The Open University

MST125

Essential mathematics 2

Unit 2

Mathematical typesetting

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2.1

Contents

Introduction

In this unit, you'll learn how to prepare mathematical documents using a computer. The aim is not to teach you *everything* about this, but by the end of the unit you should, for example, be able to use a computer to prepare a solution to a TMA question. After the introductory Section 1, you will need to work at a computer as you study the material.

Using just the symbols on a standard keyboard with a word processor (such as Microsoft Word), there is little you can do to create mathematical expressions other than entering numbers, brackets, and symbols such as $+$ and $-$. Most word processors allow you to insert other symbols (such as the Greek letter pi, π) either by selecting them from a menu or by changing the font. However, suppose that you want to type the quadratic formula:

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

To create the fraction, you could write it on a single line as follows

$$x = (-b \pm \sqrt{b^2 - 4ac})/(2a)$$

but this is rather hard to read. What is more, you still have the problem of how to create the expression $\sqrt{b^2 - 4ac}$: you need to create a square root symbol with a horizontal line extending over the whole of '$b^2 - 4ac$'.

What is needed is specialist software to create the various symbols and structures, in a process that is known as **typesetting** mathematics. The first section of this unit introduces mathematical typesetting, and there are then three further sections. Each of these sections is an exploration into a different software package that can be used to create mathematical expressions within a document, namely LaTeX, Microsoft Word and LibreOffice. You need to study only one of these three sections. Section 1 will help you choose which software package is best for you.

> Remember: you should study only *one* of the three software options after reading Section 1.

Solutions to activities in all sections of this unit are given at the end of the unit, together with separate indexes for the three software packages.

The unit makes references to material available on the *Typing mathematical notation* website, a link to which can be found on the module website.

Finally, note that some of the illustrated output in this unit may differ slightly from what you see on your screen; this may be due to variations in the version of the software that you use and how your computer is set up. Some details, such as shortcuts, may also vary according to your software.

1 Typesetting mathematics

This section discusses mathematical typesetting in general, and compares the three software packages that are described in detail in later sections.

1.1 Typeset work versus handwritten work

Learning to use a computer to communicate mathematics is an important skill. For example, it will enable you to communicate mathematics by email and on Open University forums. However, there will be occasions when it is more appropriate to write your work out by hand. For example, when solving a TMA question – even if you intend to prepare your final answer using a computer – you may prefer to solve the problem first using pen/pencil and paper.

Before looking in more detail at the three software options, consider the following advantages and disadvantages of typesetting. This may give you some impression of when it might be appropriate to use the typesetting skills you will learn in this unit, and when you should stick with handwritten work.

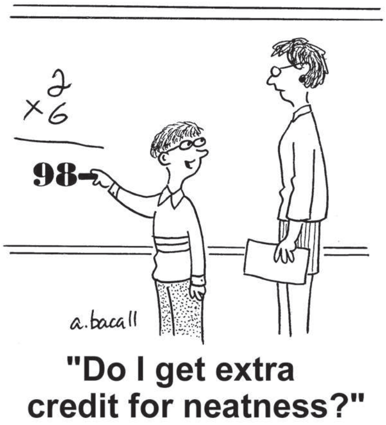
Typesetting advantages

- It forces you to think about the final presentation of your work.
- It makes it easy to communicate your work to others electronically, for example on the forums, or with your tutor.
- It is an important skill to develop if you intend to work with mathematics in the future.

Typesetting disadvantages

- You will need to spend time learning to typeset mathematics: while you are still learning, this will take you *much* longer than handwriting the same document.
- You may be tempted to skip lines of calculation to save time, which you would have written by hand.
- You may be distracted by the process of typesetting, and so make mathematical mistakes.

Of these disadvantages, by far the most serious is how much longer you will spend preparing a document containing mathematics electronically than you would spend writing it out by hand. You will get faster as you become more practised at using typesetting software, but you do need to keep using it in order to build up your expertise.



In this unit, you *do* get extra credit for neatness!

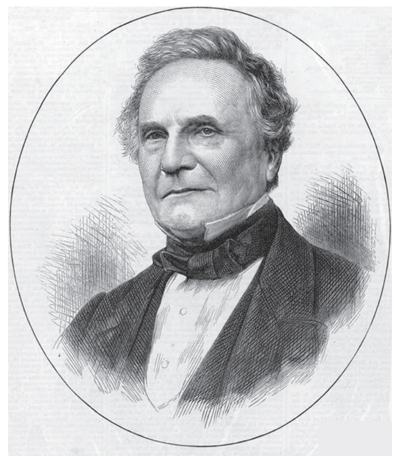
Conventions for typesetting

As well as learning the process by which you create mathematical expressions on a computer, in the course of this unit you will also become more familiar with the standards and conventions that have evolved in typed mathematics. For example, the convention is to use italics for variables (such as x and y), and bold for vectors (such as $\mathbf{v}$). While these are only conventions (so you could write vectors in italics and variables in bold), they are so universal that readers may be confused when they are not followed.

Babbage's principles for mathematical notation

Charles Babbage, most famous for inventing the first mechanical computer, published an article in 1830 entitled 'Notation' in the *Edinburgh Encyclopaedia*. In this article, he lists eleven principles for mathematical notation. Some of these are listed below, and still hold true today.

1. All notation should be as simple as the nature of the operations to be indicated will admit.
2. We must adhere to one notation for one thing.
3. All notations should be so contrived as to have parts being capable of being employed separately.
4. All letters that denote quantity should be printed in italics, but all those which indicate operations, should be printed in a Roman character.
5. Parentheses may be omitted, if it can be done without introducing ambiguity.



Charles Babbage (1791–1871)

1.2 Which software should you choose?

The three software options

The three software packages covered in this unit are LaTeX, Microsoft Word, and LibreOffice. You need to study only *one* of these options.

LaTeX is usually pronounced 'lay-teck'.

LaTeX This software is free to download and use, works on all the main operating systems, and is purpose-built for typesetting mathematics. Most OU mathematics modules, including this one, are written using it.

LaTeX is a bit like a computer programming language: you edit one file, and then process it using LaTeX to produce a PDF (**Portable Document Format**) file, which you can view and print using software such as Acrobat Reader (which is also free to download and use). Learning how to use LaTeX is more technical than the other two options, but it is, once learned, the fastest and most versatile method for typesetting mathematics.

Microsoft Word Recent versions of Microsoft Word include an 'Equation Ribbon', which makes inserting mathematics quite straightforward. It is relatively easy to learn the basics.

Warning: Versions of Word released before 2007 (before 2011 for Macs) have very limited ability to typeset mathematics.

LibreOffice This is an office suite that is free to download and use, and works on all of the main operating systems. As well as a word processor, spreadsheet, database and various other programs, it contains a stand-alone program called 'Math' for producing mathematical expressions. These expressions can be created and embedded in the other programs in the suite.

The process for typesetting mathematics in LibreOffice lies somewhere between the methods for LaTeX and Word. Its basic use is comparable to that of Word, but there also is a 'programming language' working in the background that you can see as you create an equation.

Similarities and differences between the three software options

Before you choose which of the options to study, you need to know a little about their differences and similarities.

There are two general approaches for inputting structures and symbols to typeset mathematics:

(a) **Selecting from palettes:** You insert the major structures (such as fractions and square roots) by clicking buttons from a graphical interface. For example, Figure 1 shows a palette from LibreOffice.

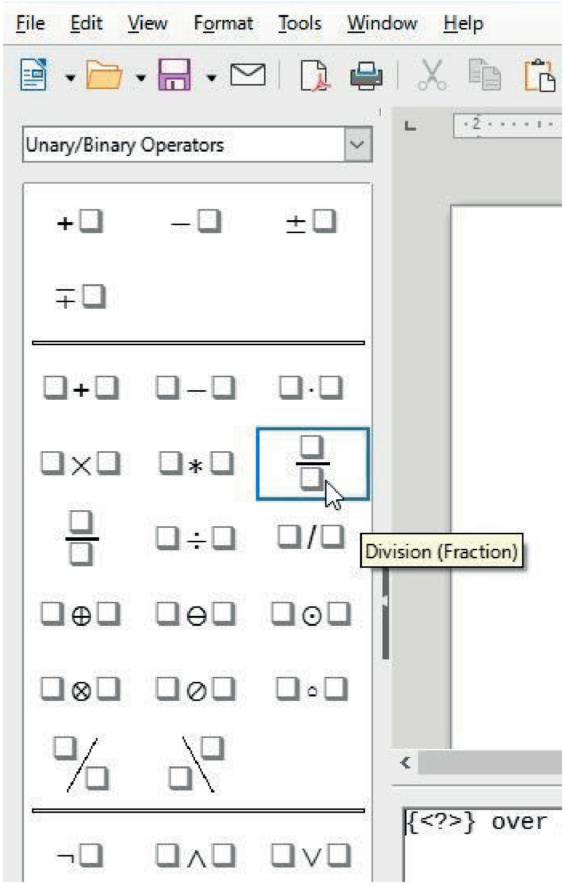


Figure 1 A palette from LibreOffice

(b) **Typing commands:** You type special commands to create the structures. For example, in LaTeX, typing `\sqrt{b^2-4ac}` into your document produces $\sqrt{b^2 - 4ac}$.

Of the two approaches, selecting from palettes is easier, but typing commands directly is faster and more versatile (once you know the commands). Word and LibreOffice provide both methods, and this is an advantage while you are learning: you can begin by using the palettes, and gradually – as you learn the commands – you can use your keyboard more. By contrast, LaTeX does not have a system of palettes, although it is possible to obtain specially designed text editors that include graphical interfaces to help you to build up your LaTeX mathematical expressions. In fact, though, most LaTeX users prefer to input LaTeX code directly.

However, the biggest difference between LaTeX and the other two pieces of software is in what you see while you are creating a formula. As you typeset an expression, both Word and LibreOffice show you how it will appear in the document. In LaTeX, you do not see the final appearance of your formula until you have processed the document and created a PDF. You can (and should) process the document frequently, but you do not get the instant feedback that Word and LibreOffice provide.

Whichever software option you choose, by the end of this unit you will be creating mathematical expressions by typing the commands directly, rather than by selecting items from palettes. You may be surprised by how similar the three methods are at this level. For example, consider the quadratic formula:

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

The keyboard commands used in each of the three software options to create this formula are:

LaTeX `x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}`

Word `x = (-b +- \sqrt(b^2-4ac))/(2a)`

LibreOffice `x = {-b +- sqrt{b^2-4 a c}} over {2 a}`

While there are differences between the three methods, there are also several similarities, and no method is any easier or harder to understand than another. The main difference between the three options, therefore, is the route by which you get to this end point.

Quick reference guides detailing the common mathematical typesetting commands and structures for each of the three pieces of software are available to download from the *Typing mathematical notation* website. These short documents are designed for you to print off and keep by your computer, or save for future reference.

Document formats

Depending on how you expect to use what you learn in this unit in the future, you may want to consider the type of document that you will need to create to share electronically: whoever you send your document to must be able to open it on their computer.

Files saved in Portable Document Format (PDF) can be opened on most devices, and all three of the software options are able to create a PDF from your document: instructions for how to do this are included in each section. Note also that PDF is the format normally required if you need to submit a TMA online as part of a mathematics module, but modules in other subjects may have different requirements.

You cannot convert the mathematics created using one of the three software options into a file that can be opened and edited by any of the other software options. For example, although you can use LibreOffice to create Word documents, any mathematics you create will be lost during the conversion to Word. Additionally, if you need to share a Word document containing mathematics with someone who has an earlier version of Word, then be aware that the mathematics may not appear in exactly the same way as you wrote it.

Making your choice

You may already have chosen which software option to use. However, if you have not yet decided, use the following questions, together with the flowchart in Figure 2, to help you.

- **How much do you think you will use mathematical typesetting software in the future?**
  LaTeX is the most versatile in its mathematical typesetting capability and is the option of choice for most professional mathematicians. It also has powerful cross-referencing and bibliography tools, though these are not covered in this unit. However, if you expect that you are only going to produce TMAs with some equations inserted, then LaTeX may be more than you need.
- **How confident are you at learning computer skills?**
  Everyone can learn LaTeX, but it takes more effort to understand the basics compared with Word and LibreOffice. So, if you are not confident learning computer skills, then you may find this initial step quite time-consuming.
- **Do you own a recent version of Word?**
  This guide is based on the version of Word supplied with Office 365 in 2021 (the downloaded version, not the online version). The functionality described is broadly applicable to versions of Microsoft Word released since 2007 on Microsoft Windows, and versions released since 2011 on Apple Macs; but the more recent the version you work with, the easier it will be to follow this guide. If you do not own a sufficiently recent version, then you will either have to obtain one, or choose a different option.

  In terms of their ability to typeset mathematics, LibreOffice and Word are comparable. Word has a slicker finish and is slightly more user-friendly, but the learning curve in either case is similar. Thus, if you have decided not to learn LaTeX, and you do not own a sufficiently recent version of Word, then LibreOffice is an excellent alternative.

If you interact with your computer by keyboard alone, or have visual impairments, then we recommend that you choose to learn LaTeX. More information on the accessibility of mathematical typesetting is available from the *Typing mathematical notation* website.

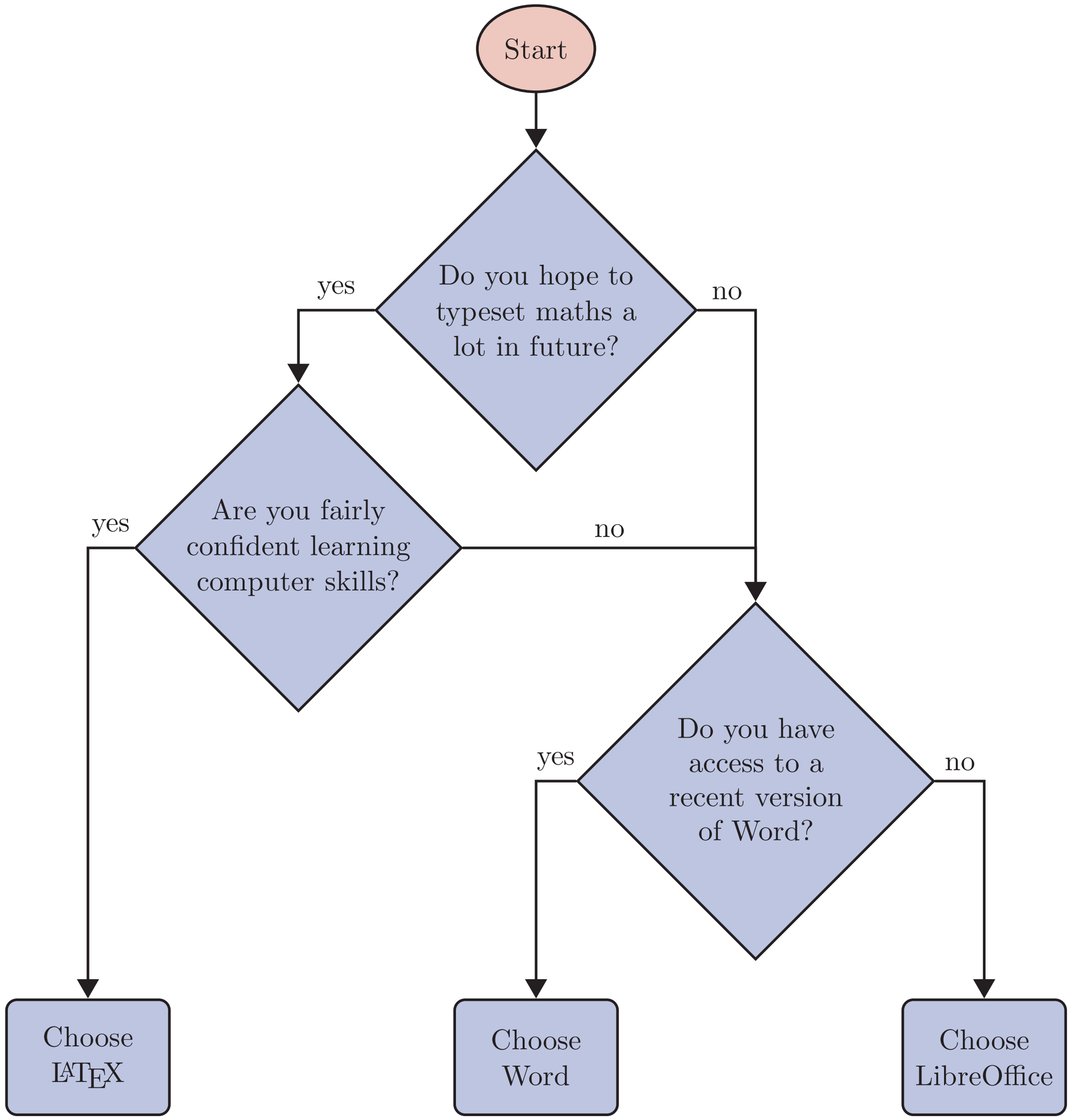


Figure 2 A flowchart to help you decide which route to take

2 LaTeX

You should study this section if you have decided to learn LaTeX.

This section will guide you through the basics of LaTeX. By the end of the section, you will have the knowledge required to produce a TMA containing mathematics.

This guide does however only scrape the surface of what LaTeX can do. The *Typing mathematical notation* website contains further, optional resources that you might find useful having studied this unit. It also provides, for download, a *LaTeX quick reference guide* detailing the main commands and structures of LaTeX.

As you work through this material, be aware that you may encounter the occasional mathematical symbol or equation that you have not seen before. Don't worry: you are not expected to understand the meaning of all of the mathematical expressions in this unit. However, you are likely to encounter most of the symbols used at some stage during your studies.

A brief history of LaTeX

LaTeX is built on a system called TeX, which was started in 1978 by a computer scientist called Donald Knuth. The idea came to him as he was looking at proofs of the second edition of his book *The Art of Computer Programming*. He was horrified by the poor quality of the printing, and resolved to create a better system.

In the 1980s, Leslie Lamport, a computer scientist working for SRI International in California, wrote a more user-friendly 'front end' for TeX, which he called LaTeX. The 'La' refers to the first two letters of his surname.

Donald Knuth (1938–)

Unlike word-processing packages such as Microsoft Word, LaTeX is deliberately designed to separate the content of the document (that is, the text and, where applicable, the mathematics) from the formatting (for example the font, text size, margin sizes, and so on). This separation ensures the formatting of the document is consistent throughout, and means you can later change aspects of the appearance (such as the font size of all sub-headings) without having to work through the whole document and change each occurrence individually. This process is sometimes called **WYSIWYM**, standing for 'what you see is what you mean', to distinguish it from **WYSIWYG** ('what you see is what you *get*') editors such as Microsoft Word.

This separation of presentation and content means that the task of editing a document in LaTeX is different from most word-processing packages. Instead of editing and viewing in the same window, with LaTeX you carry out the steps summarised in Figure 3: you edit the **LaTeX file** (sometimes called the 'source file' or 'tex source'), and **process** it (this step is sometimes called 'LaTeXing', or 'compiling') to produce the **output PDF**.

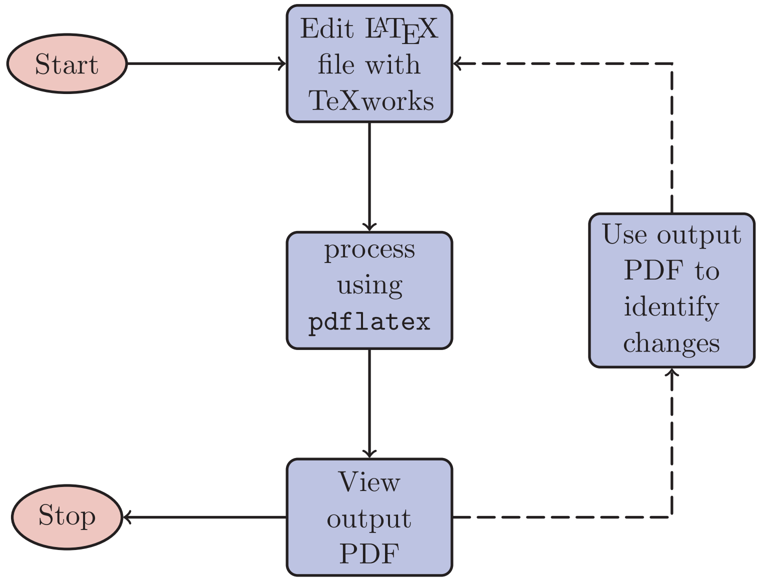


Figure 3 The steps required to edit, process and revise a document using LaTeX

The steps in Figure 3 will become clearer once you have seen in the installation instructions that the task of processing a LaTeX file is simply a matter of pressing a button, and you will quickly get used to this.

Now follow the installation instructions

Go to the *Typing mathematical notation* website and follow the instructions in the installation guide for LaTeX. These instructions will also show you how to process your first LaTeX file.

When your installation is finished and working properly, return to this point to begin learning how to use LaTeX.

2.1 First steps

Now you have a working LaTeX system and an editor installed, you are ready to start familiarising yourself with the basic text formatting features of LaTeX. By the end of this subsection, you will have a template TMA file, ready to be filled with mathematics.

The structure of a LaTeX file

Activity 1 Creating a TMA template file

First, open TeXworks (following the instructions described in the installation guide), and create a new LaTeX file (for example, by selecting `File` > `New`). Insert the following text into it, exactly as written here. Be especially careful with `\LaTeX` – notice the capital L, T and X.

```
\documentclass{article}
\author{My Name}
\title{TMA template file}
\begin{document}
\maketitle
Welcome to \LaTeX!
\end{document}
```

Choose `File` > `Save As...`, and navigate to the folder you created while following the installation instructions. Save your file with the name `tmatemplate.tex`. Now, following the steps shown in the installation guide, process your file using `pdflatex`.

What to do if LaTeX reports an error

Check that you have written exactly what is written above. If necessary, correct it and try processing it again.

If you still can't get LaTeX to process your file, jump to Subsection 2.3 to help you identify what happened, then return to here.

The output PDF should appear and look something like this:

TMA template file

My Name

February 23, 2022

Welcome to LaTeX!

LaTeX has produced a PDF file containing a title and today's date, and a welcome message.

Now change the text between the curly brackets `{` and `}` after `\author` so that it contains your name. Add a new line after this, and into this type `\date{}`. Process the file again, and notice how the output PDF has changed. Note that you do not need to resave the LaTeX file before reprocessing: TeXworks will automatically save it for you when you process it.

As expected, your name now appears underneath the title, but did you also notice that the date line has disappeared? By typing the command `\date{}`, you have told LaTeX that the date of this document is 'empty'. What happens if you enter text between the two curly brackets in `\date{}`? You should find that whatever you type between these curly brackets in the LaTeX file replaces the date that was displayed in the first output PDF in this activity.

LaTeX files, such as the one you have just created, consist of two parts: the preamble and the body. The **preamble** consists of the commands up to the line `\begin{document}`, and it contains all the instructions that LaTeX requires before actually creating the document. The **body** consists of the instructions from `\begin{document}` to `\end{document}` inclusive and it contains the text of the document itself. Any text after the `\end{document}` is ignored by LaTeX. You will not need to learn much about what can go in the preamble in order to produce a mathematical document, although later you will be shown how to add a couple of lines to it.

