privacy" that appeared in the IEEE systems journal. This article appears on the journal's website at `http://dx.doi.org/10.1109/JSYST.2007.907683`. When I visit this website, I see there is a "download citations" link on the left of the page. If I click on the link and select the BibTeX option, it opens a new window with the appropriate entry that I can simply cut and paste into my .bib file:

```
@ARTICLE{4378547,
author={Langheinrich, M. and Marti, R.},
journal={Systems Journal, IEEE},
title={Practical Minimalist Cryptography for RFID Privacy},
year={2007},
volume={1},
number={2},
pages={115-128},
keywords={cryptography;radiofrequency identification;RFID privacy;practical
minimalist cryptography;radio frequency identification;secret sharing;
Assembly;Cryptography;Intrusion detection;Jamming;Performance analysis;
Privacy;Proposals;Protection;RFID tags;Radiofrequency identification;
Minimalist cryptography;Shamir;privacy;radio frequency identification
(RFID);secret sharing},
doi={10.1109/JSYST.2007.907683},
ISSN={1932-8184},
month={Dec},}
```

This is a convenient way of obtaining the details for each reference, but it is wise to check for errors afterwards. For example, in the above entry I will want to replace the "`RFID`" in the title by "`{R}{F}{I}{D}`" to ensure that the acronym RFID remains in capitals when displayed in the bibliography.

Creating the Bibliography

First, ensure that your .bib file is placed in the same folder as the .tex file for your document. There are two commands required to create a bibliography for a document using BibTeX. The first is the `\bibliographystyle` command, which should be placed in the preamble of your document (before the `\begin{document}`)

```
\bibliographystyle{abbrv}
```

This command controls the formatting of your bibliography. The `abbrv` style results in a bibliography that is ordered by the first author's surname, and in which the authors' initials are used in place of first names. Other popular options include:

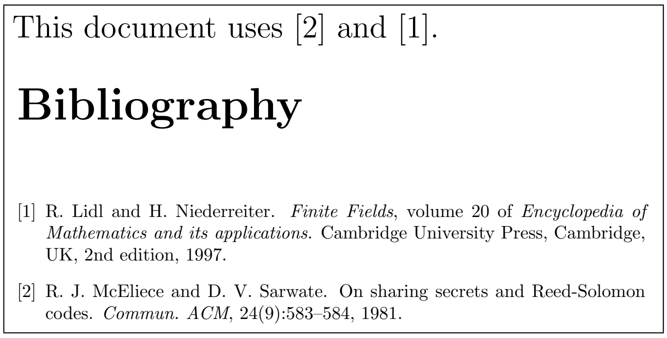
- `unsrt` (Items appear [1], [2], etc in the order in which they are cited in your document with full first names included if you have provided them.)

- `plain` (Items are ordered alphabetically by first authors' surname, full first names are given if provided.)
- `alpha` (Items are ordered alphabetically by first authors' surname, full first names are given if provided, and the citations are not [1], [2] etc but made of the surnames and year of publication.)

The second is the `\bibliography` command which is placed where you want the bibliography to appear (usually at the end of the document).

```
\bibliography{mybibliography}
```

When you compile your document, it should now create the bibliography automatically. Suppose the file mybibliography.bib contains the three entries given above and in my document I cite just the first two, in the sentence `This document uses \cite{ssandrs} and \cite{lidl}.` The numbering and bibliography will appear different for each of the different bibliography styles. For `\bibliographystyle{abbrv}` we'll get the following:



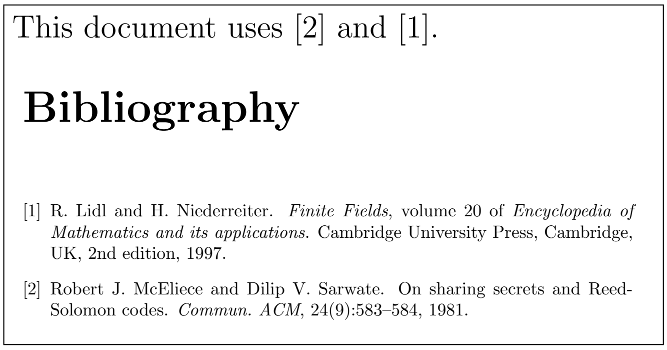
This document uses [2] and [1].

Bibliography

[1] R. Lidl and H. Niederreiter. *Finite Fields*, volume 20 of *Encyclopedia of Mathematics and its applications*. Cambridge University Press, Cambridge, UK, 2nd edition, 1997.

[2] R. J. McEliece and D. V. Sarwate. On sharing secrets and Reed-Solomon codes. *Commun. ACM*, 24(9):583–584, 1981.

With `=\bibliographystyle{plain}` we'll get full first names where given:



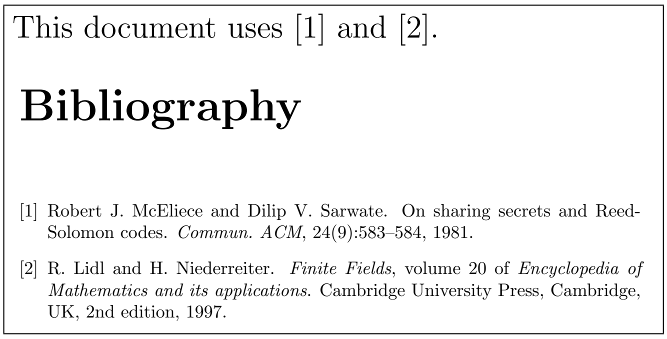
This document uses [2] and [1].