You might have noticed that the backslash symbol, `\`, is used a lot in your LaTeX file. This is a special character that tells LaTeX to interpret the next word as a LaTeX **command**, more formally called a **control sequence**, which instructs LaTeX to carry out a predefined sequence of operations. So, for example, the command `\maketitle` instructs LaTeX to create the title at the top of the document, using the `\title`, `\author` and `\date` that were set in the preamble.

Some commands need you to insert **arguments**, also known as **parameters**. For example, by typing `\title{TMA template file}` into the LaTeX file, you are using the `\title` command, and telling LaTeX that the corresponding argument is '`TMA template file`'. The effect, in this case, is to set the title to be equal to the argument.

Note: commands are case sensitive

Most commands are in lower case, but there are exceptions; for example, to display the 'LaTeX' logo you need to use the command `\LaTeX`.

The files that LaTeX produces

If you open the folder that contains the TMA template file that you created in Activity 1, then you should find that it now contains several files. Here are the most common files you will see; note that they all begin 'tmatemplate', which matches the name you gave to the LaTeX file that you created.

Table 1

File	Purpose
tmatemplate.tex	The **LaTeX file**. This is the file that you edit.
tmatemplate.pdf	The **output PDF**. This is the file created after processing the LaTeX file.
tmatemplate.aux	The **auxiliary file**. This is used by LaTeX to store page numbers, section references, cross references and so on. In this typesetting guide, you will never need to open this file.
tmatemplate.log	The **log file**. This contains a copy of the report from the last time you processed your LaTeX file. It can be useful to look inside this if your LaTeX file didn't process properly.

You may also find some other files, created by the editor as a backup of the source file (for example, TeXworks creates one called 'tmatemplate.synctex.gz').

The most important file is the LaTeX file, because everything else can be recreated from it. The next most important file is the output PDF: this is the output from LaTeX, and is the document you can share, print and/or submit as a TMA. You can open it using a PDF viewer (such as Acrobat Reader) by double-clicking it. Every time you successfully process the LaTeX file, the PDF gets replaced.

Note: close Acrobat Reader before reprocessing

If you use Acrobat Reader to view the output PDF, make sure you close Acrobat Reader before you try to reprocess the LaTeX file.

Otherwise, LaTeX will report an error, because Acrobat Reader places a 'lock' on the output PDF, meaning it can't be overwritten by LaTeX.

Formatting and organising text

You now have a LaTeX file with a title, author and (optionally) a date. Before you learn how to create mathematics, this subsection will explore some ways to format and organise text, such as placing text in *italics*. You should read through these, before following Activity 2 to edit your `tmatemplate.tex` file.

Except when instructed otherwise, you should place commands and text between the `\begin{document}` and `\end{document}` lines.

Paragraphs

To start a new paragraph, you need to leave a blank line in the LaTeX file (that is, you need to press Return *twice*). Thus, if you type the following into your LaTeX file

```
Paragraph 1.
This text is still in paragraph 1, even though
it is on a new line. To create a new paragraph, leave a
blank line in your LaTeX file.

This second paragraph starts with an indent.
Since LaTeX ignores single line breaks, you can use
them to make your LaTeX file easier to read.
```

it will produce the following in the output PDF.

> Paragraph 1. This text is still in paragraph 1, even though it is on a new line. To create a new paragraph, leave a blank line in your LaTeX file.
>
> This second paragraph starts with an indent. Since LaTeX ignores single line breaks, you can use them to make your LaTeX file easier to read.

Notice that LaTeX indents the first line of each paragraph. You may prefer your document not to use indentation, and instead for there to be vertical space to separate paragraphs (this is the style used in this unit, for example). To make this (optional) change to your document, type the following two lines into the preamble of your LaTeX file.

```
\parindent 0pt
\parskip 4pt
```

Note that ‘pt’ is an abbreviation for ‘point’, a unit often used in typesetting that is approximately 1/72 of an inch.

Sections

The `\section` command allows you to create a numbered heading, as follows.

`\section{Title of a section}`	**1 Title of a section**

Subsequent uses of the `\section{...}` command will automatically increment the numbering.

To suppress the number at the start, you can add an asterisk, as follows.

`\section*{An unnumbered section}`	**An unnumbered section**

Centre alignment

To align text in the centre of the page, place text within `\begin{center}` and `\end{center}`. Note the spelling 'center', *not* 'centre'!

```
\begin{center}
The text in here is centre-aligned on the page.
\end{center}
```

Such a pair of commands, where content is enclosed between `\begin` and `\end`, forms an **environment**. You will read more about environments shortly.

Bold, italic, underline

These can be achieved by the following three commands.

`\textbf{writing in bold}`
`\textit{writing in italics}`
`\underline{underlined writing}`
	writing in bold
	writing in italics
	<u>underlined writing</u>

You can also 'nest' these commands, to give, for example, bold and underlined text, as follows.

`\textbf{\underline{Bold and underlined!}}`	**<u>Bold and underlined!</u>**

Activity 2 Adding sections to your TMA template file

To your `tmatemplate.tex` file, add LaTeX code to do the following.

(a) Create three *unnumbered* sections entitled ‘Question 1’, ‘Question 2’ and ‘Question 3’. After these, create one *numbered* section entitled ‘Text formatting commands’. Process the file to ensure the output is as shown below.

> TMA template file
>
> My Name
>
> **Question 1**
>
> **Question 2**
>
> **Question 3**
>
> **1 Text formatting commands**

(b) Under the section ‘Text formatting commands’, add some more text and LaTeX commands to produce the following output:

> **1 Text formatting commands**
>
> This is the first paragraph of the section. Notice that it is not indented.
>
> This is another paragraph.
>
> Centre-aligned text
>
> **Text in bold and underlined!** Also, some text in *italics*.

Environments

So far, there are two commands that have appeared more often than others: `\begin` and `\end`. These commands are used to define **environments**. The general form of an environment is as follows.

```
\begin{<environment>}
...
\end{<environment>}
```

Here, the text `<environment>` should be replaced with the name of an environment. The content between the matching `\begin` and `\end` commands will all be subjected to the settings created by the environment. For example, `\begin{center}` causes everything in the LaTeX file until the matching `\end{center}` to be centred horizontally.

Let's look at two more environments: bulleted and numbered lists. These are provided by the `itemize` and `enumerate` environments, respectively. The syntax within these environments is identical: each bullet point or numbered entry is created with `\item`.

Code	Output

`\begin{itemize}`
`\item Bulleted item number 1.`
`\item Bulleted item number 2.`
`\item Number 3 ...`
`\end{itemize}`
	• Bulleted item number 1.
	• Bulleted item number 2.
	• Number 3 ...

Code	Output

`\begin{enumerate}`
`\item Numbered item 1.`
`\item Numbered item 2.`
`\item Number 3 ...`
`\end{enumerate}`
	1. Numbered item 1.
	2. Numbered item 2.
	3. Number 3 ...

In both environments, you can override the bullet point or number corresponding to an item by placing text in square brackets after the `\item` command.

Code	Output

`\begin{enumerate}`
`\item[(a)] Item starting with ‘(a)’.`
`\end{enumerate}`
	(a) Item starting with ‘(a)’.

Activity 3 Using the enumerate environment

Under the section labelled ‘Question 1’ in your TMA template, add an enumerate environment containing three items, labelled (a), (b) and (c):

> **Question 1**
>
> (a) First subquestion.
>
> (b) Second subquestion.
>
> (c) Third subquestion.

2.2 Mathematics

In the previous subsection, you learned some of the basic components of LaTeX and created a template TMA file. In this subsection, you are going to begin an exploration into the mathematical features of LaTeX. Don't worry if you've not seen some of the mathematical symbols or functions that are used as examples: you don't need to understand what these mean to learn LaTeX!

Inline and displayed mathematics

There are essentially two different ways to present mathematics: **inline maths**, where mathematics is within lines of text, for example $E = mc^2$, and **displayed maths**, where the mathematics occupies a line to itself. By default, displayed mathematics appears centred on the page like this:

$$E = mc^2.$$

You may notice, however, that this module is typeset with displayed mathematics indented, rather than centred, like this:

$$E = mc^2.$$

To change this positioning requires more sophisticated use of LaTeX, which is not covered here.

Activity 4 Creating inline and displayed mathematics

Download and save the file `mathematics.tex` from the *Typing mathematical notation* website, and open it in TeXworks. You will use this file to practise typesetting mathematics in this subsection and the next.

Alternatively, use TeXworks to create a new LaTeX file called `mathematics.tex`, containing the following text.

```
\documentclass{article}
\usepackage{amsmath}
\usepackage{amssymb}
\author{My Name}
\date{}
\title{Entering mathematical symbols}
\begin{document}
\maketitle

The equation $y=mx+c$ is inline.

The equation y=mx+c is inline, but not enclosed between
dollar signs.

The equation \[ \cos^2 \theta + \sin^2 \theta = 1\] is
in displayed maths mode.
\end{document}
```

Now process your file. The part of your output PDF after the title should look like this:

> The equation $y = mx + c$ is inline.
> The equation y=mx+c is inline, but not enclosed between dollar signs.
> The equation
> $$\cos^2\theta + \sin^2\theta = 1$$
> is in displayed maths mode.

Activity 4 illustrates that text between dollar signs, `$...$`, and between the 'backslash-square-brackets', `\[...\]` is treated differently from the other text in a LaTeX file. Such text is in **maths mode**, as opposed to the normal **text mode** which you have been using until now.

Be aware that in other material on LaTeX you may occasionally see double dollars, `$$...$$`, used to create displayed maths instead of `\[...\]`. This is an old command that still works in current LaTeX systems, but it is not guaranteed to work in future versions so you should avoid using it. Also, `\(...\)` is an alternative to `$...$` that some authors prefer.

Choosing between inline and displayed mathematics

There is no fixed rule of which to use when, but you can use the following as a general guide.

- You create **displayed maths** with `\[...\]`, and you should use this for long expressions, or expressions that contain large fractions or other tall symbols.

  For example, the quadratic formula
  $$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
  has a fraction in it, and is much easier to read when presented as displayed mathematics. Note also that tall constructions such as fractions appear differently in displayed and inline mathematics.

- You create **inline maths** with `$...$`, and you should use this for shorter expressions or single symbols that do not take up much room.

  For example, the sentence 'Let a and b be positive integers, and let d be the highest common factor of a and b.' has several inline mathematical symbols within it, and it would be harder to read if these were presented as displayed mathematics.

There are several further observations to be made about Activity 4. First, you may have noticed the lines `\usepackage{amsmath}` and `\usepackage{amssymb}` in the preamble. One of the most powerful features of LaTeX is the wide range of **packages** that are available to provide extra commands and formatting beyond the basic ones provided by LaTeX. The `amsmath` and `amssymb` packages provide enhanced tools for inputting mathematics, and are provided by the American Mathematical Society (the AMS). The LaTeX file you have just created does not actually require these packages, but later you will be using features of them (for example, to align equations on different lines, or for mathematical symbols such as $\mathbb{R}$) and so you should always include these `\usepackage` statements when your document is to contain mathematics.

Second, compare the maths mode version of the equation $y = mx + c$ in the first paragraph and the text mode version y=mx+c in the second. The biggest difference, of course, is that in maths mode the symbols are in *italics*. In typed documents, you will find that variables are always in italics, so when typesetting using LaTeX, you should always use dollar signs or the `\[...\]` 'brackets' around mathematics.

Do you notice any other differences between the equation within dollar signs and the same equation without dollar signs? Did you notice that there is more space on either side of the equals sign, =, and also on either side of the plus sign, +? LaTeX is designed to space mathematics correctly and in an attractive way, so you do not need to spend time doing this for yourself. In fact, LaTeX will override any spaces you insert in maths mode, as the next activity shows.

Activity 5 Exploring spacing in maths mode

Add a new paragraph to your `mathematics.tex` file with the following text, and process it again.

```
Extra spaces are ignored:
$y   =   m x + c$ appears the same as $y=mx+c$.
```

So, you can make your source code easier to understand if you wish by using spaces between the terms of an equation, and this does not affect the final output. Often you need to insert at least one space after a command such as `\LaTeX`, to ensure that LaTeX knows where the command finishes.

As you have seen, the displayed maths mode provided by `\[...\]` is useful for longer equations, or equations with tall symbols. Later, you will see more elaborate ways of creating displayed maths, giving you the ability to align equations and assign equation numbers.

The sample file used in Activity 4 also introduced some mathematical commands. First, the command `\theta` produces the Greek letter theta, θ. Second, notice the backslash before '`cos`'.

Activity 6 Exploring mathematical commands

What is the difference between typing `\cos` and `cos` while in maths mode?

You should use the command `\cos` to typeset the cos function, as this will help readers of your document to identify that you mean the function cos, rather than the three single-letter symbols c, o and s.

Using LaTeX to write mathematics on Open University forums

Did you know that you can include mathematics, typed using LaTeX, when you post to the forums for this module?

In order to enter maths mode on the forums, you need to use 'double dollars', `$$...$$`, around your mathematical symbols. Double dollars are needed so that a single dollar symbol can still be used to represent the currency!

Superscripts and subscripts

There is one more observation to be made about Activity 4: how did we obtain the superscript 2 (for 'squared')?

To create a superscript, use the `^` symbol, sometimes called 'caret'; for example, typing `a^b` in maths mode produces a^b. For subscripts, use the underscore `_` symbol; for example, `a_b` in maths mode produces a_b.

Activity 7 Putting several symbols within a superscript

Create the equation $x^a \times x^b = x^{a+b}$.

You can produce the $\times$ symbol by using the command `\times`. The difficulty is on the right-hand side of the equation, where the three symbols '$a + b$' need to be together in a single superscript.

To experiment, type the following into your `mathematics.tex` file, save and process it.

```
$x^a+b$
```

You should find this produces $x^a + b$: LaTeX has placed only the first character after `^` into the superscript.

Next, try typing `$x^a^+^b$`. When you process the file again, LaTeX will stop, and you will see the following error.

```
! Double superscript.
l.20 $x^a^
          +^b$
?
```

This is an example of a LaTeX **error** message: you cannot put two superscripts on the same symbol.

To escape this error and stop LaTeX from attempting to process the file, press the 'Abort typesetting' button in the top left-hand corner of the editor window or press Ctrl+T. Delete the offending code `$x^a^+^b$` and reprocess the file to ensure you have a working version again.

Instead, you need to tell LaTeX to group the '$a + b$' as a single superscript. To do this, use curly brackets; that is, place text within `{...}`.

So, the solution to the original task is that you can typeset $x^a \times x^b = x^{a+b}$ using the following text.

```
$x^a\times x^b = x^{a+b}$
```

Activity 8 Combining subscripts and superscripts

What is the effect of processing a LaTeX file containing the following? First try answering each without typing it in, and then check whether you were right.

(a) `$x^{a^b}$` (b) `$x^a^b$` (c) `$x^{a_b}$` (d) `$x^a_b$`

(e) `$x_b^a$`

Curly brackets and groupings

As you will have noticed in the examples of LaTeX code that you have used so far, curly brackets play a particular role in LaTeX: they are used to group characters and text together. Since LaTeX uses curly brackets in this way, there is a slight complication if you actually want curly brackets to appear in your document.

Activity 9 Investigating curly brackets

Place the following into your `mathematics.tex` file, save and process it.

```
(Parentheses.)

[Square brackets.]

{Curly brackets.}
```

This produces:

> (Parentheses.)
> [Square brackets.]
> Curly brackets.

Whereas the parentheses `(...)` and the square brackets `[...]` appeared exactly as expected, the curly brackets are completely invisible.

To make the curly brackets appear, modify your file by typing a backslash before each of the curly brackets as follows.

`\{Curly brackets.\}`	{Curly brackets.}

Activity 9 illustrates a more general rule-of-thumb: if a symbol is used by LaTeX for some particular purpose, then add a backslash before the symbol to make it appear in your document. For example, since the dollar sign `$` is used to switch between text mode and maths mode, you need to type `\$` to produce a dollar sign in your document.

There is one notable exception to this rule: the backslash itself, which you can produce using the command `\backslash` within maths mode.

Activity 10 Investigating the double-backslash command

What happens if you type `\\` in your file?

Activity 11 Adding some mathematics to your TMA template

Reopen your `tmatemplate.tex` file, and add:

(a) two lines to the preamble to include the `amsmath` and `amssymb` packages (see Activity 4 for these lines of code)

(b) a *numbered* section after the existing sections, entitled 'Mathematics commands' and containing LaTeX code to produce the following:

> **2 Mathematics commands**
>
> There are two ways to display mathematics: inline and displayed mode.
>
> Inline mode is written within dollar signs. For example, the quadratic equation $y = ax^2 + bx + c$ appears within the normal flow of the text.
>
> Displayed maths is written within backslash-square-brackets. For example, Euler's formula,
>
> $$e^{i\theta} = \cos\theta + i\sin\theta,$$
>
> occupies a line to itself.

2.3 Error messages

Despite your best intentions, you will inevitably make the occasional mistake while typesetting in LaTeX. These mistakes can affect how LaTeX processes the file, and this often causes an error, so no PDF output will be created. It is important to be aware of what might have caused such errors, and how to get back to a working file.

Tip: process your LaTeX file frequently

Processing frequently will help you to avoid losing unsaved work. Also, if you inadvertently introduce an error in your source file that causes LaTeX to fail to finish processing, then it will be easier to work out where the error is.

There are two types of problem: **errors**, which cause LaTeX to stop the current processing attempt and ask you to intervene, and **warnings**, which do not halt the process, but alert you to the fact that something unexpected has happened.

When LaTeX encounters an error, TeXworks opens the 'Console output' pane at the bottom of the editor and displays the error. You can use this to help you to find where in your LaTeX file the error is being caused, as shown in Figure 4.

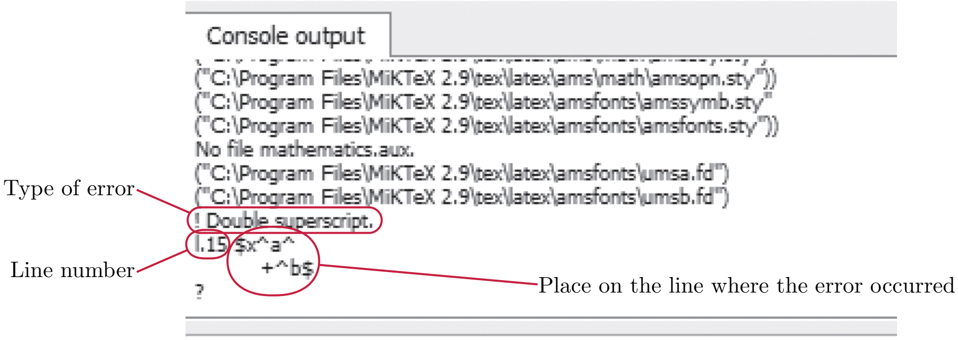


Figure 4 Understanding the information in a LaTeX error

You have already seen one error: the 'double superscript'. Recall that, in TeXworks, to escape this error and stop LaTeX from processing the file, you pressed the 'Abort typesetting' button in the top left-hand corner of the editor window. To help you locate the error, the message in the 'Console output' tells you on what line of the source file LaTeX encountered the error, but be aware that the real mistake might have happened several lines earlier! For example, a missing `$` sign at the end of a piece of mathematics might only cause an error at the next piece of mathematics. This is because LaTeX assumes that everything up to the next dollar sign is in maths mode, but then it will try to process the next piece of mathematics in text mode.

A list of common errors, and what might have caused them, is given in Table 2.

Table 2 Common errors and their causes in LaTeX

Error	Likely cause
`! Undefined control sequence.`	A mistyped LaTeX command, such as `\begni` instead of `\begin`.
`! Too many }'s.`	LaTeX matches `{`s with `}`s, so you either missed an opening curly bracket, or have too many closing curly brackets.
`Runaway argument?`	This is often caused by a missing right curly bracket, `}`.
`! Missing $ inserted`	Some commands, such as `^`, can only be typed when in maths mode.

What to do if your file doesn't process properly

- Look at the error message that appears: this tells you the line number in the file that caused the error, and the type of error.
- In TeXworks, press the 'Abort typesetting' button or press Ctrl+T to stop LaTeX from trying to process your file.
- Check your LaTeX file carefully to identify and correct mistakes that might be causing the error. The line your cursor is currently on is shown in the bottom right-hand corner of TeXworks.
- Reprocess your file. The PDF output should update if the error is fixed.

To help you to locate an error in your LaTeX file, here are a couple of strategies you can use:

1. Type `\end{document}` early: LaTeX ignores everything in the file after `\end{document}`, so if you type this in the middle of your document, and LaTeX manages to process the file, then you know that the mistake comes later.
2. Use `%` to 'comment out' lines of text. LaTeX ignores everything on a single line after a percent sign. So, if you suspect a particular line of your LaTeX file is causing the error, you can use `%` at the beginning to 'comment the line out', and see whether LaTeX can now process the file.

In addition, you may sometimes see the warnings in Table 3.

Table 3 Common warnings and their causes in LaTeX

Warning	**Likely cause**
`Underfull \hbox (...`	To fill the line, LaTeX has had to leave very long spaces between words – sometimes caused by a very long inline equation.
`Overfull \hbox (...`	The opposite of underfull: LaTeX has too much text to fit into a single line, so it has run into the right-hand margin – often caused by very long inline equations.

When you encounter 'overfull' and 'underfull' hboxes, look at the PDF output of your file and decide whether you need to change anything. If the problem is being caused by a long equation in inline maths mode, consider putting it in displayed maths by replacing `$...$` with `\[...\]`.

In the next activity you are asked to spot several errors in a piece of LaTeX code. Before looking at that code, note that the LaTeX logo has to be typeset as `\LaTeX\` rather than `\LaTeX` whenever it is to be followed by a space. (This is because LaTeX ignores any spaces that are immediately after a command, but it reads '`\ `' as a command to include a space.)

Activity 12 Spotting and correcting errors

Download and save the file `errors.tex` from the *Typing mathematical notation* website, and open it in TeXworks. Alternatively, use TeXworks to create a new LaTeX file called `errors.tex`, containing the following text.

```
\documentclass{article}
\title{Spotting errors}
\author{J. Bloggs}
\date{}
\begin{document
\maketilte

There are several types of error one might find in a
\Latex\ file. It is important to process your \LaTeX\ file
frequently in order to make sure you can identify problems
quickly and easily.

Spotting errors can get particularly complicated when there
is a lot of mathematics. Even an equation as simple as y=x^2
can go wrong in several ways, so each time you write
mathematics in your file it is sensible to check the
equation is correct by processing it, before moving on to
the next task. Remember also to match curly brackets.}
\end{document}
```

What errors can you spot in this file? By repeatedly processing and revising, identify and correct all the mistakes.

2.4 Commands for producing mathematical symbols

In the previous subsection, you learned the basic mathematical facilities of LaTeX. During this, you also encountered the `\cos`, `\theta` and `\times` commands for producing mathematical objects. Now let us look at a few more, all of which need to be input within maths mode.

Table 4 gives a small selection of the vast range of mathematical objects available. A longer list is provided on the *LaTeX quick reference guide* available to download from the *Typing mathematical notation* website. All of these commands need to be created within maths mode, so don't forget to enclose them in `$...$` or `\[...\]` if you want to try them out.

Table 4 A selection of mathematical symbols and commands

Command	Result	Notes
`\frac{abc}{def}`	$\frac{abc}{def}$	The first pair of curly brackets contains the numerator, the second the denominator.
`\sqrt{abc}` `\sqrt[n]{abc}`	$\sqrt{abc}$ $\sqrt[n]{abc}$	
`\sin`, `\cos`, `\tan`	$\sin$, $\cos$, $\tan$	Other functions are also available.

`\mathbb{N}`
`\mathbb{Z}`
`\mathbb{Q}`
`\mathbb{R}`
	$\mathbb{N}$
	$\mathbb{Z}$
	$\mathbb{Q}$
	$\mathbb{R}$
		These symbols are written using a font called '**b**lackboard **b**old', and need the `amssymb` package.

`<`, `\le`
`>`, `\ge`
`\ne`, `\in`, `\equiv`
	$<$, $\le$
	$>$, $\ge$
	$\ne$ $\in$, $\equiv$
		`\le` stands for '**l**ess than or **e**qual to'; the command `\leq` also produces $\le$.

`\alpha`, `\beta`, `\gamma`, ... `\Gamma`, `\Delta`, `\Theta`, ...	α, β, γ, ... Γ, Δ, Θ, ...	Lower-case Greek alphabet. Upper-case Greek alphabet. `\Alpha` does not exist, for example, since it is the letter 'A'.
`\infty`	∞	

You do not need to memorise the commands in Table 4: it is more important that you understand how to apply and combine commands to produce the output that you want. Of course, the more you use LaTeX, the more familiar you will become with the most common features.

OOO, I'VE THOUGHT OF A NEW ONE! TWO SQUIGGLES AND A BACKWARDS G!

Example 1 Typesetting Fermat's last theorem (the statement, not the proof!)

In the `mathematics.tex` file, typeset the statement of Fermat's last theorem:

Fermat's last theorem: The equation $x^n + y^n = z^n$ has no solutions for $x, y, z \in \mathbb{N}$ whenever $n \geq 3$.

Solution

Note that to be able to use the command for the blackboard bold letter $\mathbb{N}$, `\mathbb{N}`, you need to have `\usepackage{amssymb}` in the preamble of your document.

```
\textbf{Fermat's last theorem:} The equation $x^n+y^n=z^n$
has no solutions for $x,y,z\in \mathbb{N}$ whenever
$n\ge 3$.
```

Activity 13 Typesetting simple pieces of mathematics

Typeset the following pieces of mathematics.

(a) $\tan\theta = \frac{\sin\theta}{\cos\theta}$ (b) $\sin\frac{a}{b} \neq \frac{\sin a}{\sin b}$ (c) $x^{1/n} = \sqrt[n]{x}$

(d) If x is a positive real number, then $e^x \geq 1 + x$.

More complicated constructions

The following two examples introduce some new symbols, but also show some ways to combine symbols and commands to produce more complicated expressions or equations. Note that you may not have met all the symbols and mathematics in the following examples. If this is the case, do not worry: you do not need to understand what they mean to be able to typeset them! You may find it helpful to refer to the *LaTeX quick reference guide*.

Example 2 Typesetting more complicated constructions

Typeset the following pieces of mathematics using displayed maths.

(a) $\int_0^1 f(x)dx$ (b) $\lim_{n\to\infty} \left(1+\frac{1}{n} \right)^n = e$

Solution

(a) `\[ \int_0^1 f(x)dx \]`

The integral sign, $\int$, is produced using `\int`, with the lower and upper limits being specified using the subscript `_` and superscript `^` commands.

(b)
```
\[
\lim_{n\to\infty} \left( 1+\frac{1}{n} \right)^n = e
\]
```
The 'lim' is produced by typing `\lim`. Notice the curly brackets around `n\to\infty` so that all these symbols go in the subscript of the `\lim` command.

Note that mathematical expressions like the one in Example 2(a) are sometimes typeset so that the 'd' is not in italics, but in upright, or **Roman**, shape: d. Also, to separate the term $f(x)$ from $\mathrm{d}x$, a **thin space** is added, using the `\,` command. So, it is sometimes presented as follows.

`\[ \int_0^1 f(x)\,\mathrm{d}x \]`	$\int_0^1 f(x)\,\mathrm{d}x$

You are not expected to use this style in this unit.

In the two pieces of mathematics examples above, try changing the mathematics to inline maths, rather than displayed maths. Some of the symbols are slightly different.

For example, the inline expression $\int_0^1 f(x)dx$ takes up less vertical space than the equivalent expression in displayed maths:

$$\int_0^1 f(x)dx.$$

Similarly, the LaTeX code `\lim_{n\to\infty}` is presented differently in inline and displayed maths: inline, it appears as $\lim_{n\to\infty}$, with the subscript to the right of lim, while in displayed mode the subscript appears underneath:

$$\lim_{n\to\infty}.$$

Another important comment to make about Example 2(b) concerns the use of **scalable brackets**. These are brackets that can change their height to match the symbols and structures that they contain. To produce them, you use the following within maths mode.

```
\left(...\right)
```

Note that these brackets must be paired up, so every `\left` has a matching `\right` in the same mathematical expression.

Activity 14 Creating a really complicated formula!

Typeset the following formula (for the 'cumulative normal distribution' used in statistics) using displayed maths.

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}t^2} dt.$$

Hint: `\Phi` gives Φ.

Aligning equations

When writing mathematics by hand, you may often find yourself writing several equations on consecutive lines, lined up on the equals sign. How can you achieve the same effect with LaTeX? One method is to use the `align*` environment.

Example 3 Aligning equations on the equals sign

Use the `align*` environment to typeset the equations

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

Solution

```
\begin{align*}
y &= x^2-3x-4\\
  &= x^2-4x+x-4\\
  &= (x-4)(x+1).
\end{align*}
```

Note that you do not need `$...$` or `\[...\]` around this code, because the `align*` environment automatically knows to use displayed maths mode. Also, this code has been typed so that the equals signs are aligned, but this is just to help you read it.

First note that the `align*` environment behaves like displayed maths mode `\[...\]`, in that it starts the equation on a new line. This is as you should expect: it would be difficult to align equations *without* starting on a new line!

In Example 3, there are two commands to understand. First, the double-backslash (which you encountered in Activity 10), `\\`, tells LaTeX to begin a new line within the `align*` environment. Note that you do not need to write `\\` on the final line.

Second is the **ampersand** symbol, `&`. On each line of mathematics within the `align*` environment, there is one `&` symbol. This symbol does not appear in the output, but it causes LaTeX to 'line up' all the lines of mathematics within the `align*` environment on the position of this symbol. If you do not place an ampersand in a particular line, then LaTeX assumes that the ampersand is at the right-hand end of the equation.

Activity 15 Creating a multiple-line formula

Typeset the following double-angle formulas for cos, using the `align*` environment.

$$\begin{aligned}\cos(2\theta) &= \cos^2\theta - \sin^2\theta\\ &= 2\cos^2\theta - 1\\ &= 1 - 2\sin^2\theta.\end{aligned}$$

Equation numbering

Why does `align*` have an asterisk at the end of it? The only other command you have seen with an asterisk was `\section*{...}`, which produced an unnumbered section header.

Activity 16 Creating numbered equations

Place the following code into your `mathematics.tex` file, and process it.

```
\begin{align}
y &= x^2-3x-4\\
  &= x^2-4x+x-4\\
  &= (x-4)(x+1).
\end{align}
```

LaTeX should produce the following.

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

Notice how LaTeX has automatically given each line of the equation a unique number. If you have another `align` environment later in the same file, the numbering of equations within it will continue sequentially, so the first equation will be given the number (4), the second (5), and so on.

Suppose that instead of numbering all three equations in the example above, you wanted only the first and last to be given a number. In this case, you can type `\nonumber` at the end of the middle line (before the `\\`):

```
\begin{align}
y &= x^2-3x-4\\
  &= x^2-4x+x-4\nonumber\\
  &= (x-4)(x+1).
\end{align}
```

To produce a single numbered equation, such as

$$E = mc^2 \tag{1}$$

you can use the `equation` environment as follows.

```
\begin{equation}
E=mc^2
\end{equation}
```

As with the `align` environment, the `equation` environment automatically uses displayed maths mode.

Activity 17 Mixing numbered and unnumbered lines in an align environment

Modify your answer to Activity 15 so that the second line is numbered, but not the first or third, as follows.

$$\begin{align} \cos(2\theta) &= \cos^2\theta - \sin^2\theta \nonumber\\ &= 2\cos^2\theta - 1 \tag{1}\\ &= 1 - 2\sin^2\theta. \nonumber \end{align}$$

Matrices and vectors

The final mathematical construction in this LaTeX section is the method to create matrices. This is provided by the `amsmath` package. If you omit the line '`\usepackage{amsmath}`' from your LaTeX file, then this construction will not work properly and LaTeX will report an error.

Providing you have the **amsmath** package included in your file, then the following LaTeX code, inserted *within* maths mode, will produce a matrix.

`\begin{pmatrix}`
`a&b\\`
`c&d`
`\end{pmatrix}`
	$\begin{pmatrix} a & b \\ c & d \end{pmatrix}$

You may be wondering why the name of the `pmatrix` environment begins with the letter 'p'. This stands for 'parentheses', which is another name for the round brackets containing the entries of the matrix. It is needed to distinguish it from two other matrix constructions: `bmatrix`, which gives the matrix square brackets, and `vmatrix`, which places vertical lines on either side of the matrix. In this module, you mainly need the `pmatrix` version and occasionally the `vmatrix` version.

Within the `pmatrix` environment, you use the ampersand symbol, `&`, to specify separation between columns when moving along a row, and `\\` to end a row and start a new one. Notice that this use of `&` and `\\` is the same as in the `align` environment.

You can have as many rows and columns in a matrix as you wish: LaTeX automatically calculates how many of each you have used, and selects appropriately sized brackets to match.

Tip: displayed versus inline matrices

To make your output PDF easier to read, it's a good idea to use the `pmatrix` command only in displayed maths mode (that is, `\[...\]` or the `align` or `equation` environments) rather than in inline maths mode (that is, `$...$`).

Example 4 Creating a matrix

Typeset the following formula for the determinant of a 2×2 matrix.

$$\det \begin{pmatrix} a & b \\ c & d \end{pmatrix} = ad - bc$$

Solution

```
\[
\det
\begin{pmatrix}
a&b\\
c&d
\end{pmatrix}
= ad-bc
\]
```

Notice that in Example 4 the displayed equation appears on a single line, but the LaTeX code to produce it was written over several lines to make it easier to read.

Activity 18 Exploring matrix environments

(a) Use a matrix environment to create the following column vector.

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

(b) Use a matrix environment to create the following equation, which represents a rotation through angle θ about the z-axis.

$$R_z(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Creating a table in your document

Creating a table in LaTeX requires a similar approach to creating matrices, and uses the `tabular` environment. The main difference is that here you have to specify the alignment of each column, and indicate where to draw lines between rows and/or columns. Let's look at an example.

```
\begin{tabular}{l|c}
Name & Notation\\
\hline
sine & $\sin \theta$\\
cosine & $\cos \theta$\\
tangent & $\tan \theta$\\
\hline
\end{tabular}
```

Name	Notation
sine	$\sin\theta$
cosine	$\cos\theta$
tangent	$\tan\theta$

The first thing to notice is that the `&` and `\\` commands are used in the same way as they are in the `pmatrix` environment, so `&` separates cells within a row, and `\\` ends the current row and starts a new one.

However, the `tabular` environment differs from the `pmatrix` environment in several ways:

- The `tabular` environment is not inside maths mode. This means that in order to place mathematics within a cell of the table, you should place it within dollar signs, `$...$`. Be sure to close maths mode (by placing the second `$` sign) before typing `&` or `\\` to start a new cell, otherwise LaTeX will report an error when you try to process the file.
- You need to specify the number and alignment of columns within the `tabular` environment. You do this using the pair of curly brackets after the `\begin{tabular}` command, and inserting a sequence of commands from the following:

Command	**Effect**

`l`
`r`
`c`
	Creates a left-aligned column.
	Creates a right-aligned column.
	Creates a centre-aligned column.

`p{3cm}`	Creates a 'paragraph box' with width fixed at 3 cm. Useful for cells that are going to contain a lot of text, as it automatically adjusts its height to keep the width fixed.
`|`	The vertical bar is used to create a vertical line in the table, either between two columns or marking the left- or right-hand edge of the table.

  For example, typing `\begin{tabular}{rlc|p{4cm}|}` will start a `tabular` environment with 4 columns, which are (from left to right) right-aligned, left-aligned, centred, and fixed at 4 cm wide, and with a vertical line on either side of the fourth column.

- Finally, the `\hline` command draws a horizontal line across the width of the table. You need to type `\hline` at the *beginning* of the row that it lies above.

Activity 19 Adding a table to your TMA template file

Insert LaTeX code into your `tmatemplate.tex` file to produce the following table.

Right-aligned	Left-aligned	A cell with width fixed at 4 cm
cell 1	cell 2	cell 3

2.5 Preparing to typeset a TMA

While this introduction has covered only a few of the features available in LaTeX, you have seen almost enough now to be able to typeset a TMA. You have created a TMA template, which has shown you how you can organise your document by question, subquestion, and so on, and you have learned some of the principal techniques required to typeset mathematics.

Do remember, however, that you can submit handwritten working as answers to all TMA questions, apart from those assessing this unit, where you are specifically asked to typeset your answers.

Including graphics in your document

For some TMA questions you may want to include graphs or other diagrams. While there are a number of powerful LaTeX packages that allow you to draw these (for example, Ti*k*Z), it's best to wait until you are confident with using LaTeX before you try to use one of them.

For now, you can include pictures in your document that have been created by some other piece of software. For example, you may have drawn a graph using a computer algebra system, or scanned in a hand-drawn diagram.

In order to insert pictures, another package needs to be loaded by your LaTeX file. This package is called `graphicx`, and can be included by inserting the following in the preamble of your LaTeX file.

```
\usepackage{graphicx}
```

Now, suppose you have a file called 'picture.jpg' that you wish to include in your document. With the picture file *in the same folder* as your LaTeX file, you can insert the picture in your document by typing the following command at the appropriate place in your LaTeX file.

```
\includegraphics{picture.jpg}
```

You can include JPEG, PNG and PDF graphics files.

The `\includegraphics` command has a number of optional arguments, which you can place in square brackets after `\includegraphics`, in order to adjust the way the graphic appears. For example, to halve the size of the picture, type the following.

```
\includegraphics[scale=0.5]{picture.jpg}
```

If you are including a graphic from a PDF file with several pages, then only the first page of the PDF will be displayed by default. To specify a different page, use the option `page=x`. So, for example, the following command specifies that the second page of the PDF file should appear, at half size.

```
\includegraphics[page=2,scale=0.5]{picture.pdf}
```

Some of the options that you can use are listed in Table 5.

Table 5 Options to use with the `\includegraphics` command

Option	**Effect**
`width=x`	Sets the width to be `x`. You need to include units, for example `width=4cm`. Other units are `in` (inches), `mm` (millimetres) and `px` (pixels).
`height=x`	Sets the height to be `x` (units are required). If only one of width and height is set, the graphic will be scaled to maintain the aspect ratio.
`scale=x`	Scales the graphic by the factor `x`.
`page=x`	When including a PDF graphic, specifies to use page `x`.
`trim=l b r t`	Crops the graphic by `l` from the left, `b` from the bottom, `r` from the right and `t` from the top. All four of `l b r` and `t` need units.
`clip=true`	Needed in order for the `trim` option to work.

Activity 20 Adding an image to your TMA template file

Download the image `ou-logo.jpg` from the *Typing mathematical notation* website. Include this image in your `tmatemplate.tex` file, scaled to half its original size.

3 Microsoft Word

You should study this section if you have decided to learn about mathematical typesetting in Microsoft Word.

This section will introduce you to the mathematical features provided in Microsoft Word.

The screenshots and other version-specific details are based on the 2021 Office 365 version of Word, but the functionality described is broadly applicable to versions of Microsoft Word released since 2007 on Microsoft Windows, and versions released since 2011 on Apple Macs.

This introduction assumes you already have some familiarity with the basic features of Word, such as the formatting and simple manipulation of text.

As you work through this typesetting guide, be aware that you may encounter the occasional mathematical symbol or equation that you have not seen before. Don't worry: you are not expected to understand the meaning of all the mathematical expressions in this unit. However, you are likely to encounter most of the symbols used at some stage during your studies. A *Word maths quick reference guide* detailing some of the most useful mathematical features of Word is available to download from the *Typing mathematical notation* website.

The *Typing mathematical notation* website also contains further, optional resources that you might find useful having studied this unit.

Warning

It is important to note that mathematical notation created in versions of Word since 2007 (2011 on Macs) will not be preserved if the document is subsequently opened or saved in an earlier version of Word. When opened in earlier versions of Word, the mathematics is converted into relatively low-quality images that cannot subsequently be edited.

A safer way to ensure that a Word document containing mathematics can be viewed on a computer that doesn't have a recent version of Word installed is to save a copy in Portable Document Format (PDF). Instructions on how to do this are included at the end of this section.

3.1 Inserting mathematics into a document

Once you have opened a document, you can access the mathematical facilities in Word by clicking on the ‘Insert’ tab, which reveals the **Insert ribbon**, shown in Figure 5. The ‘π Equation’ and ‘Ω Symbol’ icons are found at the right-hand end of the ribbon.

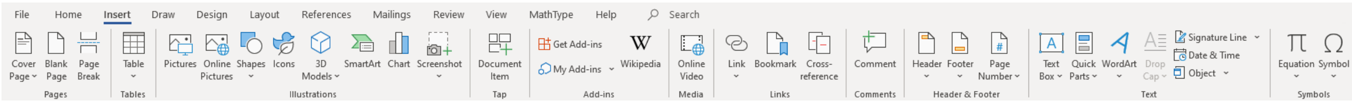


Figure 5 The Insert ribbon

The exact appearance of the Insert ribbon (and other menus mentioned later) will vary depending on the size of the document window, the size of your computer screen, and the version of Word that you are running. For example, you may find that the π Equation and Ω Symbol icons are instead stacked one above the other, rather than side-to-side as they are in Figure 5.

Use Ω Symbol when you wish to insert a single mathematical character (for example ‘$\leq$’) into your document. For longer equations, use π Equation.

Activity 21 Inserting single symbols

From the Insert ribbon, click on Ω Symbol. This will reveal a small palette of common symbols. Click on one of these symbols, and it will immediately be inserted into the text.

Click on Ω Symbol again then click on ‘More Symbols...’ to open the **Symbol window**, which has a much larger selection of characters. Select a symbol of your choice from this list, and click ‘Insert’ to place it at the position of the cursor in your document.

Close the Symbol window, and click again on Ω Symbol. The small palette of symbols that appears displays your most recently used symbols, and so it should now include the symbol that you just inserted into your document.

The Symbol window is arranged into font categories. You can scroll through an entire font category in the symbol window, but font categories containing a large number of symbols are typically arranged into subsets so, depending on the selected font, there may be an additional drop-down menu labelled ‘Subset’. If it is present then you can use it to quickly locate the subsets that are more likely to be useful for mathematics; for example, ‘Mathematical Operators’ and ‘Greek and Coptic’ are useful subsets of the ‘(normal text)’ category.

Warning: inserting single symbols

Be careful when you insert single symbols into a document. The symbols available will vary depending on the choice of font you have made for the text of your document, and some symbols will not appear properly if, for example, you later convert your file to a PDF document. You are advised to check your final document to ensure it appears as you intended it to.

Note that Greek letters, inserted from the Symbol window, are usually displayed correctly in a document converted to PDF.

Activity 22 Creating your first equation

From the Insert ribbon, click on π Equation. The **Equation ribbon** will become visible:

Also, a **mathematical input box** (often called an **equation box**) will appear at the position of the cursor:

(If the cursor is at the beginning of a new line the box may appear in a different position, in the centre for example. You will see how to amend this later.)

You are now in **mathematics input mode** (as opposed to the usual **text input mode**), where you can begin to create mathematical expressions and equations. Note that Word refers to all mathematical expressions as 'equations'.

To get a feel for it, type exactly the following text into the mathematical input box. Here, the **space symbol** '␣' means 'press the spacebar once', and $\boxed{\rightarrow}$ means 'press the right arrow key once' (the need for these will be explained later).

sin^2␣x$\boxed{\rightarrow}$ +cos^2␣x$\boxed{\rightarrow}$ =1

As you type, you will see that the formatting changes as Word establishes what mathematical expressions you are using, and it should now appear as follows.

$$\sin^2 x + \cos^2 x = 1$$

Press ↵ (the 'Enter' or 'Return' key) on your keyboard to finish creating the equation and return to text input mode on a new line. Note that you can also press → to finish creating the equation, but keep the cursor on the same line.

Notice how 'sin' and 'cos' are not in italics, but 'x' is. Notice also that space has automatically been put around the plus sign and the equals sign: you do not need to spend time inserting spaces in formulas, as Word will do this for you. Later in this introduction, you will explore in more depth this method of inputting mathematics using the keyboard.

Shortcut to switch between mathematics and text input

Holding down Alt (the 'Alt' key on your keyboard) and pressing '=' has the same effect as clicking the π Equation icon. Pressing Alt and = again returns you to standard text input mode.

This keyboard shortcut, which will in future be indicated by the symbol Alt+=, is the easiest way to toggle between mathematics input mode and standard text input mode.

(Alt+= is the Windows shortcut for switching between mathematics and text input. Other operating systems may differ, for example on a Mac the shortcut is obtained by holding down the 'ctrl' key and pressing '='.)

The **Equation ribbon** has four sections: 'Tools', 'Conversions', 'Symbols' and 'Structures'. The last two of these are the palettes that you will soon use to input some mathematical equations, but first take a look at the Tools and Conversions sections.

The **Tools** section occupies the left-hand end of the Equation ribbon, and it should appear as shown in Figure 6.

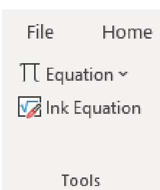
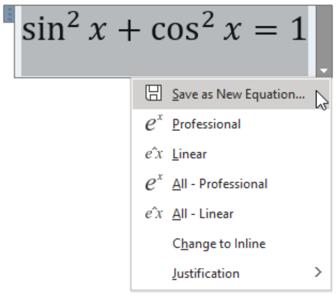


Figure 6 The Tools section of the Equation ribbon

Clicking on the π Equation icon in the Tools section of the Equation ribbon reveals a gallery of nine built-in equations. This can also be accessed directly from the Insert ribbon by clicking on the small down arrow, which is either next to or below the π Equation icon (depending on the particular version of Word you are using).

Activity 23 Adding your own equation to the gallery

Select your previously-written equation ‘$\sin^2 x + \cos^2 x = 1$’ by clicking on it. Then click on the down arrow at the bottom of the thick right-hand border of the equation box to reveal a drop-down menu, and select ‘Save as New Equation…’.



This will open a new window in which you can, if you want to, change the name of the equation and the category under which it is listed. Click ‘OK’ to add this equation to the bottom of the equation gallery.