Bibliography

[1] R. Lidl and H. Niederreiter. *Finite Fields*, volume 20 of *Encyclopedia of Mathematics and its applications*. Cambridge University Press, Cambridge, UK, 2nd edition, 1997.

[2] Robert J. McEliece and Dilip V. Sarwate. On sharing secrets and Reed-Solomon codes. *Commun. ACM*, 24(9):583–584, 1981.

Using `\bibliographystyle{unsrt}` changes the order of references:



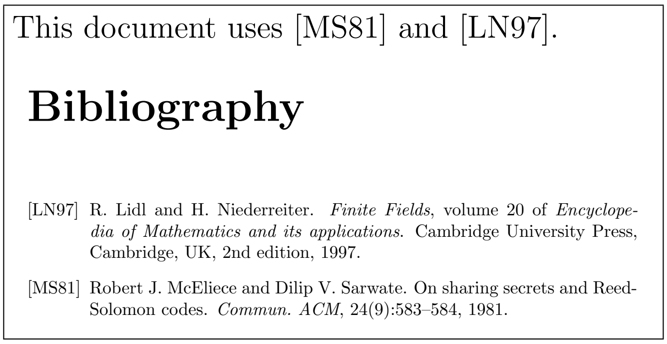
This document uses [1] and [2].

Bibliography

[1] Robert J. McEliece and Dilip V. Sarwate. On sharing secrets and Reed-Solomon codes. *Commun. ACM*, 24(9):583–584, 1981.

[2] R. Lidl and H. Niederreiter. *Finite Fields*, volume 20 of *Encyclopedia of Mathematics and its applications*. Cambridge University Press, Cambridge, UK, 2nd edition, 1997.

For `=\bibliographystyle{alpha}` we get a different citation style.



This document uses [MS81] and [LN97].

Bibliography

[LN97] R. Lidl and H. Niederreiter. *Finite Fields*, volume 20 of *Encyclopedia of Mathematics and its applications.* Cambridge University Press, Cambridge, UK, 2nd edition, 1997.

[MS81] Robert J. McEliece and Dilip V. Sarwate. On sharing secrets and Reed-Solomon codes. *Commun. ACM*, 24(9):583–584, 1981.

Sometimes TEXstudio seems not to want to play ball if you change the bibliography style – it seems to want to stick to the style it's been using! If this happens, resaving your tex file with a new name will do the trick.

Exercise 50. Create a sample bibliography using BibTeX.

One final point. It may be that you prefer to have a single .tex file to produce your LATEX document. Once you have a final version, you can actually dispense with the services of BibTex in the following way. If your file is called myfile.tex, then to produce the bibliography BibTeX creates a file called myfile.bbl, that is basically just a standard LATEX bibliography with bibitems as we were producing in Section 5.6. You can create a self-contained bibliography in myfile.tex by

- opening myfile.bbl, copying the entire contents
- deleting the command `\bibliography{mybibliography}` from myfile.tex
- replacing that command with the pasted text from myfile.bbl

5.8 Ten Guidelines for a Good Dissertation

1. Give your dissertation a structure of chapters and sections (and possibly subsections). Each of these should be a coherent topic of discussion, not just random new chapters every ten pages because you know you are supposed to have chapters! So it can be appropriate to have a 5 page chapter and a 20 page chapter, for example.

2. Your abstract should summarise the main results of your dissertation. You do not need to define every piece of notation in detail just enough to give broad brush strokes. The reader can be referred to Chapter 1 for detail.

3. The first chapter of your dissertation should be introductory, setting up background results and notation, and include pointers for the reader as to where to find more detail, and the structure of the rest of the dissertation.

4. You may assume that the reader has an undergraduate knowledge of mathematics. It is sensible to establish your terminology in any case, for example whether your functions will act on the right or the left, or any conventions for your dissertation such as that G will always be a finite group. Any notation not commonly used in undergraduate mathematics should be carefully defined and used consistently.

5. You must be sure to include plenty of examples, wherever possible examples that you have invented yourself. It helps the reader to confirm that they have understood what you are saying. It shows that you are doing original work, not just writing down a lot of theorems from books. It also means that if there is a slip somewhere in a definition, like a missing minus sign, its correct use in an example will show the examiners that the slip was just a slip, and not an error of understanding on your part.

6. When you reintroduce a topic after several pages, it is sensible and kind to remind the reader what all the symbols mean. So you could say something like ‘recall that H_α is the hyperplane orthogonal to α, as defined in Section 1.4’. Similarly, in a proof, don’t just say ‘by Lemma 2.3, the group G is cyclic’. The reader doesn’t remember what Lemma 2.3 said! Remind us: ‘Lemma 2.3 showed that any finite subgroup of the multiplicative group of a field is cyclic. Therefore G is cyclic’.

7. Take the trouble to display equations and to break text up into paragraphs. It is much easier to read well laid-out text than to struggle through streams of consciousness.

8. Use simple, clear language.

9. Include a bibliography. Do not pad it out with items that you have not cited — this is unhelpful and misleading. Label and describe the items clearly and consistently, for example by putting them in alphabetical order.

10. When using a reference, always cite it properly, and include guidance as to where in the reference to look. If you state a theorem and then say that the proof is in [3], when [3] is a 600 page book, it’s not very helpful! Much better to say that the theorem is proved as Proposition 4.6 of [3].