The **Conversions** section of the Equation ribbon, shown in Figure 7, is immediately to the right of the Tools section. It offers various ways to enter and present the content of equations.

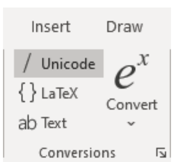


Figure 7 The Conversions section of the Equation ribbon

The first two labels on the left of the Conversions section offer a choice between entering mathematics using the standard command syntax ‘/ Unicode’ or LaTeX command syntax ‘{ } LaTeX’. Unicode is the default setting, so if it is not already highlighted, click on / Unicode to select standard syntax. The { } LaTeX option is not explored further in this section as it has limited functionality compared with a full implementation of LaTeX.

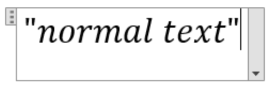
The third label on the left, ‘ab Text’, is a toggle switch that enables you to insert non-mathematical text within a mathematical input box. Click on ab Text to enable this mode; click again to disable. When ab Text is highlighted, anything you type in a mathematical input box will be entered as normal text. You can also enter normal text in the mathematical input box by enclosing it in double quotes.

Activity 24 Typing normal text inside an equation

Create a new mathematical equation (either by using Alt+= , or by clicking on π Equation from the Insert ribbon) and type the following into it:

```
"normal␣text"
```

This should produce:



Now press the spacebar on your keyboard. The quotation marks should disappear, and you will be left with the following:

Press Alt+= again to leave the equation and return to text input mode.

The final feature of the Conversions section is the large e^x above the word Convert. This control provides conversion between ‘Professional’ and ‘Linear’ display and you will learn more about those modes in the next subsection.

Inline and display mathematics

Word distinguishes between **inline** mathematics, which is shown within a paragraph of (normal) text, and **display** mathematics, which is on a line of its own. A mathematical input box created within a paragraph that already contains text will automatically be inline.

Activity 25 Choosing inline or display mathematics

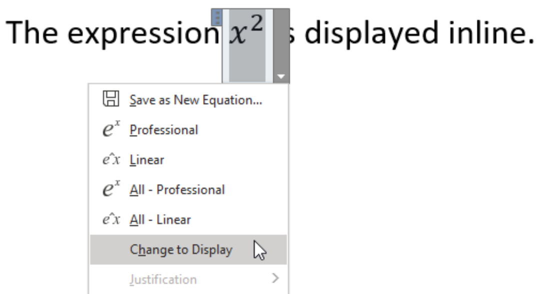
Making sure you are in text mode, start a new paragraph in your document, and type the following. Remember that Alt+= means 'press the Alt key and the = key at the same time,' and note the '␣' after typing `x^2` to instruct Word to build the index notation 'to the power 2'.

```
The␣expression␣[Alt+=] x^2␣[Alt+=] ␣is␣displayed␣inline.
```

You should now have the following in your document:

The expression x^2 is displayed inline.

Now select the x^2 expression. Click on the down arrow in the right-hand border of the equation box, and select 'Change to Display'.



The expression will now occupy its own line. It may be left-justified or centre-justified depending on the display mode default justification setting in your version of Word.

The expression

$$x^2$$

is displayed inline.

You can restore the expression to inline by using the drop-down menu again and selecting 'Change to Inline'.

One distinction between inline and display mathematics, apart from the location of the equation relative to other text, is that, for certain mathematical structures, inline automatically adopts a more compact presentation than display. This is most noticeable for fractions, integrals and summations, as illustrated in the table below.

This behaviour is automatic and cannot be disabled or re-configured.

Table 6 Inline mathematics is sometimes more compact.

Display mathematics	Inline mathematics
$\displaystyle \sin\phi = \frac{12\sin\theta}{45}$	$\sin\phi = \frac{12\sin\theta}{45}$
$\displaystyle \int_a^b f(x)\,\mathrm{d}x$	$\int_a^b f(x)\,\mathrm{d}x$
$\displaystyle \sum_{k=1}^{n} k^2$	$\sum_{k=1}^{n} k^2$

Inputting mathematics using palettes

The easiest (but, as you will discover, often not the quickest) way to get started with inserting mathematics is to use the palettes available on the Equation ribbon. You'll still need to use your keyboard to insert 'normal' characters, such as numbers and letters of the Roman alphabet.

First, the **Symbols** section of the Equation ribbon contains a palette of 'symbols', as shown in Figure 8.

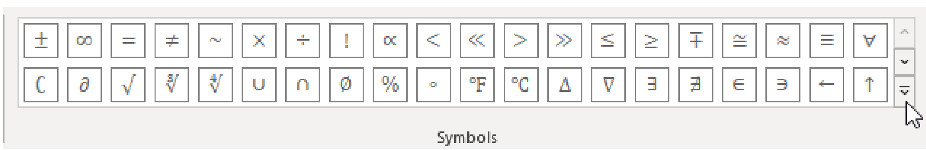


Figure 8 A symbols palette on the Equation ribbon.

Clicking on one of the visible symbols will immediately paste it into the currently active mathematical input box.

Further symbols on the current palette can be accessed by scrolling using the up and down arrows at the right-hand side of the palette. Click on to reveal the whole of the current symbols palette.

Once the whole palette is open, you can click on the bar at the top (where it first says 'Basic Math') to reveal a drop-down menu of all the symbols palettes, as shown in Figure 9. The main symbols in these palettes are listed in the *Word maths quick reference guide*.

Figure 9 Choosing which of the symbols palettes to display

After one of the palettes has been selected, it will appear on the Equation ribbon until another symbols palette is selected. To close a palette, click anywhere in the document outside of the palette.

Activity 26 Creating symbols using the palettes

Insert the following equation into a Word document using (where required) characters from the palettes in the Symbols section of the Equation ribbon.

$$c = 2\pi r$$

The right-hand section of the Equation ribbon, labelled **Structures**, contains a palette of icons representing different types of mathematical structure, as shown in Figure 10.

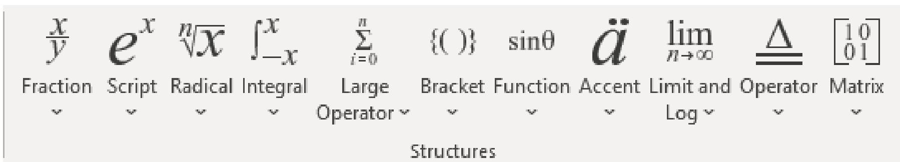


Figure 10 The Structures palette on the Equation ribbon

Click on any one of these icons to reveal a submenu of structures that can be used singly, or in combination, to build up mathematical expressions. When you click on a structure, it will immediately be pasted into the currently active mathematical input box.

Each structure has a number of **placeholders**, indicated by a blank square with a dotted frame. For example, in the 'Fraction' submenu, the 'Stacked Fraction' structure has two placeholders:

Each placeholder can be filled with numbers, letters, symbols or another structure, or a combination of these, by clicking on the placeholder so that it becomes highlighted. You can also move between placeholders using the keyboard up, down, right and left arrow keys. Thus, the process for creating the expression $\dfrac{x^2}{\sqrt{32\pi bc}}$ might proceed as shown in Figure 11.

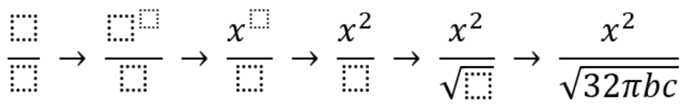


Figure 11 The process of creating an expression by building up and filling placeholders

Any expression selected from one of the submenus can subsequently be edited, as the next activity demonstrates.

Activity 27 Editing an existing expression

Create a new mathematical input box, and select $\sqrt{a^2+b^2}$ from the 'Common Radicals' section of the 'Radical' submenu. This will insert the expression into your new input box.

Now modify it, using the keyboard to type the necessary characters, so that it is the following.

$$\sqrt{(ax)^2 - \pi b^2}$$

Activity 28 Creating expressions using the Equation ribbon

Use the Equation ribbon to generate the following mathematical expressions.

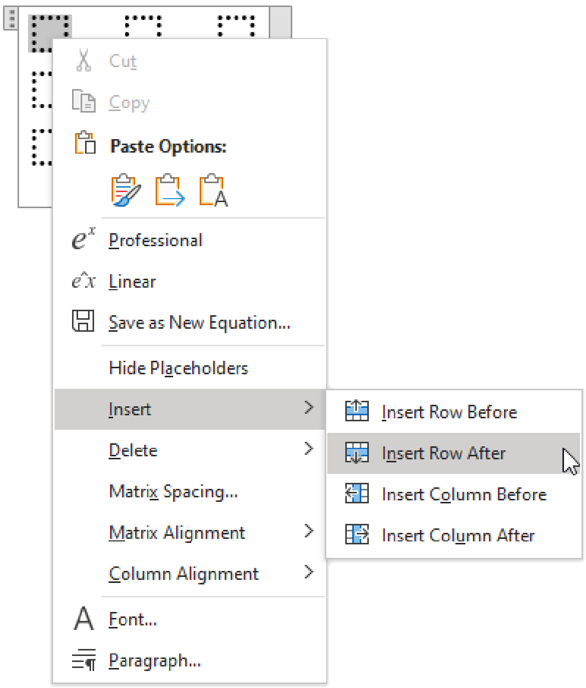
(a) $\tan\theta = \dfrac{\sin\theta}{\cos\theta}$

(b) $\sin\dfrac{a}{b} \neq \dfrac{\sin a}{\sin b}$

(c) The 3×3 identity matrix:

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

In the previous activity, you created a 3×3 matrix using palettes. This is the largest size of matrix offered by the ‘Matrix’ submenu. If you need to create matrices with more than 3 rows or 3 columns, insert a small empty matrix as a starting point, then select any cell within the matrix and click the right mouse button to give the pop-up menu for cells.



Use the Insert option on this menu repeatedly to insert as many additional rows and columns as required. You may also find that setting Column Alignment to Right gives a more uniform appearance if your matrix contains negative numbers.

Later, you will also see how to create matrices using the keyboard only.

Quick Access toolbar

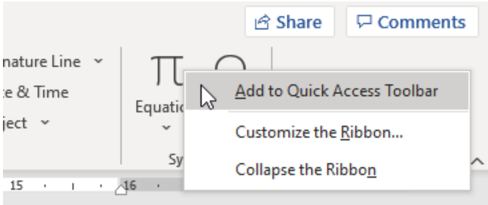
You will quickly grow tired of clicking ‘Insert’ before clicking on Ω Symbol or π Equation. As you have seen, you can obtain the Equation ribbon by pressing Alt+= on your keyboard, but it can also be useful to add two icons to your **Quick Access** toolbar.

By default, the Quick Access toolbar is embedded in the title bar of the Word window at the left-hand end, and by default this toolbar contains commands such as Save and Undo. You can add commands to the Quick Access toolbar so that they are always available, irrespective of which ribbon is visible.

Activity 29 Adding buttons to your Quick Access toolbar

To add the π Equation command, first select the Insert ribbon, right-click on the π Equation icon and select 'Add to Quick Access Toolbar'.

Similarly, right click on the Ω Symbol icon and add it to the Quick Access toolbar.



Your Quick Access toolbar should now contain icons for the π Equation and Ω Symbol commands:

3.2 Inputting mathematics using the keyboard

Word has two input modes for mathematical expressions. The first, which you learned about in the last subsection, is the graphical user interface (GUI) using the palettes on the Equation ribbon and related menus, and these are most naturally accessed with a mouse.

The second mathematics input mode uses the keyboard to type in commands and symbols that are automatically rendered as properly formatted mathematical expressions; it is this mode that you will explore in this subsection. Using the keyboard gives almost instant feedback, so that corrections can be made as the mathematical expression is being created. This keyboard approach (which is called **keyboard mode**) is similar to mathematical typesetting programs such as LaTeX and, once you become familiar with the commands, it is often faster than selecting structures from the Equation ribbon.

In both approaches (that is, keyboard mode, and using the Equation ribbon), the process of creating mathematical expressions automatically ensures that the size of brackets, fractions, square roots, and so on, is increased to accommodate whatever expression is created within them.

In fact, any mathematical expression can be built up by using a mixture of the two approaches, and it is easy to move between the two. Typically, the Equation ribbon is used for creating complicated expressions, and keyboard mode is used for simpler ones, either within a more complicated structure or on their own. Word documentation refers to the incremental formatting of a typeset equation as 'building up' the equation.

Delimiters

To work effectively in keyboard entry mode it is helpful to understand the role of **delimiters**.

Delimiters are characters that have special meaning as breaks in a sequence of otherwise plain text. In keyboard mode, several characters including spaces, brackets and punctuation marks can act as delimiters to trigger various formatting actions, depending on the context. You have already seen this in action when you typed `^2␣` to trigger the formatting of ‘to the power 2’ in Activity 25.

Don’t worry if this description sounds complicated; whether any particular character acts as a delimiter, or is treated as a normal character, is remarkably consistent and intuitive once you understand what is happening.

The next two activities take you through some simple examples of delimiters in action.

Activity 30 Using spaces as delimiters

Type the following and watch what happens as you enter each character:

```
[Alt+=] \theta␣ [↵]
```

The backslash marks the start of a **control word** and the space acts as a delimiter marking the end of the word. The control word `\theta` is then ‘auto-corrected’ to the corresponding symbol θ. Because the trailing space is acting only as a delimiter to trigger the build up (that is, the auto-correction), it is suppressed and does not appear in the typeset output. If you wanted a space after the θ you would have to enter two spaces; the first space causes the build up and is suppressed, and the second appears as a normal space.

When entering mathematics in keyboard mode we rarely need to explicitly insert space characters because Word automatically inserts appropriate spacings. This conveniently leaves the space character free to be used widely as a delimiter.

Type the following, again watching carefully what happens after each keystroke:

```
[Alt+=] (a+5/6)␣ [↵]
```

The closing bracket serves two purposes. It acts as a delimiter on the preceding fraction `5/6` causing it to be built up as a stacked fraction, but in this case the closing bracket is mathematically significant, so it is not suppressed.

The space character following the closing bracket acts as a delimiter on the bracket pair causing them to be matched and built up to a height appropriate to properly enclose the stacked fraction. Here the space is only acting as a delimiter so it is suppressed in the output.

In general, spaces and punctuation that act only as delimiters tend to be suppressed in the typeset output. Mathematically relevant symbols such as brackets, operators and other control words can also act as delimiters, but are not suppressed.

One exception to this rule is where a bracket pair serves to group mathematical terms in the keyboard input, but those brackets become redundant after the equation has been built up.

Activity 31 Using brackets as delimiters

This time, type the following, once again watching carefully what happens after each keystroke:

```
[Alt+=] ((a+5)/6)␣ [↵]
```

The extra inner brackets show that we want the numerator of the fraction to be $a + 5$, not just 5 as it was previously. Now the second closing bracket acts as a delimiter on the preceding fraction `(a+5)/6` again causing it to be built up as a stacked fraction. This closing bracket is still significant mathematically, so it is retained, but the bracket pair surrounding the two terms in the numerator is mathematically superfluous in the stacked arrangement so is suppressed in the output. If you wanted to have the numerator in brackets, you would enter:

```
[Alt+=] (((a+5))/6)␣ [↵]
```

Another example of the built equation being automatically 'tidied up' occurs with the square root control word. Try this:

```
[Alt+=] \sqrt(b^2-4ac)␣ [↵]
```

The opening bracket following the control word `\sqrt` delimits the control word and causes it to be immediately 'auto-corrected' to the radical symbol √. The subtraction symbol following the `b^2` delimits this first term and causes it to be built up to index notation form, b^2. The closing bracket encloses and defines the expression within the radical symbol but it is the following space character that delimits the square root structure as a whole and causes the overbar of the radical symbol to be re-drawn to cover the whole expression. The bracket pair enclosing the expression is then redundant and is suppressed in the output, as is the final space character which only served as a delimiter.

The last two activities introduced the role of control words such as `\theta` and `\sqrt`, which are commands from the **Math AutoCorrect** facility in Word, and they also illustrated the way that certain characters can act as delimiters to trigger the incremental construction of mathematical expressions.

You will explore these ideas further shortly, but first there is another equation building mechanism that you should be aware of.

Recognised functions

This feature is conceptually similar to the auto-correction of control words but in this case function names are matched or 'recognised' from plain text.

Activity 32 Using function recognition

Type:

Alt+= absinC ↵

All six letters appear in italic font, indicating that they have been interpreted as a simple variable name (or names; for typesetting purposes no distinction is made between *ab* repesenting a single variable called *ab* and the product of two variables, called *a* and *b*). The embedded letter sequence 'sin', which a human reader might still take as a reference to the sine function, is not identified.

Now type:

Alt+= ab␣sin␣C→ ↵

The extra spaces act as delimiters breaking the letter sequence into 'words'. When each 'word' is completed by a delimiter (a space in this case) it is automatically checked against the list of recognised functions. If the 'word' matches an entry in the list then it is automatically formatted in non-italic font to indicate that it is a recognised function. In this case *ab* is not recognised as a function name, but *sin* is. When a function name is recognised in this way, the delimiting space is replaced by a placeholder for the function's input. Subsequent characters are placed in the placeholder.

In this case the letter C is placed in the placeholder and the cursor sits inside the placeholder awaiting further input, so the $\boxed{\rightarrow}$ is necessary to exit this placeholder before the $\boxed{\hookleftarrow}$ can finish the expression.

Keyboard input for simple expressions

As you have seen, when mathematics is input in keyboard mode, control words and recognised function names are replaced by appropriate symbols and structures, and the expression is sequentially 'built up' (that is, formatted as standard mathematical notation) as each component of the expression is completed. Typically, this build up occurs upon pressing the spacebar at the end of an expression or part-expression.

The keyboard inputs for simple expressions are reasonably intuitive. Table 7 shows some of the most common; you can find more in the *Word maths quick reference guide*.

Table 7 Keyboard input for simple expressions

Type the following, followed by a space	**Result**
`x^2` `x_2`	x^2 x_2
`/`	$\frac{\square}{\square}$
`sin` `log`	$\sin \square$ $\log \square$

`\pi`
`\theta`
`\sigma`
`\Sigma`
	π
	θ
	σ
	Σ

`\infty`	∞

`\leq`
`\geq`
`\neq`
	$\leq$
	$\geq$
	$\neq$

`\sqrt`	$\surd$
`\angle`	$\angle$
`\quadratic␣`	$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
`\pm` (or type `+-`)	$\pm$
`\doubleN` `\doubleR`	$\mathbb{N}$ $\mathbb{R}$
`\in`	$\in$, meaning 'is an element of'

Note that you need to type *two* spaces after `\quadratic` in order for it to appear correctly. The first space causes the code word `\quadratic` to be replaced with '$x = (-b \pm \sqrt{}(b^2 - 4ac))/2a$'. Pressing the spacebar the second time causes the expression to be built up into its final form.

Example 5 Typesetting Fermat's last theorem (the statement, not the proof!)

Using only the keyboard, typeset the statement of Fermat's last theorem:

The equation $x^n + y^n = z^n$ has no solutions for $x, y, z \in \mathbb{N}$ whenever $n \geq 3$.

Hint: type `\doubleN` to create the symbol $\mathbb{N}$ for the natural numbers.

Solution

The sequence to type is the following; note that only the spaces in mathematics input mode have been marked explicitly by ␣ here.

`The equation` Alt+= `x^n+y^n=z^n␣` Alt+= `has no solutions for` Alt+= `x,y,z\in\doubleN␣` Alt+= `whenever` Alt+= `n\geq␣3` Alt+= `.`

Recall that Alt+= means pressing Alt and = simultaneously, to toggle between mathematics and normal modes.

Now here's one for you to try. Remember that you can create the quadratic formula very quickly by typing `\quadratic` (followed by *two* spaces) within a mathematical input box.

Activity 33 Creating mathematics using only the keyboard

Typeset the following, using only the keyboard.

The solution to the general quadratic equation $ax^2 + bx + c = 0$ with $a, b, c \in \mathbb{R}$ and $a \neq 0$ is given by the quadratic formula:

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

Combining keyboard inputs and grouping items

To create more complicated expressions by combining control words and function names you need to know how to group symbols and structures together so that Word understands precisely how the expression should be formatted.

You have already seen examples of how certain characters can act as delimiters to control and inform the build-up of mathematical expressions, the most important of these being the space character, closely followed by brackets.

In Activity 25 you saw how to use the space character to instruct Word to build up the expression x^2, and in Activity 31 you saw how to use brackets to define the numerator of a stacked fraction and the expression inside a radical. You also saw how the delimiter characters are often then suppressed in the formatted output having effectively been replaced by Word's own mathematical spacing.

In Activity 34 you will explore the use of spaces and brackets in more detail.

Activity 34 Grouping items together using brackets

Identify the differences between the following keyboard inputs placed in a Word document. Watch carefully as you enter each character to be sure to see its effect. In particular, notice, when entering the character following a closing bracket, that the closing bracket and its matching opening bracket often shift upwards slightly at this point. This is indicative that the brackets have been paired and they will now re-size, if required, to properly enclose the content between them.

(a) [Alt+=] `x^2␣sin␣(x)␣`[→] [Alt+=]

(b) [Alt+=] `x^2sin␣(x)␣`[Alt+=]

(c) [Alt+=] `x^2sin(x)␣`[Alt+=]

(d) [Alt+=] `x^(2sin(x))␣`[Alt+=]

(e) [Alt+=] `x^((2sin(x)))␣`[Alt+=]

As you have seen, brackets sometimes appear in the output, and sometimes act as delimiters in order to group items together. Brackets that are used to group items are removed when an expression is built up, and in this case extra brackets can be added for clarity. For example, typing `x^(y+z)` produces x^{y+z}, whereas `x^((y+z))` gives $x^{(y+z)}$.

However, when you type 'sin␣(x)␣', the brackets are not used as delimiters, and so they are not suppressed. The reason for this is that when you press the spacebar after typing 'sin', a placeholder is automatically created and the cursor is placed inside it. With practice, you will become familiar with when Word needs brackets to group items, and when it does not need them; but until then be careful to check that your output is what you expect it to be!

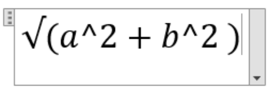
Professional and linear display

Word has two modes for displaying mathematics in an input box: **professional** and **linear**. Professional display corresponds to standard mathematical formatting, and is the default when using either of the input modes (as a result of the automatic build-up process in the case of text input). Linear display corresponds, roughly, to the sequence of commands you should type to create the expression using only the keyboard.

Activity 35 Understanding linear and professional display

In a new mathematical input box, create the expression $\sqrt{a^2 + b^2}$ (either by using keyboard input or by using the Equation ribbon). By default, this expression is displayed in professional mode.

With the cursor inside the mathematical input box, change the view to linear display. You can do this either by clicking the word Convert that is immediately below the large e^x in the Conversions section of the Equation ribbon then selecting 'Current - Linear' from the drop-down menu, or by clicking on the down arrow at the bottom of the thick right-hand border of the mathematical input box and selecting 'Linear' from the drop-down menu. The result is:



Linear display consists of a sequence of inline characters, which shows you the order in which you should type commands to create the expression using keyboard input.

You can often use linear display to learn the keyboard input required to produce a particular expression, or to investigate why an expression is not formatting as you expected. However, be aware that in some cases the control word, in the form that you would type it, is replaced by a special character that means the same thing to Word.

Sometimes the replacement character is a helpful reminder, as in the previous activity where the control word `\sqrt` is replaced by the character √, but with a few control words, `\matrix` for example, the replacement character renders, rather unhelpfully, as a black square.

For example, in Figure 12 the 3×3 identity matrix is in professional mode on the left and in linear mode on the right.

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \qquad (■(1\&0\&0@0\&1\&0@0\&0\&1))$$

Figure 12 Professional and linear displays for a matrix

Linear display also does not show the spaces required to trigger formatting actions such as indices and bracket pairing / resizing. In such cases, it may be easier and faster to use the Equation ribbon to create the expression. In fact, a matrix structure can be obtained by typing the command `\matrix`.

You can use linear or professional display while entering mathematical expressions, but remember to revert the expression to professional display when you have finished.

Text input for complicated structures

Now you have seen how to group characters together, it is time to explore creating some more complicated formulas. Note that you may not have met all the symbols and mathematics in the following examples. If this is the case, do not worry: you do not need to understand what they mean to be able to typeset them! You may find it helpful to refer to the *Word maths quick reference guide*.

Example 6 Creating expressions using only the keyboard

Use keyboard input to produce the following expressions.

(a) $\int_0^1 f(x)dx$ (b) $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ (c) $\lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n = e$

(d) $\sqrt[n]{x+y}$

Solution

In the following, the symbol [→] means that you should press the right arrow key on your keyboard. This is discussed in more detail after this example.

(a) [Alt+=] `\int_0^1␣f(x)dx`[→] [↵]

(b) [Alt+=] `(\matrix(1&0@0&1))␣`[↵]

Matrices are built up row-by-row, starting from the top. The **ampersand** symbol, `&`, indicates to move to the next column, while the **at** symbol, `@`, creates a new row.

(c) `Alt+=` `lim_(n\rightarrow\infty)␣(1+1/n)^n␣` → `=e` ↵

In this example, notice how after the build-up the 'subscript' for `lim` has been placed underneath the text, rather than to the right (as would normally happen when applying a subscript to a symbol). Also notice that `lim` does not begin with a backslash and that the second pair of brackets appears in the output: Word has not used these brackets to group items together.

(d) `Alt+=` `\sqrt(n&x+y)␣` ↵

This command is identical to the normal square root, except that here the ampersand symbol, `&`, separates the index n on the left from the the expression $x+y$ under the radical on the right.

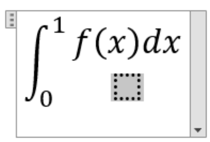
In a number of input expressions you have seen, the right arrow key, → , has been needed in order to 'leave' a placeholder; that is, to escape from it. The following activity will help you to explore why and when this is needed.

Activity 36 Escaping from placeholders with →

Type the following into a mathematical input box. This is the same as part (a) of Example 6, but with the → removed.

```
\int_0^1␣f(x)dx↵
```

This should produce:

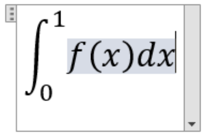


which is not what was intended!

The reason for this is that the integral sign, produced using `\int`, creates a placeholder to its right. The cursor will stay within this placeholder until you use either the mouse or an arrow key to move the cursor to somewhere else. Pressing ↵ causes Word to create a new line *within* the current placeholder.

To correct this, select the unwanted new line placeholder, then click the right mouse button and select 'Delete Equation' from the pop-up menu, then press → → ↵ to finish the expression correctly.

In Activity 36, immediately before pressing ↵ the mathematics after the integral sign is highlighted:



This tells you that the cursor is currently inside a placeholder. Pressing → (instead of ↵) at this point moves the cursor out of the placeholder. This is indicated by the fact that the grey background disappears, so it is then safe to press ↵ or → to close the mathematical input box.

Simply pressing the spacebar or enclosing the mathematics after the integral sign in brackets is not sufficient to exit the placeholder. It is, therefore, very important to be aware when the cursor is within one of these placeholders.

In the activity you will also have noticed that, having corrected the error, you had to press → *twice* to fully deselect the expression before finishing. This suggests that there were two nested placeholders to exit, and this is correct. There is the original integrand placeholder, but there is also an inner placeholder created automatically by Word as a result of your 'accidentally' making and then deleting the new line. Extra placeholders like this, created as a result of edits, are not necessarily problematic, but can cause unexpected results if you are not aware that this can happen.

Commands that call for some care in this respect include the trigonometric functions (sin, cos, tan, and so on), and the `lim` and `\int` commands.

Activity 37 Creating a more complicated expression

Typeset the following equation using keyboard input.

$$\frac{d}{dx}(x^2 \sin(x)) = 2x \sin(x) + x^2 \cos(x)$$

Activity 38 Creating a really complicated equation!

Typeset the following formula for the 'cumulative normal distribution', used in statistics, using keyboard input.

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}t^2}\, dt$$

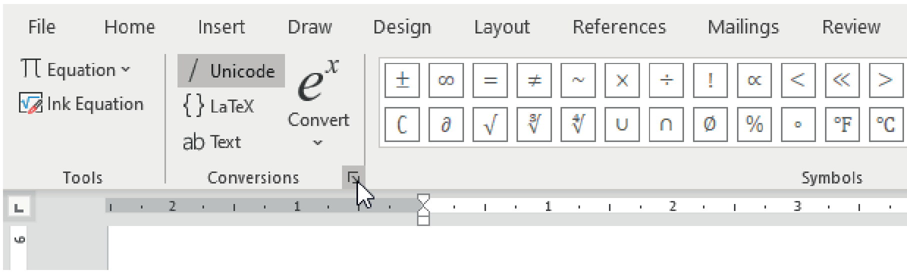
Hint: `\Phi` gives Φ.

Recognised Functions and Math AutoCorrect

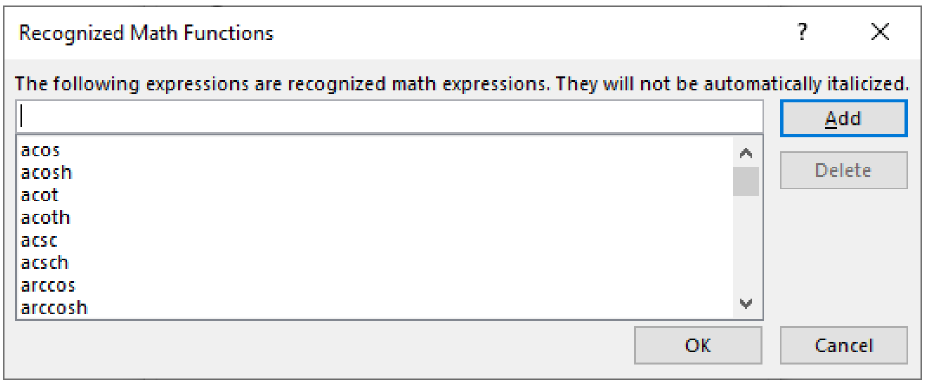
You can access and modify the full list of function names and Math AutoCorrect control words that Word recognises, and it is helpful to be familiar with what is available.

Activity 39 Viewing the recognised functions in Word

To view the lists of recognised functions and control words, create a new mathematical input box. On the Equation ribbon, click on the small arrow in a box in the bottom right corner of the 'Conversions' section (as shown in the screenshot below). This will open the **Equation Options** dialogue box.



In the dialogue box, click the 'Recognized Functions...' button to gain access to the list of letter sequences that Word recognises as the names of mathematical functions.



These are the names that will *not* appear in italics within a mathematical input box and will cause a placeholder to be inserted. For example, typing `cos␣x` within an expression produces $\cos x$, with 'cos' in plain lettering and x in italics in the associated placeholder (which requires a ⇥ to escape).

It is possible to add your own function names to the list, or remove function names.

Function name recognition is case sensitive. For example, by default the letter sequence 'cos' is recognised, but 'Cos' and 'COS' are not. The names in this list can only contain the letters 'A...Z' and 'a...z'.

From the Equation Options dialogue box, clicking the 'Math AutoCorrect…' button gives you access to the complete list of control words and the corresponding symbols that appear in linear display, as shown in Figure 13.

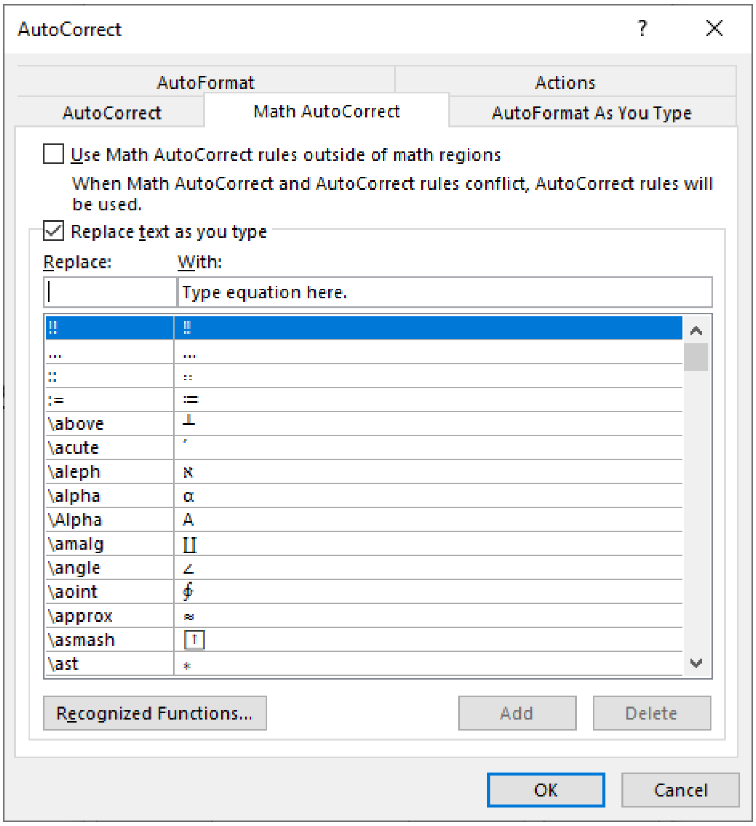


Figure 13 The Math AutoCorrect dialogue box

From this dialogue box, among other things, it is possible to do the following:

- change the symbol that appears in linear display corresponding to any control word — but beware, this is rarely something you would want to do and it can have unintended consequences; for example, changing the symbol associated with certain control words such as `\sqrt`, `\int`, `\matrix` or `\eqarray` will disconnect those functionalities because they are actually initiated by the original symbol itself, not by the control word
- tick a checkbox that enables the 'Math AutoCorrect' rules to be used outside mathematical input boxes; for example, this would mean that typing `\pi␣` anywhere in a Word document (not just in a mathematical input box) would automatically insert the symbol 'π'
- change AutoCorrect settings for normal text (by selecting the 'AutoCorrect' tab)
- change other AutoFormat settings.

Returning to the parent Equation Options dialogue box, notice that the lower panel, entitled 'Display Math' contains several controls for changing the appearance of display mathematics (when rendered in professional mode).

Note the 'Justification:' drop down, which controls the page position of display mode equations (left, right, centred). You may wish to use this to change the default Word positioning. The other controls, while useful to explore, will not be covered in this unit.

3.3 Line breaks, alignment and numbering

There are two distinct ways you may need to use line breaks while typesetting mathematics: either to type a follow-on expression, or because your expression is too long for one line. The method for each of these is different in Word, and so they will be covered in turn in this subsection.

Follow-on expressions

When you type mathematics into an input box and then press Enter, ↵ , the cursor will be placed at the beginning of a new paragraph, and not in a mathematical input box. To add a new line and create a new mathematical input box, press Shift and Enter at the same time (this will be denoted Shift+↵). This is known as a **soft return**. The new input box is associated with the previous one, meaning that the spacing between the two is reduced and (as you will see shortly) they can be aligned together as a group.

Having created one or more of these follow-on expressions, you may find that the expressions appear, by default, to be too bunched up vertically. This problem can be addressed by selecting all the expressions in the series (using the mouse, or by holding down the Shift key and using the arrow keys) and increasing the line spacing via the **line spacing** button in the Paragraph section of the Home ribbon.

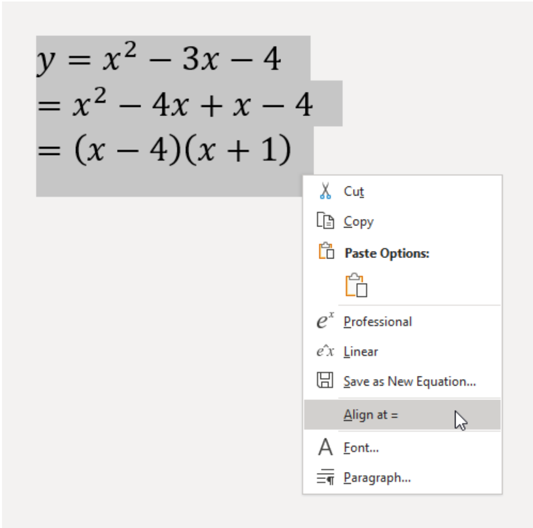
The following activity will guide you through the process of creating a series of follow-on expressions, and then aligning them on the equals sign.

Activity 40 Aligning several equations on the equals sign

Using Shift+↵ between lines, type in the following mathematics:

$$
\begin{array}{l}
y = x^2 - 3x - 4 \\
= x^2 - 4x + x - 4 \\
= (x - 4)(x + 1)
\end{array}
$$

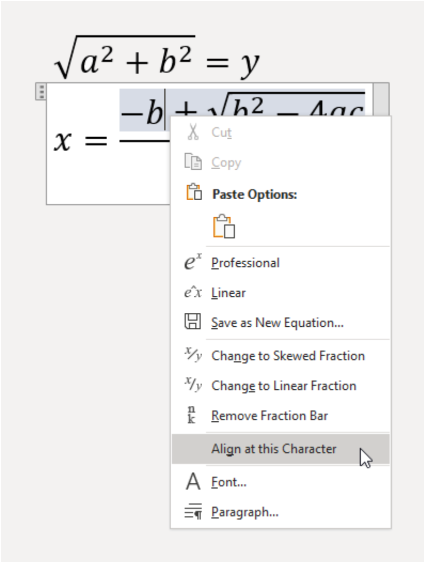
Now use the mouse or keyboard to highlight *all* the expressions at the same time, then right-click and select 'Align at =' as shown below.



The three lines of equations will now be formatted so that the equals signs are lined up:

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

It is also possible to align on an individual character within each expression, by inserting alignment points within each expression. To insert an alignment point, right-click at the required alignment point and select 'Align at this Character' — you have to specify the alignment character in each expression separately, even if it is the same character in each case.



Note that the 'Align at...' options only work for equations that are on consecutive lines. These options will not align equations that are separated by any text, even blank lines. If you align equations and then insert a line of text between them, the alignment linkage is broken and the equations revert to being unaligned. Editing an equation in the group can also cause it to drop out of alignment, but this can usually be restored by switching alignment off and then on again.

The selection of the character to which you align also has to make sense considering the structure of each equation and this can be quite restricting. For example, you cannot place an alignment point in the denominator (the bottom) of a fraction, and there are also restrictions on the available alignment points within a square root. In general you can align at characters such as $+, -, \times, \div$. If it is not possible to align at a character you have selected, then the 'Align at this Character' option will not appear in the right-click menu.

Splitting long expressions

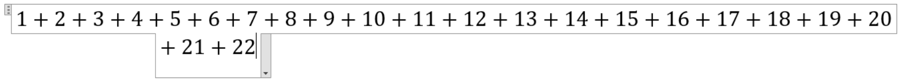
You may encounter a need to create equations or expressions that are too long for one line, or which (for other reasons) you may wish to split over several lines. While you could use the Shift+↵ method, Word provides a separate solution to this situation, through **automatic** and **manual line breaks**.

As the name suggests, automatic line breaking occurs whenever you type an expression that is too long to fit on one line.

Activity 41 Investigating automatic line breaking

Create a mathematical input box on a new line, and type $1 + 2 + 3 + 4 + \ldots$ until you have an expression that is too long for a single line.

You should now have something like the following:



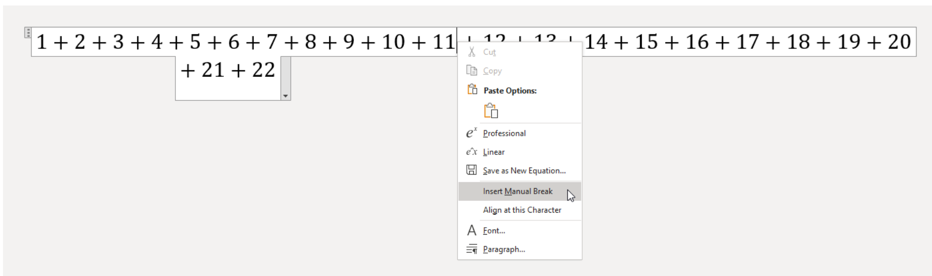
Word has automatically started a new line, and the second line has been indented to indicate that the expression continues over the line break.

Notice also that in the above activity, the outline of the mathematical input box contains both lines of the expression: this is different from the Shift+↵ method you saw earlier, which creates a new input box for each line, and then groups these boxes together.

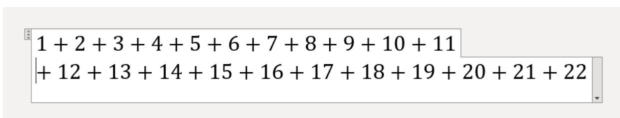
Often, automatic line breaking is sufficient, but you can instruct Word to break at a different point by inserting a manual line break.

Activity 42 Investigating manual line breaking

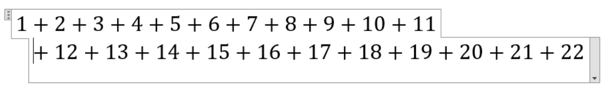
Using the long expression you created in the previous activity (or by creating the same expression again), right-click just before '+ 12' to open a pop-up menu. Select 'Insert Manual Break':



As expected, this instructs Word to break at the cursor, but notice that the second line is no longer indented:



To restore the indentation, with the cursor at the start of the second line press Tab on your keyboard. The '+' at the start of the second line will line up with the first '+' of the first line:



Now press 'Tab' again. What happens?

Equation numbering

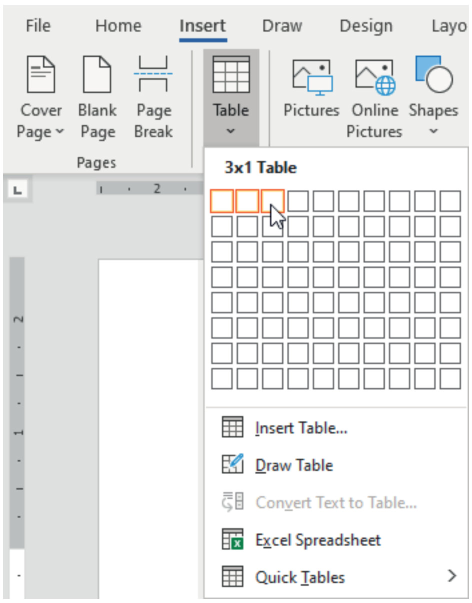
Word can number equation objects automatically using its captioning functionality (the same mechanism as is used for other insertions such as figures, tables and images) but captioning in Word does not support the usual arrangement for equations in which the equation number is positioned on right-hand side, aligned with the equation.

To get the desired layout, a satisfactory approach in most cases is to set up a one-row table containing the mathematics in one cell, and the equation number in another.

The following activity will show you how to set up a manually numbered equation, and save it as a 'template' so that you can quickly produce numbered equations in the future. Thus, while the steps below are rather lengthy, you will only need to follow them once.

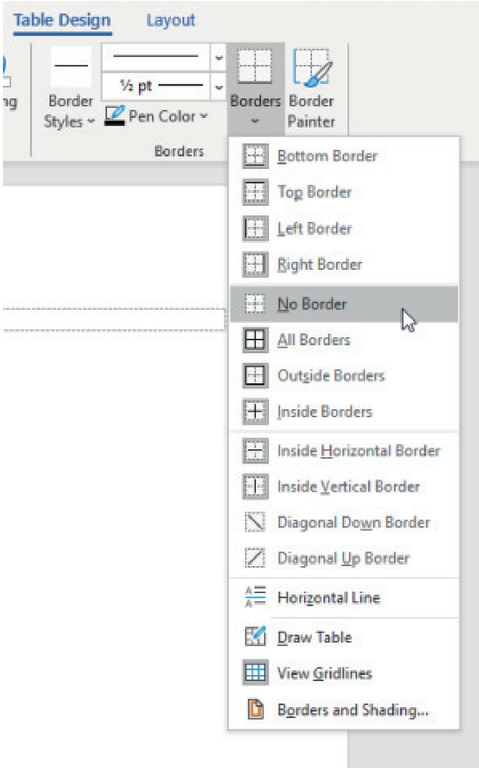
Activity 43 Creating and saving a numbered equation template

From the Insert ribbon, select and insert a 3×1 table.



Your mathematical input box will be placed in the central cell, and the equation number will be placed in the right-hand column. The left-hand column is needed to ensure that the equation is still properly centred on the page.

Next, remove the borders from the cells as follows: select all three cells of the table and then, on the 'Table Design' ribbon (or the dialogue box that pops up when you select the table), click on the small down arrow close to 'Borders'. From the drop-down menu, choose 'No Border'.

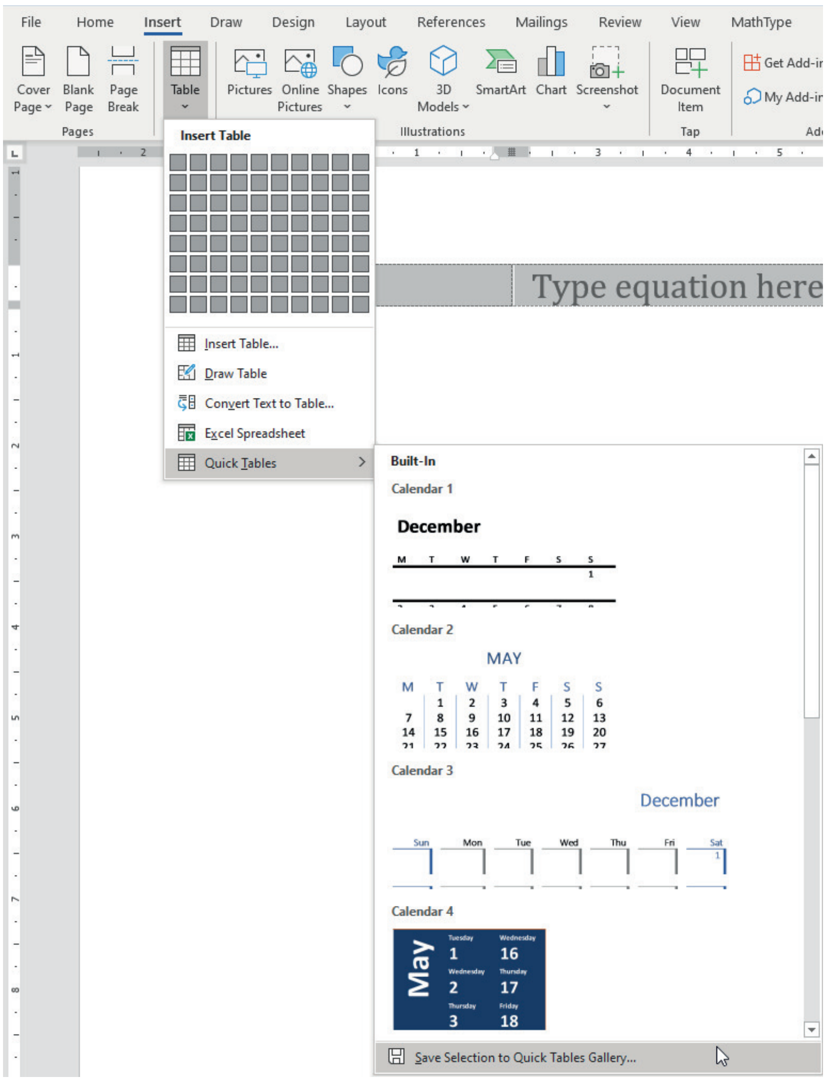


From the same drop-down menu, click on 'View Gridlines' so that dotted lines appear around the table. These will not appear when the document is printed, but they will help you to see where the three cells are while you work. You should now have the dotted outline of three cells, as shown below. (Note the double slashes indicating where the screenshot has been shortened horizontally to better fit on the page.)

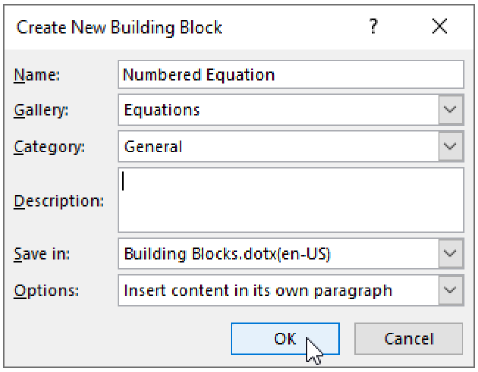
Next, in case you ever need to insert wide equations, make the middle cell wider. You can do this with the mouse by clicking and dragging the divider between the left and middle cells to the left, and then, similarly, dragging the divider between the middle and right cells to the right. Try to ensure that the left and right columns are the same width. Your table should now look like this:

Finally, place the cursor in the middle cell of your table, and press Alt+= to create a mathematical input box. It should position itself automatically in the cell according to the Display Mode justification setting in the Equation Options dialogue. Do not, however, insert any mathematics into it: you want it to be empty for the template. Now place the cursor in the right-hand cell of the table. Centre align it (either by pressing Ctrl+E, or by clicking on the 'Center' button in the Paragraph section of the Home ribbon), and type `(1)` to create a number in brackets.

Your table is now ready to be saved as a 'template' for future use. Select the whole table and then, from the Insert ribbon, click on 'Table' and then 'Quick Tables'. At the bottom of the Quick Tables menu, choose 'Save Selection to Quick Tables Gallery…':



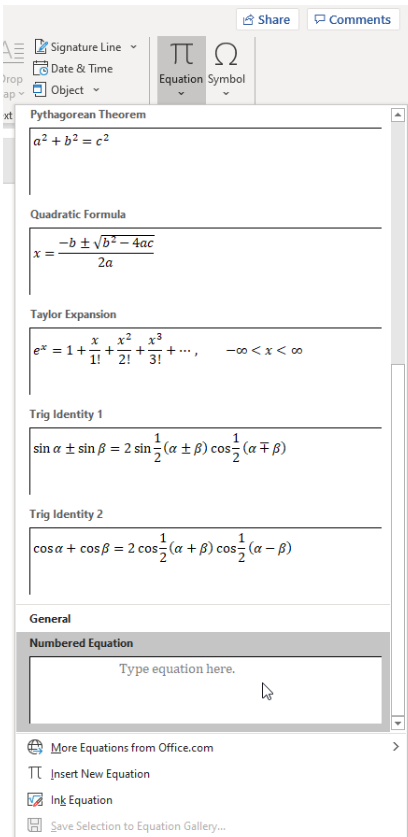
This will open the ‘Create New Building Block’ dialogue box. Type `Numbered Equation` as the ‘Name’, and select ‘Equations’ from the ‘Gallery’ menu, and ‘General’ from the ‘Category’ menu. Click ‘OK’.



You’re done! Word has now saved your numbered equation template, and you can use it for this document, and any other document you create on the same computer.

Activity 44 Using the numbered equation template

With the cursor on a blank line, open the Insert ribbon, and click on the small down arrow by the π Equation icon. Scroll down to the bottom, and you should be able to see your custom-made ‘Numbered Equation’:



Click on your ‘Numbered Equation’ to insert a copy of the template into your document.

Click on the mathematical input box in the middle column and add your favourite equation into it. Don’t forget to change the number manually if you insert more than one numbered equation into a document!

3.4 Preparing to typeset a TMA

This introduction to the mathematical features of Word has shown you enough to typeset your answers to a TMA by using a combination of inputs using the Equation ribbon and the keyboard, and you have learned some of the principal techniques required to typeset mathematics.

Do remember, however, that you can submit handwritten working as answers to all TMA questions, apart from those assessing this unit, where you are specifically asked to typeset your answers.

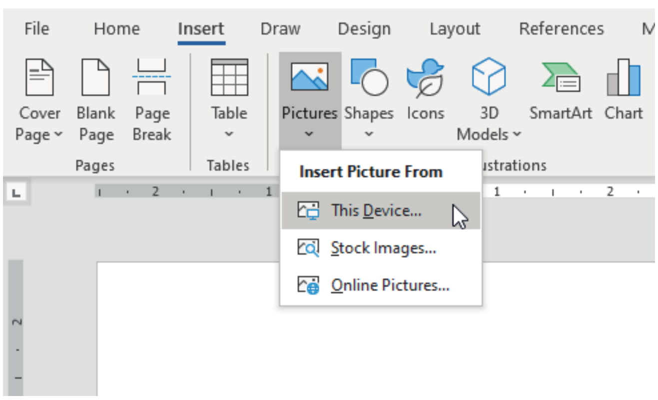
The best way to continue to learn about Word is to practise using its many features, and learn how to use the keyboard to create complicated mathematical structures by studying the linear display of expressions you have created using the Equation ribbon.

Including graphics in your document

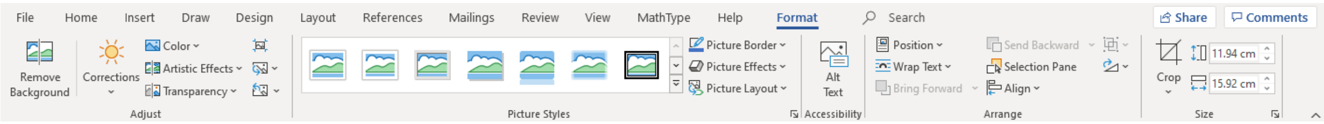
Some TMA questions may ask you to draw graphs, illustrations or other graphics. Word provides several ways to embed graphs from Excel, tables of data, and so on, but these go beyond the scope of this introduction. The next activity shows you how to include pictures in your document, such as scanned-in hand-drawn diagrams, digital photographs or graphics created using other software.

Activity 45 Inserting a picture in your document

With the cursor at the point where you wish to insert the picture, from the Insert ribbon select ‘Pictures’. You are offered a choice of source; pick ‘This Device…’.



A dialogue box will open. Here, you can navigate to the folder containing your picture, select it and then click ‘Insert’ to place the picture in your document. Then you can resize it, rotate it, and carry out other basic formatting to it using the ‘Picture Format’ ribbon, which appears when the picture is selected.



Be aware of the file sizes of pictures: large high-resolution images can add considerably to the space your Word document takes up on your computer, and this can also make it difficult to send your document to others electronically. Information on how to reduce the file size is available from the *Typing mathematical notation* website.

Exporting your Word document as a PDF

If you wish to share your document electronically with recipients who do not have a sufficiently recent version of Word, then you should export your document to PDF format, as described below. This will make your document viewable (but not editable) on any computer or tablet device.

Note that if you have Word 2007, then you will need to download an ‘add-in’ from the Microsoft Download Center in order to be able to export a document to PDF format.

Warning

When saving to PDF, make sure you also save a copy of the original document as a Word (.docx) document, otherwise you will not be able to edit the document later!

1. Select `File` > `Save as` > `Browse` to open the ‘Save As’ dialogue box.
2. Enter a name for your file in the text box next to where it says ‘File name’.
3. From the drop-down menu next to where it says ‘Save as type’, select ‘PDF (*.pdf)’. Notice that the file name you gave your document has now been given the ‘.pdf’ extension.
4. Click ‘Save’. The ‘Save As’ dialogue box will disappear. By default, the newly-created PDF will open in a PDF viewer (for example Acrobat Reader) if you have one installed.

4 LibreOffice

You should study this section if you have decided to learn about mathematical typesetting in LibreOffice.

This section will introduce you to the mathematical features provided in the Writer word-processing package, which is part of the LibreOffice suite of programs. This office suite is free to download and use, and contains many of the features of Microsoft Office. Note that this section assumes you already have some familiarity with the basic features of word-processing packages, such as the formatting and simple manipulation of text.

This guide is based on LibreOffice version 7.1, and we do not describe all its features. Later versions of LibreOffice may differ in small ways from the version described here.

As you work through this material, be aware that you may encounter the occasional mathematical symbol or equation that you have not seen before. Don't worry: you are not expected to understand the meaning of all the mathematical expressions in this unit. However, you are likely to encounter most of the symbols used at some stage during your studies. A *LibreOffice maths quick reference guide* detailing some of the most useful features is available to download from the *Typing mathematical notation* website.

The *Typing mathematical notation* website also contains further, optional resources that you might find useful having studied this unit.

You may have heard of, or even already have installed, a suite of programs called OpenOffice. In 2010, LibreOffice separated from OpenOffice and both are now developed separately. However, because of their common root, they are still quite similar. Thus, if you already use OpenOffice, you can probably continue to use it as you work through this typesetting guide.

Now follow the installation instructions

If you do not already have a copy of LibreOffice installed on your computer, go to the *Typing mathematical notation* website and follow the instructions in the installation guide for LibreOffice.

When your installation is finished, return to this point to begin learning how to use LibreOffice.

4.1 Getting started with LibreOffice

If you are already familiar with the common features of LibreOffice, you can skip this subsection.

By default, the installer will have placed a LibreOffice icon on your desktop. When you double-click this icon, after a short moment you will be shown the main menu page, depicted in Figure 14.

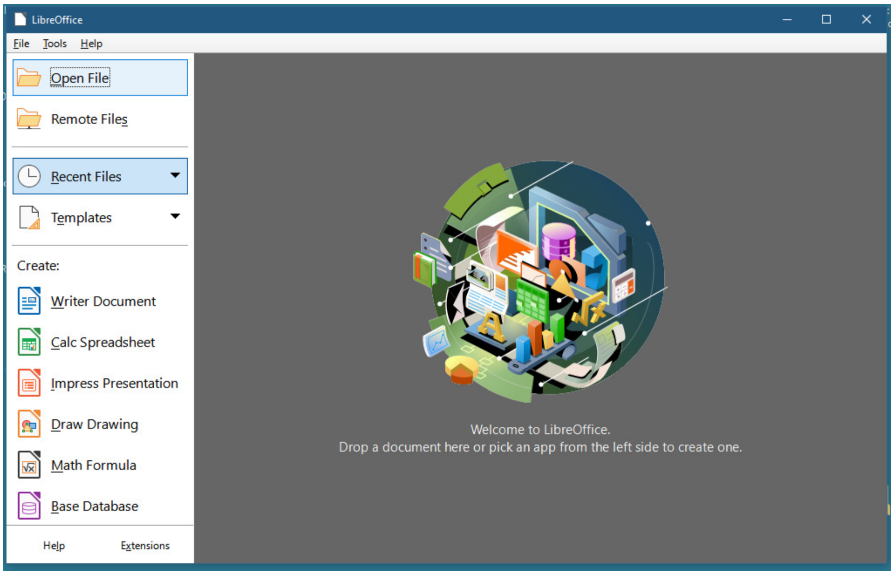


Figure 14 The main menu page that appears on first opening LibreOffice

There are six different types of LibreOffice files, and you must choose which one you want:

Writer Document Clicking on this option loads 'Writer', which is the word processor part of LibreOffice (equivalent to Microsoft Word). You will mainly be using Writer for this introduction.

Calc Spreadsheet This loads 'Calc', which is LibreOffice's spreadsheet package (equivalent to Microsoft Excel).

Impress Presentation This loads 'Impress', used for creating slides for presentations (equivalent to Microsoft PowerPoint).

Draw Drawing Invokes the 'Draw' package for creating diagrams. You will learn how to embed pictures in Writer documents, but not how to use this package.

Math Formula This loads 'Math', which is what you will be using to create mathematical expressions. However, you will mainly be using the features of Math within the word processor, so you will not need to open 'Math' as a stand-alone program.

Base Database Invokes 'Base', the database software (equivalent to Microsoft Access).

Activity 46 Familiarising yourself with the features of Writer

Start LibreOffice using the icon on your desktop to load the menu shown in Figure 14, and click on 'Writer Document'. The **LibreOffice Writer** word-processing package will load, with a blank document.

The basic features are much the same as in other word-processing packages, with options to format the font (for example changing the font face or its size, transform to **bold**, *italic*, or <u>underlined</u>), change the text alignment (left, centre, right, justified), add bullet points, numbering, and so on.

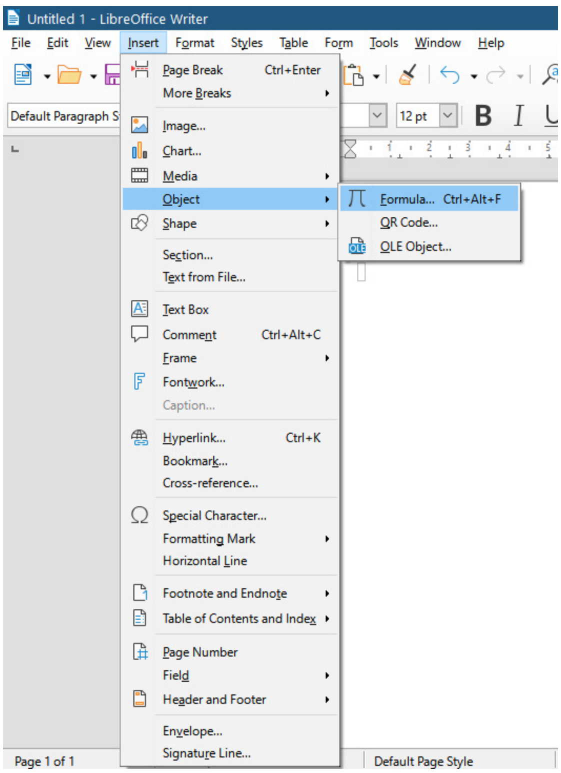
Spend some time familiarising yourself with the basic text formatting features and menus of Writer before you begin the next subsection.

4.2 Embedding maths in Writer documents

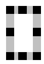
Mathematical equations and expressions are inserted in **formula objects** within the document.

Activity 47 Creating your first formula

With a new, blank document open in Writer, open the `Insert` menu, and select `Object` > `Formula`. Later, you will create a button on the toolbar, and add a keyboard shortcut to make inserting formula objects quicker.



Writer will create a new, blank, 'formula object', indicated by a grey border with black squares marking the corners and the mid-points of the edges:

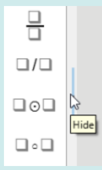


Also, a panel opens at the bottom of the screen, called the **Formula Editor**. The Formula Editor is the area where you can type and view the set of instructions used to create your formula: these instructions are called the **markup** for your formula.

A panel also opens on the left of the main window called the **Elements Dock**. This panel provides an alternative means of entering symbols in the Formula Editor.

Tip: show or hide the Elements Dock

When a formula object is open, you can close the Elements Dock by clicking on the 'Hide' icon on the right-hand edge of the panel:



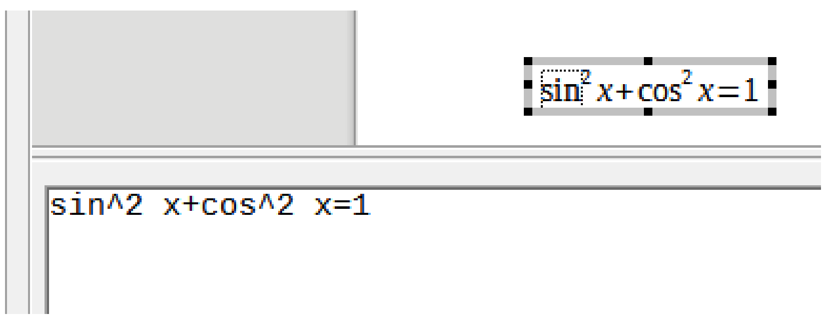
To restore it, click on the 'Show' icon that appears on the left-hand side of the window.

The Element Dock can also be opened and closed by selecting `View` > `Elements`.

Let's create a simple expression inside your new formula object. Click on the Formula Editor panel to move the cursor into it. Then type:

```
sin^2␣x+cos^2␣x=1
```

The **space symbol** ␣ indicates that you must insert a single space, using the spacebar on your keyboard. As you type, you will see the formula appear in the document itself. Once completed, you should have created the following:



For now, exit the formula object by pressing 'Esc' on your keyboard. (You can also exit the formula object by clicking anywhere in the document part of the window outside the formula.) The Elements Dock and Formula Editor will disappear, and the border around the expression you just created will change to a thin line with squares:

$$\sin^2 x + \cos^2 x = 1$$

The squares around the border indicate that the formula object is currently *selected* (so, for example, pressing 'Delete' now would cause the formula to be deleted), but not *open* (so you cannot currently edit it). When the formula object is neither selected nor open, the squares disappear, leaving a thin grey border. Note that this border only indicates the extent of the formula object, and will not appear when you print your document or save it as a PDF.

To reopen a formula object, double-click on it. This will reopen the Elements Dock and the Formula Editor, and you can then edit the mathematics that the object contains. Notice that as you switch between editing the document and editing a formula object, the contents of the menus at the top of the LibreOffice window change. This reflects the fact that when you have a formula object open, you are not editing the Writer document but a formula embedded within it. The editing of this formula is handled by a different program within the LibreOffice suite, namely the program called 'Math'.

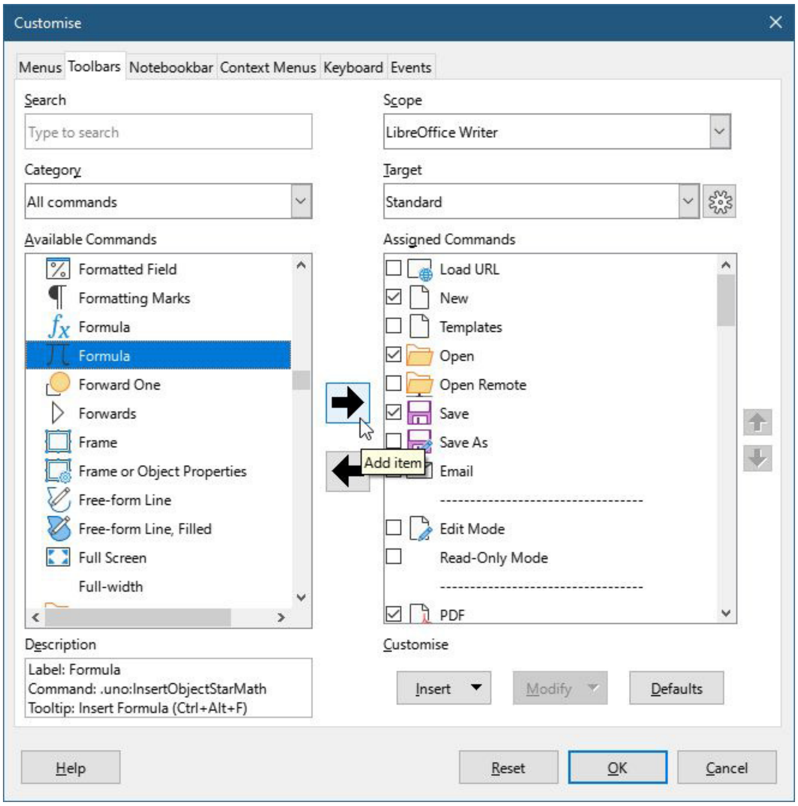
Writing mathematics often requires you to switch between text and formula objects frequently, and you will quickly grow tired of using menus to create a new expression. So, the next activity shows you how to add an 'Insert Formula' button to the toolbar to speed up the process. First check that you have returned to your Writer document; that is, you have exited from any formula objects.

Warning: 'Formula' means two things!

The word 'Formula' in LibreOffice has two different meanings. As well as referring to mathematical expressions such as the one you just created, it is used to refer to expressions that you might use, for example, in a spreadsheet to carry out calculations.

Activity 48 Adding a shortcut button to create formula objects

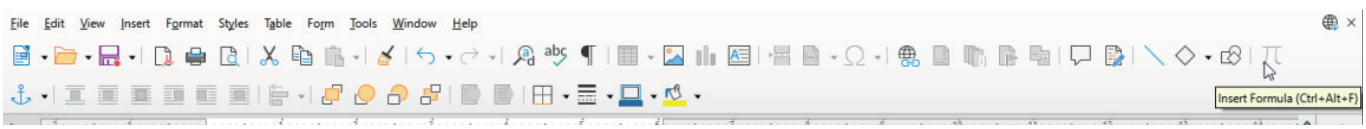
In Writer, *without* a formula object open, select `View` > `Toolbars` > `Customise...`. A dialogue box will open. In this box, select the 'Toolbars' tab, and ensure that the drop-down menu under 'Target' is set to 'Standard'.



Scroll down the 'Available Commands' list to the two 'Formula' entries. You now need to select the correct 'Formula': the one with an icon that looks like 'π'.

Click on the right-pointing 'Add item' arrow to include the selected icon in the standard toolbar, then click 'OK' to close the 'Customise' window.

The new 'Insert Formula' icon you just added is placed as the rightmost button on the toolbar.



With the cursor on a new line in the document, click on your new Insert Formula button. This will create a new formula object in your document.

Inputting mathematics using the Elements Dock

The easiest way (but, as you will discover, often not the quickest) to get started with inserting mathematics into Writer documents is to use the Elements Dock, shown in Figure 15. Note that you will still need to use your keyboard to insert many of the single characters, such as numbers, and letters of the Greek and Roman alphabets. Additionally, not all structures are available via the Elements Dock.

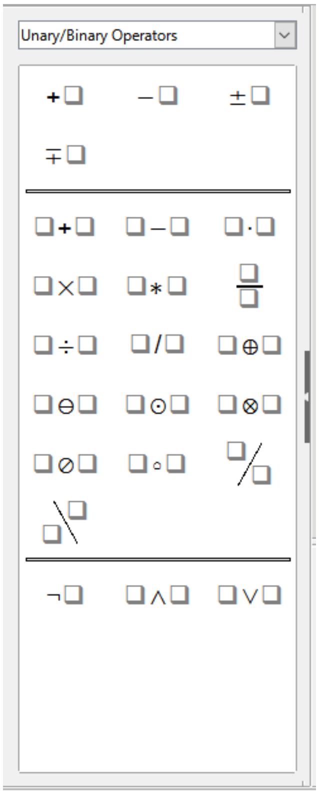


Figure 15 The Elements Dock

The Elements Dock is divided into two parts: the top part is a drop-down menu which lists the **categories**, while the bottom part is a palette of **symbols** within the currently-selected category. In Figure 15 the category 'Unary/Binary Operators' has been selected.

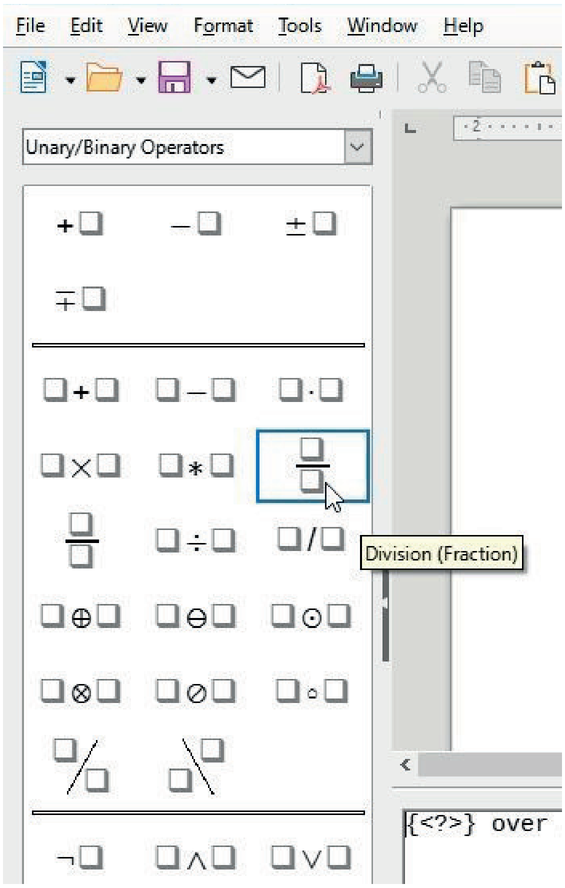
When you click on the down arrow at the right of the drop-down menu, a list of categories is displayed. The final option in the list is 'Examples', which provides some example formulas that you can adapt for your own use: we do not discuss this further.

With one of the categories selected, hover the mouse pointer over any of the items in the symbols palette and a description of that item will pop up. A list of the categories and the main symbols within each category is given in the *LibreOffice maths quick reference guide*.

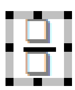
Activity 49 Creating an expression using the Elements Dock

In this activity, you're going to create the expression $\dfrac{x^2}{\sqrt{32\pi bc}}$.

First, create a new formula object using the Insert Formula button that you created in Activity 48. The Elements Dock should open. In the Elements Dock, select the 'Unary/Binary Operators' category, shown as the first category in Figure 15, and click on the 'Division (Fraction)' symbol. A blue rectangle around the symbol indicates that this item has been selected.



This inserts a fraction into your formula. In the document window, you will now see a fraction, with square boxes on top of and below the line:



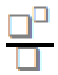
In the Formula Editor, you will now have the following markup:

```
{<?>} over {<?>}
```

The `<?>` symbols are **placeholders** corresponding to the square boxes in the document. Each placeholder can be filled with numbers, letters, symbols or other structures from the Elements Dock, or a combination of these. Surrounding each placeholder are **curly brackets** `{` and `}`, which instruct the program Math to group items together. You will investigate how to group items together in greater detail in the next subsection.

The first placeholder is highlighted in black, indicating that it is currently selected. Now in the Elements Dock select the 'Formats' category from the drop-down menu. In the symbols palette select the 'Power' symbol:

The placeholder you selected is now replaced by two placeholders, and the expression in the document should look like this:

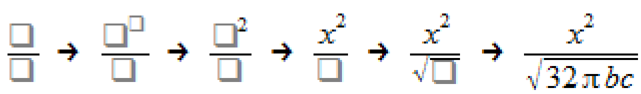


The corresponding markup in the Formula Editor panel is as follows.

```
{<?>^{<?>}} over {<?>}
```

Click on the smallest (superscript) box, and type the number 2. The placeholder will disappear and be replaced by the number 2.

Now finish typesetting the expression $\dfrac{x^2}{\sqrt{32\pi bc}}$ by building the structures in the sequence shown below. Note that you have already completed the first three steps of this process.



The square root symbol can be found in the 'Functions' category of the Elements Dock, and you can create the Greek letter pi, π, by typing `%pi`, followed by a space, into the markup.

Once finished, the final markup should be as follows.

```
{x^{2}} over {sqrt{32%pi␣b␣c}}
```

As well as the space after '%pi', notice there is a space between the 'b' and the 'c'. When this space is missing, the term 'bc' is presented as a single item and the two letters are placed slightly closer together.

Activity 50 Using the mouse to edit an existing expression

Within the expression $\dfrac{x^2}{\sqrt{32\pi bc}}$ that you just created, click on any of the symbols or structures. In the Formula Editor panel, you will find that the cursor moves to the beginning of the item you selected.

Now double-click the symbol π. You will find that the markup `%pi` corresponding to π has been highlighted. With `%pi` still highlighted, type `%alpha`. The symbol π will be replaced with α. In this way, you can quickly select and replace items within an expression.

Symbols

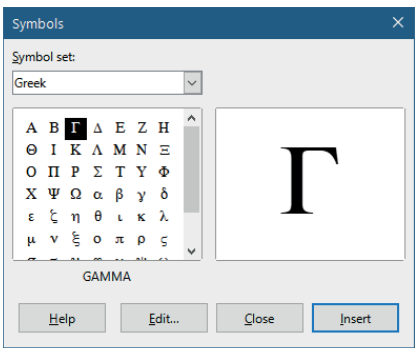
While the Elements Dock contains many of the most frequently used mathematical structures, there are some omissions such as the Greek alphabet.

Usually, the quickest way to input such characters is to use the **markup command**; for example, as you saw in the last activity, `%pi` produces π. However, there may be occasions where you don't know the markup command, and in these cases you can use the Symbols box.

Activity 51 Exploring the Symbols box

With a new formula object open, click on the 'Symbols' button on the toolbar, shown below.

This will open the 'Symbols' dialogue box. (You can also open this box by selecting `Tools` > `Symbols...`.)



On the left of this dialogue box is a drop-down menu, which allows you to select the symbol palette to display. The options are 'Greek', 'iGreek' (Greek letters in *italics*) and 'Special'. Below the drop-down menu is a palette of symbols. When you select one, a large version appears in the box on the right, and the markup command (excluding the initial %) appears below the palette.

As in the previous screenshot, select the capital Greek letter Γ. Click ‘Insert’ to place this symbol at the cursor’s current position in the formula. Once inserted, notice that the markup for this symbol is `%GAMMA`. Finally, click ‘Close’ on the Symbols dialogue box.

The context menu

The **context menu** in the Formula Editor provides an alternative to the Elements Dock in order to select commands. To access the context menu, place the mouse pointer in the Formula Editor panel and right-click.

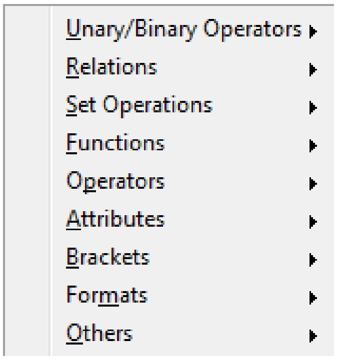


Figure 16 The context menu

The categories, shown in Figure 16, correspond to those in the Elements Dock. Selecting a category from the context menu gives a sub-menu consisting of the majority of the commands in the corresponding Elements Dock category, but here the commands are represented by their markup commands, rather than by the symbols they produce. Some less commonly-used commands are only found via the Elements Dock; you will not need to use these in this module so you can safely rely on the context menu if you wish.

Example 7 Creating a matrix using the context menu

You will now use the context menu to create the 2×2 identity matrix

$$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}.$$

Open a new formula object, and right-click in the Formula Editor panel to open the context menu.

First you need to create brackets to go around the outside of the matrix array. Select ‘left (x right)’ from the ‘Brackets’ category in the context menu. The Formula Editor will now contain the following.

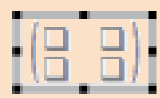
```
left ( <?> right )
```

Notice that the placeholder, `<?>`, between the brackets is automatically highlighted, ready for you to insert the matrix in between.

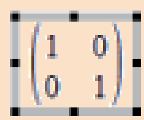
With the placeholder still highlighted, open the context menu again, and from the 'Formats' category, select 'matrix {...}'. Your Formula Editor should now contain the following.

```
left ( matrix{<?> # <?> ## <?> # <?>} right )
```

In your document, the formula object will now appear as follows.



The structure of the expression is complete, and all that remains is for you to insert the numbers. Select each placeholder in turn and replace it with the appropriate number so that your expression looks as follows.



Let's study the markup of the expression you created in Example 7. The Formula Editor should contain this markup:

```
left ( matrix{1 # 0 ## 0 # 1}  right )
```

There are several observations to make about this markup.

1. It's possible to replace the `left (` and `right )` commands with `(` and `)`. Try it! However, the `left` and `right` cause the parentheses to be **scalable**; that is, they stretch to be the same height as the mathematics contained within them. You will learn more about brackets later.
2. As with earlier formulas that you've created, the curly brackets `{` and `}` are used to **group** elements together. You'll learn more about grouping later.
3. The `#` command within the `matrix` structure indicates to move to the next column along. Similarly, `##` indicates to start a new row. From the markup, LibreOffice automatically works out how many rows and columns it needs.

Finally, notice that the *only* matrix command available in the context menu or the Elements Dock is the one you've just used to create a 2×2 matrix. In order to create larger matrices, you'll need to type the markup directly into the Formula Editor panel.

Example 8 Creating a bigger matrix

Modify the markup from your 2×2 identity matrix to produce the following equation, which represents an anticlockwise rotation through angle θ about the z-axis.

$$R_z(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Solution

Typing the following markup produces the correct equation.

```
R_z(%theta) =
left( matrix{cos %theta # -sin %theta # 0##
             sin %theta #  cos %theta # 0##
             0          #           0 # 1} right)
```

In the solution to Example 8, extra spaces and linebreaks have been included in the markup for clarity. These do not affect the appearance of the output. So, as you become more familiar with typing markup, you can use spaces and line breaks to make your markup easier to follow.

Note that as you type the markup for Example 8, the formula in the document looks very confusing until the markup is complete and correct!

Also note that when you type an opening bracket of any sort the Formula Editor sometimes adds the corresponding closing bracket automatically.

Activity 52 Creating a column vector using the matrix command

Either by modifying the markup from an earlier matrix command, or by creating a new matrix, typeset the following column vector.

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

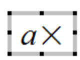
4.3 Inputting mathematics using the keyboard

In the last subsection, you learned about two methods to input mathematics – by the Elements Dock and by the context menu – both of which are most naturally accessed using the mouse. However, you saw in Example 8 that not every piece of mathematics can be created using only these two methods.

Here, you'll learn how to input mathematics directly by typing the markup into the Formula Editor. As you type the markup, the corresponding mathematical expression in the document then builds up automatically, giving you instant feedback so that you can make corrections.

While typing formulas into the Formula Editor, you encounter inverted question marks, ¿, which indicate that the formula is incomplete. For example, try typing '`a times `' into the Formula Editor. It should produce the following in the document.

In this case, the `times` command is expecting an object to come after it. After you type the next object, the ¿ will disappear. Alternatively, if you do not want to put anything after the $\times$ symbol, you can add a 'null' character by typing opening and closing curly brackets `{}`. (In fact all you need to is type the opening bracket as the corresponding closing bracket is added automatically.) In other words, `a times {}` produces the following:



Note that ¿ is also used to indicate errors in your markup; for example, a matrix in which different rows have specified different numbers of columns.

Markup for simple expressions

The commands for most expressions and symbols in Math are reasonably intuitive: the markup language is designed, roughly, to be written as the mathematics would be read out loud. Some common expressions and symbols are listed in Table 8, and you can find a longer list in the *LibreOffice maths quick reference guide*. Note that the spaces shown in the 'Markup' column are essential.

Table 8 Markup to produce simple expressions.

Markup	Result
x^2 x_2	x^2 x_2
<?> over <?>	$\frac{\square}{\square}$
sin log	$\sin$ $\log$
%pi %SIGMA	π Σ
infinity	∞
<?> >= <?>	$\square \geq \square$
sqrt{<?>} nroot{<?>}{<?>}	$\sqrt{\square}$ $\sqrt[\square]{\square}$
<?> times <?> <?> cdot <?>	$\square \times \square$ $\square \cdot \square$
+- <?>	$\pm \square$
setN setR	$\mathbb{N}$ $\mathbb{R}$
<?> in <?>	$\square \in \square$

In Table 8, the placeholders <?> are included to show you where Math is expecting to see more characters. This is so that the result displays correctly, without instances of inverted question marks ¿. When using these formulas, you do not need to type the placeholders. Instead, you can directly insert whatever symbols or structures you would like. For instance, to create the fraction $\frac{2}{3}$, you can type `2 over 3`.

Tip: typing text within formula objects

You often have to switch between text and mathematics. In a formula object, you can type normal (non-mathematical) text by including it within quotation marks as follows.

```
"This is normal text"
```

Activity 53 Creating mathematics using only the keyboard

Typeset the following, using only the keyboard to create the markup.

(a) For any number x, $e^x \geq 1 + x$.

(b) The area of a circle of radius r is $A = \pi r^2$.

(c) $\sqrt[3]{64} = \sqrt{16}$

Adding a keyboard shortcut

A **keyboard shortcut** is a sequence of keys that tells the program to perform a specific task. For example, Ctrl + S is the keyboard shortcut to save your document. Now that you are learning to use the keyboard rather than the mouse to create mathematical expressions, let's define a keyboard shortcut to enable you to create new formulas directly from the keyboard.

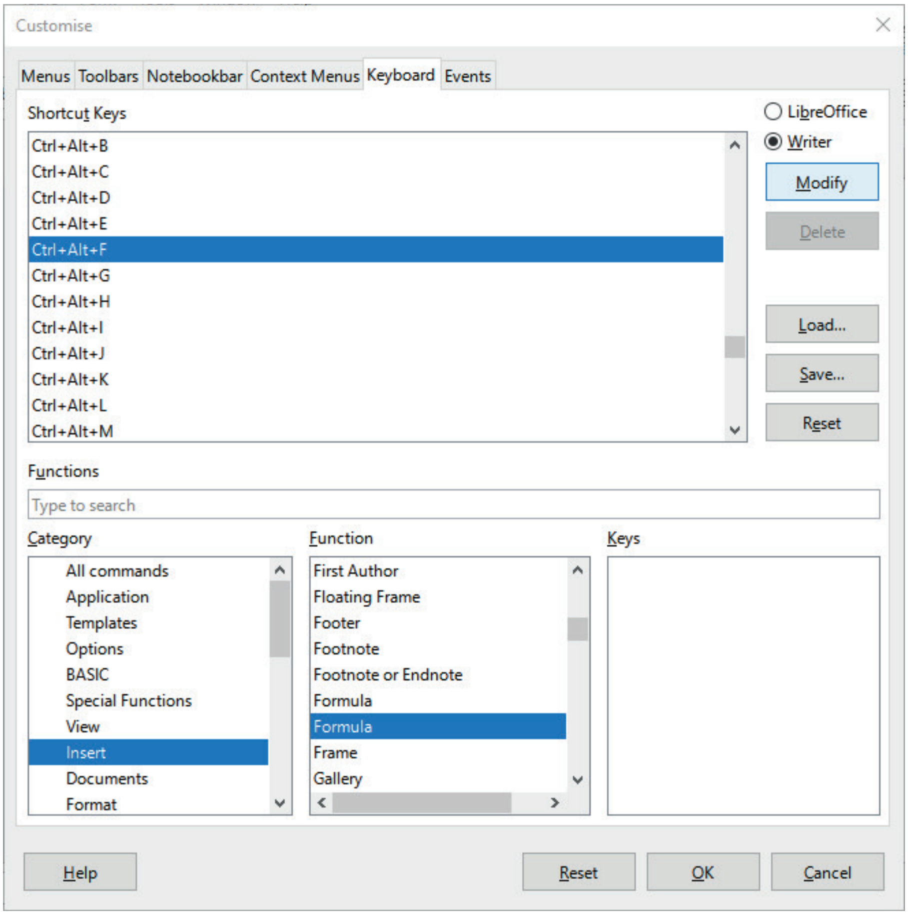
Activity 54 Adding a keyboard shortcut to create formula objects

In Writer, *without* a formula object open, select `Tools` > `Customise...`. This will open the customisation dialogue box shown below. Click on the 'Keyboard' tab.

LibreOffice already has quite a few keyboard shortcuts defined. To avoid clashes with ones that already exist, we suggest you make Ctrl + Alt + F the keyboard shortcut to create a formula. To do this, under 'Shortcut Keys' scroll down (a long way!) and select 'Ctrl+Alt+F'.

Next, at the bottom of the dialogue box, under 'Category' select 'Insert', and then 'Formula' from the list of functions. You need to choose the second 'Formula'. The first one is the spreadsheet formula command, and you can identify it because it will already say 'F2' in the 'Keys' box, whereas the second one should currently have nothing in that box.

Now click 'Modify'. This instructs Writer to add the 'Ctrl+Alt+F' shortcut to mean 'Insert Formula'. Finally click 'OK', and then try out your new keyboard shortcut in your document by pressing Ctrl , Alt and F at the same time.



For the rest of this typesetting guide, the keyboard shortcut to create a formula object will be denoted by Ctrl+Alt+F .

Tip: keyboard shortcut to leave a formula object

Press the escape key *twice*: Esc Esc . The first Esc closes the formula object, but leaves the formula object selected. The second Esc returns the cursor to the page, so you can continue writing.

Activity 55 Practising keyboard-only sentences containing mathematics

Typeset the following sentence, which is the statement of Fermat's last theorem, using only the keyboard.

The equation $x^n + y^n = z^n$ has no positive integer solutions for $n \geq 3$.

Tip: really fast formula insertion

If you already know the markup needed to create a formula, then you can use the following steps to insert the formula.

- Type the markup *directly* into the document (that is, do not create a formula object).
- Select the text of the markup.
- Press Ctrl+Alt+F . The markup will be replaced with the formula.

Brackets and grouping symbols together

When you type a formula object, you will often need to specify how to group items together. For example, should the markup

```
1 over x - 1
```

produce $\dfrac{1}{x-1}$ or $\dfrac{1}{x} - 1$? Try this in your document.

You should find that it produces the second of these, since Math requires one symbol (or group of symbols) before the command `over`, and one after. In this case, it does not group '$x - 1$' as the denominator of the fraction. To instruct Math to **group** items, place them in curly brackets, `{...}`.

Thus, to produce $\dfrac{1}{x-1}$, type the following. Remember that to obtain a pair of curly brackets in the Formula Editor you only need to type the opening curly bracket.

```
1 over {x - 1}
```

The curly brackets in the markup do not appear in the Writer document: characters such as these and the space symbol ␣ are called **delimiters**. As mentioned in the last subsection, when you select structures from the Elements Dock or from the context menu, these curly brackets are automatically inserted. However, when typing the markup directly you only need to use them when grouping two or more symbols and commands together.

So, for example, to produce

$$1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \ldots$$

you could type

```
1 + 1 over 2 + 1 over 4 + 1 over 8 + dotslow
```

rather than the more time-consuming

```
1 + {1} over {2} + {1} over {4} + {1} over {8} + dotslow
```

Note also that curly brackets must pair up, with every opening curly bracket having a matching closing curly bracket; otherwise your formula will appear incorrectly, and there will be inverted question marks ¿ visible. In fact, Math expects *every* kind of bracket to be matched and it facilitates this by often adding a closing bracket automatically when you type an opening bracket, as you saw earlier.

Although the requirement to match brackets can sometimes present problems, it provides one useful advantage: all types of bracket can be used to group items together. Consider the following markup.

```
1 over (x-1)
```

This produces $\frac{1}{(x-1)}$, without the need to also insert curly brackets.

Since curly brackets, also known as **braces**, are invisible in the Writer document, another command is needed to make visible curly brackets.

```
1 over lbrace x - 1 rbrace
```

The result here is $\frac{1}{\{x-1\}}$.

Finally, you may be wondering what to do if you want to produce mismatched brackets. For example, suppose you wanted to typeset '$[0,1)$', meaning all the real numbers between 0 and 1, including 0, but not 1. Earlier, you created **scalable** brackets, the markup for which was `left ( ... right )`. The same construction can be used here. Typing the markup for the left bracket causes a corresponding right bracket to appear, which you need to delete. (Note that the spaces after `left` and `right` are not required.)

```
left[ 0,1 right)
```

To create an opening bracket with no closing bracket, type `left( ... right none`.

Activity 56 Exploring the effects of brackets

Identify the differences between the following examples of markup. You may find it helpful to zoom in on the document, which can be done by selecting `View` > `Zoom...`. (The Formula Editor must be closed in order to zoom in on the document.)

(a) `x^sinx` (b) `x^sin␣x` (c) `x^{sin␣x}` (d) `x^{(sin␣x)}`

(e) `x^(sin␣x)`

More complicated expressions

With the basic tools of typing simple symbols and grouping symbols together using delimiters, you are now ready to look at a few examples of more complicated expressions. Note that you may not have met all the symbols and mathematics in the following examples. If this is the case, do not worry: you do not need to understand what they mean to be able to typeset them! You may find it helpful to refer to the *LibreOffice maths quick reference guide*.

Example 9 Creating more complicated expressions with the keyboard

Use the keyboard to produce the following expressions.

(a) $x^{1/n} = \sqrt[n]{x}$. (b) $\displaystyle\int_0^1 f(x)dx$ (c) $\displaystyle\lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n = e$

Solution

(a) `x^{1/n}= nroot{n}{x}`.
Notice that the fraction uses the `/` symbol instead of `over`. When there are fractions in exponents, it is sometimes clearer to use this notation.

(b) `int_0^1 f(x) dx`
It is also possible to create a similar (but not identical) expression by typing
`int from 0 to 1 f(x) dx`
In this case, the upper and lower limits of the integral appear above and below the integral sign as follows.

$$\int\limits_0^1 f(x)dx$$

(c) `lim from {n rightarrow infinity} left( 1 + 1 over n right)^n=e`

Note that in the markup `int_0^1 f(x) dx` in part (b) the space before f is essential, but the space before d is optional.

Now here's one for you to try.

Activity 57 Creating a really complicated equation!

Typeset the following formula for the 'cumulative normal distribution', used in statistics.

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}t^2}\, dt$$

Hint: `%PHI` gives Φ.

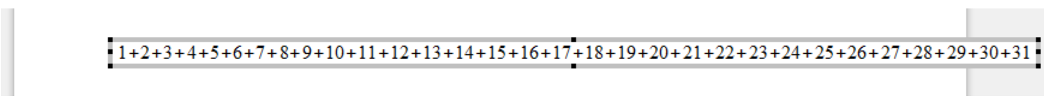
4.4 Line breaks, alignment and numbering

Breaking long lines

As mentioned earlier, LibreOffice Math ignores extra spaces and line breaks in the markup, so you can use these to make your markup easier to understand. The command '`##`' is used to start a new row in the markup for matrices, but it does not work when used outside a matrix command, where it would produce inverted question marks indicating that something is missing. Instead, you need to use the markup command `newline`.

Activity 58 Investigating line breaks

Type $1 + 2 + 3 + 4 + 5 + 6 + 7 + \ldots$ into a new formula object, until the expression is longer than the width of the page. You'll notice that Math does not automatically add any linebreaks, and so the expression falls off the edge of the page:



Now insert the text `newline` after '+11', and another one after '+22':

`1+2+3+4+5+6+7+8+9+10+11 newline`
`+12+13+14+15+16+17+18+19+20+21+22 newline`
`+23+24+25+26+27+28+29+30+31`
	$1+2+3+4+5+6+7+8+9+10+11$
	$+12+13+14+15+16+17+18+19+20+21+22$
	$23+24+25+26+27+28+29+30+31$

Each line is centred, but you can change the alignment. For example, type `alignl` at the start of the first line and `alignr` at the start of the last line, as follows.

`alignl 1+2+3+4+5+6+7+8+9+10+11 newline`
`+12+13+14+15+16+17+18+19+20+21+22 newline`
`alignr +23+24+25+26+27+28+29+30+31`
	$1+2+3+4+5+6+7+8+9+10+11$
	$+12+13+14+15+16+17+18+19+20+21+22$
	$23+24+25+26+27+28+29+30+31$

As you saw in the activity above, `alignl` and `alignr` change the alignment of the line they are on. Often when you need to create expressions that take up several lines, it is clearest to left align the first line, right align the last line, and leave the intermediate lines centred.

Tip: choosing where to break lines

Typing

`11 + newline 12`

produces a '¿' symbol, and no line break. This is because the '+' needs a character or structure to follow it.

In this situation, the `newline` command should normally be placed *before* the '+'. However, when you need to break an expression after a '+', then you can insert an empty symbol, as follows.

`11 + {} newline 12`.

Aligning equations

As well as dividing long expressions over several lines and aligning them appropriately, another common task is to align several lines of equations on the equals sign. The easiest way to do this is to use a `matrix` structure.

Example 10 Using a matrix structure to align equations

This example will show you how to align the following piece of mathematics involving factorising a quadratic equation.

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

The lines of mathematics are 'lined up' on the equals sign. To create this, first start a new formula object and create a matrix with 2 columns and 3 rows, as shown below. (Notice that this isn't yet the final markup required.)

```
matrix{y # = x^2-3x-4 ##
         # = x^2-4x+x-4 ##
         # = (x-4)(x+1)}
```

$y \quad$ ¿ $x^2 - 3x - 4$
¿ $\quad$ ¿ $=(x-4)(x+1)$

Not quite right! What has happened? There are some placeholders missing: remember that '=' expects symbols or structures both before it and after it. Also, you are not allowed to have empty cells in a matrix. To fix these issues, insert 'null' symbols, `{}` as shown below:

```
matrix{y # {} = x^2-3x-4 ##
       {}# {} = x^2-4x+x-4 ##
       {}# {} = (x-4)(x+1)}
```

$$\begin{matrix} y & =x^2-3x-4 \\ & =x^2-4x+x-4 \\ & =(x-4)(x+1) \end{matrix}$$

It's getting closer to the desired output, but the equals signs are not yet aligned. The left-hand column needs to be right-aligned, and the right-hand column to be left-aligned. For this, use the **alignl** and **alignr** commands. You need to specify the alignment of each cell individually.

```
matrix{alignr y # alignl {} = x^2-3x-4 ##
              {}# alignl {} = x^2-4x+x-4 ##
              {}# alignl {} = (x-4)(x+1)}
```

$$\begin{matrix} y & =x^2-3x-4 \\ & =x^2-4x+x-4 \\ & =(x-4)(x+1) \end{matrix}$$

You'll notice in the above example that the final version of the equation has a lot of space between the y on the first line and the $=$ sign next to it. This is caused by the spacing between columns of the matrix. The formula as it stands is clear enough to read, but it's possible to adjust the spacing between the columns if you wish. To do this, open the formula object and then select `Format` > `Spacing...` from the menu bar at the top. This will open the 'Spacing' dialogue box. From the 'Category' drop-down menu select 'Matrices' to load the spacing settings for matrices. You can now change the spacing between columns or rows by adjusting the values and clicking 'OK'.

Note that this change only applies to the matrices in the currently-active formula object, so any future `matrix` commands in other formula objects will not be affected by any such changes.

Activity 59 Creating aligned equations

Typeset the following set of double-angle formulas for cos, using the `matrix` structure.

$$\begin{aligned}\cos 2\theta &= \cos^2\theta - \sin^2\theta\\ &= 2\cos^2\theta - 1\\ &= 1 - 2\sin^2\theta.\end{aligned}$$

Numbering equations

Creating numbered equations involves two easy steps.

Adding a numbered equation

1. Start a new line in your Writer document.
2. Type `fn`, and then press F3.

The effect of the above is that a numbered formula will appear, in place of `fn`, and it will display a well-known equation!

$E=mc^2$	(1)

Writer actually creates a table in your document with one row and two columns, as indicated by the pale grey guidelines. These grey guidelines are not visible when you print the document. The grey background for the number indicates that this is part of an automatic numbering sequence. Thus, if you later delete one of these numbered equations, then the subsequent ones will all be renumbered automatically.

It is also possible to cross-reference these numbers automatically (so that the reference changes if the equation number itself changes), though this process is not covered here.

Activity 60 Creating a numbered equation

Follow the steps above to make a new numbered equation.

Now double-click $E = mc^2$ in order to open the formula object. Replace the contents with '$e^{i\pi} = -1$', to convince yourself that this is a standard formula object.

Close the formula object, and repeat the procedure of making a numbered equation. In this second numbered equation, the number on the right-hand side will automatically be incremented.

$$e^{i\pi}=-1 \tag{1}$$

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

4.5 Preparing to typeset a TMA

This introduction to the features of LibreOffice Math has shown you enough to typeset your mathematical answers to a TMA by using a combination of inputs with the Elements Dock, the context menu in the Formula Editor, and the keyboard. The best way to continue to learn about LibreOffice is to practise using its many features.

Do remember, however, that you can submit handwritten working as answers to all TMA questions, apart from those assessing this unit, where you are specifically asked to typeset your answers.

Including graphics in your document

Some TMA questions may ask you to draw graphs, illustrations or other graphics. Writer provides ways to embed graphs or tables of data from the LibreOffice Spreadsheet and Drawing programs, but these methods go beyond the scope of this introduction. This subsection shows you how to include pictures in your document, such as scanned-in hand-drawn diagrams, digital photographs or graphics created using other software.

Activity 61 Inserting a picture in your document

With the cursor at the point where you wish to insert the picture, select `Insert` > `Image...` from the menu bar at the top of the window.

A dialogue box will open. Here you can find the picture that you wish to insert, select it and then click 'Open' to place the picture in your document. Once inserted you can resize it using the boxes in the corners. Other formatting options are available from the dialogue box that opens when you double-click anywhere on the picture.

Be aware of the file sizes of these pictures: large high-resolution images can add considerably to the space your Writer document takes up on your computer, and this can make it difficult to send the document to others electronically.

Exporting your Writer document as a PDF

If you wish to share your document electronically, then (unless you know that all the recipients use LibreOffice) you should export your document to PDF format. This will make it viewable (but not editable) on any computer or tablet device.

1. Select `File` >`Export As` >`Export as PDF...`. This will open a 'PDF Options' dialogue box.
2. There are a lot of options that can be changed here, but it is fine to ignore these and use the default settings. Click 'Export'.
3. The 'PDF Options' window disappears and is replaced by a window prompting you to specify the filename and folder location for your file. Once you have set these as you wish, click 'Save'.

Solutions to activities

Solution to Activity 2

(a) The four commands to be included in the file are:

```
\section*{Question 1}
\section*{Question 2}
\section*{Question 3}
\section{Text formatting commands}
```

(b) Below the 'Text formatting commands' section declaration, the following code will produce the correct output:

```
This is the first paragraph of the section. Notice that
it is not indented.

This is another paragraph.
\begin{center}
Centre-aligned text
\end{center}

\textbf{Text in bold \underline{and underlined!}} Also,
some text in \textit{italics}.
```

Notice that LaTeX did not indent the first line of the paragraph after the section heading.

Comment

Don't worry if your LaTeX code is not identical to the code given in the solution: the important point is to ensure the output PDF looks the same!

Solution to Activity 3

The code required to create the subquestions underneath Question 1 is:

```
\begin{enumerate}
\item[(a)] First subquestion.
\item[(b)] Second subquestion.
\item[(c)] Third subquestion.
\end{enumerate}
```

Solution to Activity 6

`\cos` produces 'cos', while `cos` produces '*cos*'.

In the first version, the backslash tells LaTeX to process the command 'cos', which causes 'cos' to appear in Roman (that is, non-italic) font. In the second version, LaTeX processes each of 'c', 'o' and 's' as a single character within maths mode, and so places them all in italics.

Solution to Activity 8

(a) x^{a^b}: This is a superscript of a superscript.

(b) LaTeX reports a 'double superscript' error: this is the same issue as you saw in Activity 7.

(c) x^{a_b}: The curly bracket tells LaTeX to group the `a_b` in the superscript.

(d) x_b^a: There are no curly brackets, so LaTeX assigns the superscript and the subscript to the *same* object, namely the 'x'.

(e) x_b^a: this output is identical to (d).

Solution to Activity 10

The 'double-backslash' creates a linebreak. Note that this is not the same as starting a new paragraph, as it does not indent the next line.

Solution to Activity 11

(a) This is produced by adding `\usepackage{amsmath}` and `\usepackage{amssymb}` to the preamble of your file (the part before the line `\begin{document}`).

(b) The new section can be added using the following text.

```
\section{Mathematics commands}
There are two ways to display mathematics: inline and
displayed mode.

Inline mode is written within dollar signs. For example,
the quadratic equation $y=ax^2+bx+c$ appears within the
normal flow of the text.

Displayed maths is written within backslash-square-brackets.
For example, Euler's formula,
\[e^{i\theta}=\cos \theta + i \sin \theta,\]
occupies a line to itself.
```

Notice in the source code above, the displayed maths has been given a new line. This is not needed, but you can use new lines in this way to make your LaTeX file easier to follow.

Solution to Activity 12

There are five errors in the file:

- Missing `}` at the end of `\begin{document`.
- `\maketilte` should be `\maketitle`.
- `\Latex` should be `\LaTeX` (it could also be written without a backslash, so it is no longer a command).
- Missing dollars around `$y=x^2$`.
- Extra right curly bracket `}` at the end of the final sentence.

The corrected file should therefore read:

```
\documentclass{article}
\title{Spotting errors}
\author{J. Bloggs}
\date{}
\begin{document}
\maketitle

There are several types of error one might find in a
\LaTeX\ file. It is important to process your \LaTeX\ file
frequently in order to make sure you can identify problems
quickly and easily.

Spotting errors can get particularly complicated when there
is a lot of mathematics. Even an equation as simple as $y=x^2$
can go wrong in several ways, so each time you write
mathematics in your file it is sensible to check the
equation is correct by processing it, before moving on to
the next task. Remember also to match curly brackets.
\end{document}
```

Solution to Activity 13

(a) `$\tan\theta = \frac{\sin\theta}{\cos\theta}$`

(b) `$\sin\frac{a}{b}\ne \frac{\sin a}{\sin b}$`

(c) `$x^{1/n}= \sqrt[n]{x}$`

(d) `If $x$ is a positive real number, then $e^x\ge 1+x$.`

Solution to Activity 14

```
\[ \Phi(x) = \frac{1}{\sqrt{2\pi}}
   \int_{-\infty}^x e^{-\frac{1}{2}t^2}dt. \]
```

Notice that a single line break in LaTeX code does not affect the output. Also, to obtain the full stop after the integral you must place it inside the displayed maths brackets.

Solution to Activity 15

```
\begin{align*}
\cos (2\theta) &= \cos^2\theta - \sin^2\theta\\
&= 2\cos^2\theta -1\\
&= 1-2\sin^2\theta.
\end{align*}
```

Solution to Activity 17

The required modifications are to change from an `align*` environment to an `align` environment, and to add the `\nonumber` command to the first and third lines.

```
\begin{align}
\cos (2\theta) &= \cos^2\theta - \sin^2\theta\nonumber\\
&= 2\cos^2\theta -1\\
&= 1-2\sin^2\theta.\nonumber
\end{align}
```

Solution to Activity 18

(a)

```
\[
\begin{pmatrix}
x\\
y\\
z
\end{pmatrix}
\]
```

(b)

```
\[
R_z(\theta) =
\begin{pmatrix}
\cos\theta&-\sin\theta&0\\
\sin\theta&\cos\theta&0\\
0&0&1
\end{pmatrix}
\]
```

Solution to Activity 19

```
\begin{tabular}{|r|l|p{4cm}|}
\hline
Right-aligned & Left-aligned & A cell with width fixed at 4 cm\\
\hline
cell 1 & cell 2 & cell 3\\
\hline
\end{tabular}
```

Solution to Activity 20

The LaTeX code is

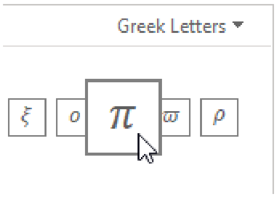
```
\includegraphics[scale=0.5]{ou-logo.jpg}
```

Don't forget to include `\usepackage{graphicx}` in the preamble.

Solution to Activity 26

In a new mathematical input box, first type `c=2` to obtain the first three characters.

Next, to create the lower-case Greek letter pi, π, select the 'Greek Letters' palette from the Symbols section of the Equation ribbon (remember that to change palettes the current palette must be fully open) and click on the appropriate symbol:



Note that you can also access the Greek letter pi, π, from the 'Basic Math' palette, and you may find it more convenient to access it from here.

Finally, type the letter `r`, and press $\hookleftarrow$ to leave the mathematical input box.

Solution to Activity 27

To modify the expression $\sqrt{a^2 + b^2}$, first delete the 'a'. To do this, place the cursor to the right of the 'a' (for example, by using the mouse), and press Backspace on your keyboard. The letter a will disappear and be replaced with a placeholder. Next, type `(ax)`, which will cause the placeholder to disappear and be replaced by the desired expression.

Now move the cursor to the right of the plus sign, delete the sign, and type a minus sign (a dash) instead.

The cursor should now be to the left of the letter 'b'. Find the π symbol in either of the 'Greek Letters' or 'Basic Math' palettes of the Symbols section of the Equation ribbon, and click on the symbol to insert it. Then click anywhere outside the mathematical input box to finish the equation.

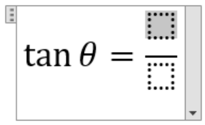
Note that you could close the equation by pressing the $\rightarrow$ several times to move the cursor to the end of the expression before pressing $\hookleftarrow$, but clicking outside the box is the quickest way.

Solution to Activity 28

(a) Begin by selecting ‘tan’ from the ‘Function’ submenu:

Click on the placeholder to select it. From the Symbols section of the Equation ribbon, select the ‘Basic Math’ (or ‘Greek Letters’) palette and insert ‘θ’ by clicking on it. (Note that there is also a variant of this Greek letter, ϑ.) Press → to escape from the tan function placeholder.

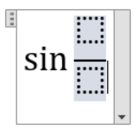
Next, type an equals sign, =, and then insert a ‘Stacked Fraction’ from the ‘Fraction’ submenu:



Finally, click on each of the two placeholders in turn, and insert ‘$\sin\theta$’ above and ‘$\cos\theta$’ below the fraction line, in the same way as you created the left-hand side of the equation. Press → → ↵ or click outside the box to finish the equation.

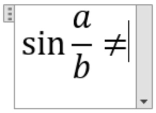
(b) First, select ‘sin’ from the ‘Function’ submenu:

With the placeholder selected, now insert a ‘Stacked Fraction’ from the ‘Fraction’ submenu:

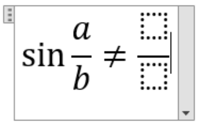


Type `a` in the numerator (top of the fraction) placeholder, and `b` in the denominator (bottom) placeholder. You may find it easiest to use the down arrow key on your keyboard to move the cursor from the top of the fraction to the bottom.

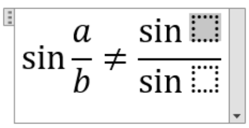
Next press the right arrow key *twice*, → → . The first exits the fraction placeholder and moves the cursor to the right of the fraction, the second exits the placeholder of the 'sin' function. Click on the $\neq$ symbol from the 'Basic Math' palette to insert it into your equation:



Now insert another 'Stacked Fraction':

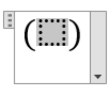


Finally, insert the 'sin' function into both the top and bottom placeholders of this fraction then click anywhere outside the mathematics input box. Clicking outside the box to temporarily close the equation is often the quickest way to escape from multiple levels of placeholder.

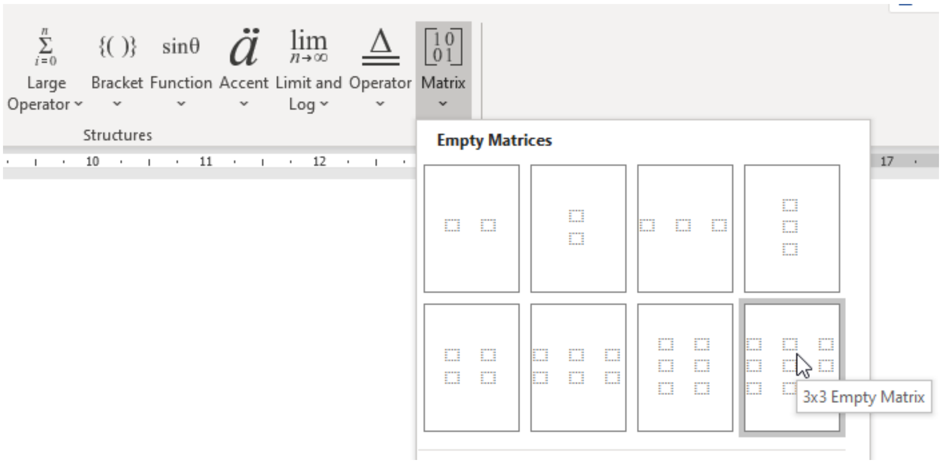


Next, re-open the equation and fill the two placeholders by clicking on them in turn; typing `a` in the upper placeholder, and `b` in the lower.

(c) First, notice that most of the options on the 'Matrix' submenu do not have brackets around them. Thus, the first task is to insert 'Parentheses' from the 'Bracket' submenu:



Next, ensuring that the placeholder is selected, insert a '3×3 Empty Matrix' from the 'Matrix' submenu:



Observe that the brackets automatically resize when you insert the matrix. Finally, fill in the entries of the matrix by selecting each of the nine placeholders in turn; the arrow keys are particularly useful for moving between elements of the matrix.

Alternatively, the 'Matrix' submenu has a pre-completed 3×3 identity matrix that you could have used instead of selecting the empty matrix and then filling in the entries.

Solution to Activity 33

`The solution to the general quadratic equation` [Alt+=] `ax^2+bx+c=0` [Alt+=] `with` [Alt+=] `a,b,c\in\doubleR␣` [Alt+=] `and` [Alt+=] `a\neq␣0` [Alt+=] `is given by the quadratic formula:` [↵] [Alt+=] `\quadratic␣␣.` [↵]

Solution to Activity 34

(a) $x^2 \sin(x)$: the first space character builds the superscript and [→] is needed in order to 'escape from' the placeholder that 'sin' creates.

(b) $x^{2\sin}(x)$: the first space character causes Word to terminate the expression within the superscript.

(c) $x^{2\sin}(x)$: this is the same result as (b), because there is no grouping of symbols to tell Word that it should include '(x)' within the superscript.

(d) $x^{2\sin(x)}$: the brackets around the expression are delimiters, causing it to be grouped as a single entity and so appear within the superscript.

(e) $x^{(2\sin(x))}$: the outermost brackets are interpreted by Word as delimiters to group the expression, while the inner brackets actually appear in the output.

Solution to Activity 37

You need to use → after each instance of sin and cos to escape from the associated placeholder.

Alt+= `d/dx␣(x^2␣sin␣(x)`→ `)=2x␣sin␣(x)`→ `+x^2␣cos␣(x)`→ ↵

Solution to Activity 38

Alt+= `\Phi(x)=1/\sqrt(2\pi)␣␣\int␣(-\infty)^x␣e^(-1/2␣t^2)␣dt`→
↵

Notice the two space delimiters, ␣␣, after the fraction: the first is needed to build the square root in the bottom of the fraction, and the second then builds the fraction itself.

Solution to Activity 42

When 'Tab' is pressed again, the + sign on the second line aligns itself with the second + sign on the first line.

Solution to Activity 52

The following markup produces the correct expression.

```
left( matrix{x ## y ## z} right)
```

Solution to Activity 53

(a) `"For any number " x, e^x >= 1+x.`
It is also possible to type the text 'For any number' outside the formula object.

(b) `"The area of a circle of radius " r " is " A=%pi r^2"."`
In this example, it is definitely faster to type the word 'is' between the two pieces of mathematics *within* a single formula object, rather than typing it between two objects.

(c) `nroot{3}{64}=sqrt{16}`
In fact the curly brackets in this particular example are not actually necessary, so you can type the following.
`nroot␣3␣64=sqrt␣16`

Solution to Activity 55

The following markup produces the statement.

`The equation` Ctrl+Alt+F `x^n + y^n = z^n` Esc Esc `has no positive integer solutions for` Ctrl+Alt+F `n >= 3.` Esc Esc

Solution to Activity 56

(a) x^{sinx}: Math has placed all the items in the superscript because there are no spaces. However, this also means that it didn't recognise 'sin' as a function and instead read in all of 'sinx' at the same time, so everything is in italics.

(b) $x^{\sin}x$: the space symbol causes Math to terminate the expression within the superscript.

(c) $x^{\sin x}$: the curly brackets have caused '$\sin x$' to be grouped within the superscript.

(d) $x^{(\sin x)}$: as in (c), the curly brackets group the expression '$(\sin x)$'. Notice that the curly brackets are invisible, but the parentheses are visible.

(e) $x^{(\sin x)}$: this is the same as (d). Math has used the parentheses to group the content together: curly brackets are only needed when you need to group items together that are not contained in another kind of bracket.

Solution to Activity 57

Within a formula object, type

```
%PHI(x)=1 over sqrt{2%pi} int from {-infinity} to x
e^{- {1 over 2} t^2}dt
```

Note the curly brackets around the fraction '`1 over 2`'. Without these, the fraction would appear as $\frac{-1}{2}$.

Solution to Activity 59

Use the following markup.

```
matrix{
 alignr cos 2%theta # alignl {}= cos^2 %theta - sin^2 %theta ##
                 {} # alignl {}= 2cos^2 %theta - 1 ##
                 {} # alignl {}= 1 - 2sin^2 %theta .}
```

This solution uses the same method as that used in Example 10 to create a 'matrix' (without brackets or parentheses) with two columns.

Acknowledgements

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